The Trading and Use of Agrochemicals

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Abstract The use of synthetic chemicals has revolutionized agriculture, bringing at the same time huge gains in the form of increased food yields and many significant problems arising from the toxic nature of many of the formulations. The global demand for greater quantities and a certain standard of food has continued to encourage agrochemical use at the same time as the health, safety and environmental sustainability of doing so has brought this ever more into question. Principles of agroecology have come to inform agrochemical use, but the prioritization of traditional over sustainable development in many countries and the perceived complexity of alternative strategies for improving crop yields have limited this shift mainly to the Global North. This review covers the rise of agrochemicals, assesses the costs and benefits of their production, use and trade and then describes and evaluates international political responses to the dilemmas that they pose to humanity.

1 The Rise of Agrochemicals and Their Benefits to Humanity

1.1 What are Agrochemicals?

‘Agrochemical’ is the generic term for a range of chemical products used in agriculture. Typically agrochemicals are divided into two broad categories, pesticides and fertilizers, although it is possible to consider veterinary drugs used on farm animals, such as antibiotics or growth hormones, as a third type. However, since such chemicals are pharmaceuticals rather than formulations designed specifically for agricultural usage, the focus of this review is on fertilizers and particularly pesticides.

1.1.1 Pesticides

The term ‘pesticide’ refers to any substance used in the control of pests as defined by humans. Such pests include insects (hence the term ‘insecticide’), weeds (herbicides) and also fungi (fungicides). Pesticides may also be used in ways which fall short of killing pests. The term additionally covers defoliants used to strip trees and plants of their leaves, plant growth regulators and substances which deter insects from certain locations (for example, mosquito repellents) or attract them away from crops (for example, through the use of pheromones).

Pesticides can also be subdivided according to their chemical composition. Four principal categories can be identified:

1. **Natural** (botanical) - derived from plant extracts like nicotine and pyrethrum.
2. **Biological** (biopesticides) - the use of microorganisms in pest control such as the bacteria *Bacillus thuringiensis* or biochemicals such as pheromones.
3. **Inorganic-** substances derived from minerals such as sulphur and arsenic.

4. **Synthetic** (organic) - the dominant form of pesticides comprising chemical substances manufactured from combinations of carbon, hydrogen and oxygen with other elements. Synthetic pesticides can be sub-divided as:

    a) organochlorines (e.g. DDT, lindane)

    b) organophosphates (e.g. parathion, malathion)

    c) phenoxyacetic acids (e.g. 2,4,5-T)

    d) carbamates (e.g. aldicarb, propoxur)

    e) synthetic pyrethroids.

The commonly used names of pesticides are usually distinct from their technical chemical names. The herbicide paraquat, for example, is the popular term for the chemical 1,1'-dimethyl-4,4-bipyridinium ion. Pesticides also acquire trade names and paraquat is marketed under a variety of names such as 'Pathclear™' and 'Gramoxone™'.

The use of chemicals as an aid to pest control did not take off until the late nineteenth century, although some use was made of sulphur as a domestic insecticide prior to this time. Homer even refers to sulphur being used in Ancient Greece (Homer 1802: 271). The effects of the notorious Colorado beetles on potato crops and gypsy moths on trees in the United States prompted the entomologist Charles Riley to pioneer the use of the arsenical compound Paris Green (an acetoarsenite of copper originally used as a paint pigment) and London Purple (an arsenical dye residue) as insecticide sprays. The most extensive use of Paris Green in the immediate years after its development as an insecticide was, though, actually more as a deterrent to human pests. Roadside vines are known to have been sprayed to prevent pilfering by passers-by and a number of children were killed as a consequence (Ordish 1976: 160). Doubtless, some of the consumers of the wine from such vineyards must also have been the earliest victims of poisoning through pesticide residues that remained in foodstuffs.

Organic pesticides have their origins in the Second World War. The insecticidal properties of the original and still most notorious pesticide diclorodiphenyltrichloroethane (DDT) were discovered by Swiss chemist Dr. Paul Muller in 1939 and it was quickly patented. A series of other chlorine-based compounds, the 'organochlorines', were soon found to have similar properties, leading to the marketing of insecticides such as benzene hexachloride (BHC), aldrin and dieldrin. A second branch of organic pesticides, the phosphate-based 'organo-phosphorous' compounds, emerged as a side-effect of wartime research into toxic gases by the German scientist Dr. Gerhard Schrader. After the war Schrader put his research before the allied states and revealed the potential insecticidal application of the compounds. Parathion was the first major insecticide in this group to be marketed, and others such as malathion soon followed. Further branches of organic pesticides subsequently developed include carbamates (derived from carbamic acids), such as aldicarb, and phenoxyacetic (phenol-based) acids such as 2,4,5-T.

Insecticides are, of course, poisons and can also be classified according to how they poison their pest victims. Stomach poisons are poisonous when ingested, contact poisons are poisonous when they penetrate any bodily opening, while fumigants are poisonous when inhaled. Arsenical pesticides are stomach poisons and nicotine is a contact poison. Examples of fumigants include methyl-bromide and hydrogen-cyanide. Most synthetic organic insecticides, though, combine all three methods of poisoning so this form of classification has become less commonly used.

Herbicides can be categorized as selective or non-selective, the former used for specific weeds, the latter usable for a range of weeds. Paraquat is a non-selective and contact herbicide that kills only the plant organs it contacts. In contrast, ‘systemic’ or ‘translocated’ herbicides such as 2,4-D can be transported to leaves from elsewhere in the plant such as its roots.

Fungicides or antimycotics can be applied to seeds as a protective coating (seed fungicides) or work as systemic fungicides to protect the whole plant. Sulphur compounds are prominent traditional fungicides, and methyl-bromide was frequently used in this way until its recent phase-out began. Additionally, some other categories of pesticides target pests other than insects, weeds and fungi. Larvicides are insecticides that target the pest during the larval stages of the life-cycle, of which *Bacillus thuringiensis* is a prominent example. Moluscicides target snails and slugs, while rodenticides such as warfarin target rats and other larger pests.

1.1.2 Fertilizers

A fertilizer is a substance used to improve the growth and productivity of plants. Fertilizers enhance the natural fertility of the soil or replace chemical elements removed from the soil by previous crop production. Modern chemical fertilizers include one or more of three key elements; nitrogen, phosphorous or potassium. Most nitrogen-based fertilizers are obtained from synthetic ammonia, such as ammonium sulphite. Calcium phosphate and potassium sulphite are examples of the latter two fertilizer groups. Mixed fertilizers are combinations of two or three of these types.

1.2 The Global Agrochemical Market

Fig. 1 World's biggest agrochemical companies by 2007 sales and 2007 % market share

1. Bayer (Germany) - $7.458 billion - 19%
2. Syngenta (Switzerland) - $7.285 billion - 19%
3. BASF (Germany) - $4.297 billion - 11%
4. Dow (USA) - $3.779 billion - 10%
5. Monsanto (USA) - $3.599 billion - 9%
6. DuPont (USA) - $2.369 billion - 6%
7. Makhteshim Agan (Israel) - $1.895 billion - 5%
8. Nufarm (Australia) - $1.470 billion - 4%
9. Sumitomo Chemical (Japan) - $1.209 billion - 3%
10. Arysta Lifescience (Japan) - $1.035 billion - 3%

Source: Agrow (2008)

The global agrochemical industry is dominated by a small group of Western-based Multi-National Corporations. The top ten listed in Fig. 1 account for nearly 90% of world production. However, over half of global agrochemical use is now in Asia. Of the rest, over a quarter of global use is in the Americas, 17% is in Europe and less than 4% in Africa and the Middle East. Fertilizers make up 63% of the global agrochemical market, with pesticides accounting for the remaining 37%. The world's biggest selling single pesticide product is Roundup™, an herbicide produced by Monsanto®. Of the United States pesticide market, 70% is comprised of herbicides, 20% of insecticides and 10% of fungicides (Datamonitor 2011).

As can be seen in Fig. 2, the global market value of agrochemicals has fallen in recent years although the volume of sales has remained fairly constant. The original reason for the

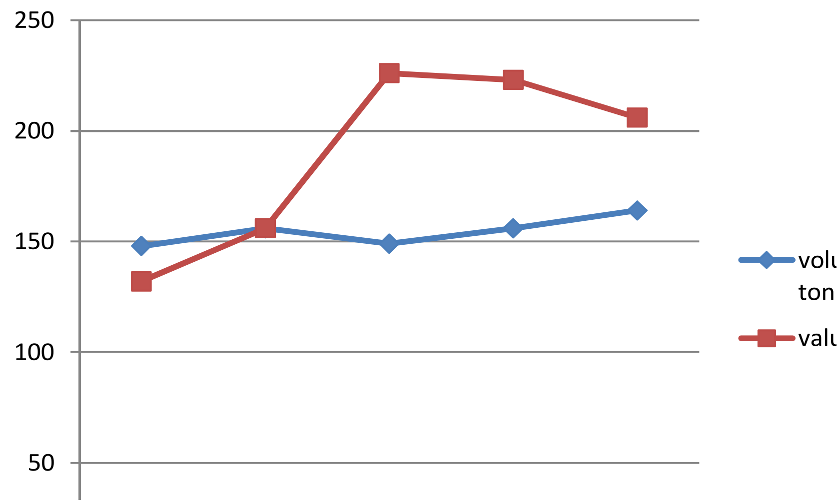

Fig. 2 The global agrochemical market from 2006 to 2010 (Datamonitor 2011)

development and use of agrochemicals was to ensure better yields by reducing crop losses to insects, fungi, and weeds through the use of pesticides, as well as to improve the fertility of soil through the application of fertilizers.

1.3 Agrochemicals and Food Yields

The barrier that pests, in their various guises, pose to satisfying the goal of obtaining optimal crop yields is considerable. It has been estimated, for example, that insects destroy 13% and weeds 12% of crops in the United States and that each dollar invested in pesticides reaps a return of around $4 for protected plants (Pimentel 2005). Fertilizer applications are considered to increase food yields by between 40 to 60% (Stewart et al. 2005).

It is, of course, in the overpopulated Global South that the need for optimal crop yields is most apparent, the same arena in which the prohibitive norms concerning agrochemical use are most pertinent. The moral dilemma facing the actors concerned with agrochemical politics is the stark fact that while imposing strict restrictions on their use and imports in the Global South would reduce accidental deaths and environmental pollution, it would also be likely to reduce the amount of food on the plates of already undernourished peoples. This continues to be the spur for the maintenance of agrochemical use despite the international voices calling for restraint in the name of human safety, environmental protection, and food purity. The compromise practice of adopting 'integrated pest management', balancing the norms of optimizing crop yields and minimizing pesticide use, is a complex procedure making up a separate issue which is examined later.

Chemicals have undoubtedly made food and fibre production more efficient. It is estimated that while the average farmer in the United States produced enough food for himself and nine others in the 1940s, this had increased to include the farmer and thirty-one others by the 1970s (Green 1976: 17). The mechanization of farming, the introduction of high-yielding crop species, advances in the use of chemical fertilizers and the application of pesticides have all helped in this regard. More recent studies continue to bear this out. Khan et al. (2010: 124), for example, posit that there has been a linear relationship between pesticide and fertilizer usage and cotton and rice production in Pakistan.

There is a correlation between the input of agrochemicals and the subsequent yield in crops, but the relationship between the two variables is not straightforward and needs to be qualified. Yields certainly do not rise in strict proportion to the amounts of pesticides used. It appears that ultimately, more pesticides do not equate to more food or fibre. A number of cases show evidence of this. 'In India, where cotton growers used three million kilograms of

DDT in 1970 to produce just over five million bales of fibre, DDT use had doubled but cotton yields remained the same six years later' (Norris 1982: 23). A more extreme example comes from Nicaragua, where cotton yields 'fell by a total of 30% from 1965 to 1969', despite increased insecticide applications (Swezey et al. 1986: 9).

Partial explanations for such cases and this general trend include the raising of cosmetic standards demanded of fruit and vegetables by retailers, the unintentional destruction of natural pest predators, the use of high-yielding but more vulnerable crop species, and the move away from crop-rotation to monoculture. Pimentel (2005: 230) notes that the 13% of crops lost to pests in the United States has actually risen from a figure around 7% in 1945, in which time there has been a tenfold increase in insecticide use. Yields have increased, but so has waste due to a shift away from the traditional practice of crop rotation. The chief cause of continued crop losses in the face of pesticide use, however, is pest resistance, which develops in the face of continued exposure to chemicals. In the Nicaraguan case, the explanation offered for the drop in cotton yields was an increase from five to nine in the number of species of resistant cotton pests that were 'economically important' in the previous ten years (Swezey et al. 1986: 9). Reducing agrochemical use can also reduce costs without diminishing the benefits. By 2002, Swedish pesticide use had declined by 68% without any reduction in crop yields or standards, but with a 77% decline in public poisoning incidents (Pimentel 2005: 249). Khan et al. (2010) note that increased Pakistani yields have been accompanied by increased poisonings, pollution and insect resistance to the agrochemicals being used.

The problems posed by pest resistance and resurgence are such that even the agrochemical industry has come to question the future of purely chemical crop protection and to explore alternative options. However, despite the growth in non-chemical integrated pest control techniques, pesticide sales continue to be buoyant and they are still widely considered as an essential means of optimizing crop yields. It needs also to be remembered that many of the same chemicals have also benefited humanity in public health campaigns, such as the continuing use of the infamous organochlorine DDT in combating malaria. Evaluating the appropriateness of utilizing chemicals known to have environmental and health side-effects thus needs to consider a range of pros and cons. Hence, even the most toxic of agrochemicals have their advocates, such as Roberts and Tren (2010: ix) in their defence of the 'excellent powder'; 'DDT is unique in its power to cheaply, effectively and safely protect poor people in poor countries against diseases'.

2 Problems Associated with Agrochemicals

The use, production and transportation of agrochemicals come with several side-effects, particularly with regards to pesticides since these are, by definition, poisonous substances.

2.1 Human Poisoning

Chemical pesticides are by their very nature poisonous. The toxicity of such substances can never be applicable only to the targeted pest, so they need to be produced, transported and applied with care in order to avoid human poisoning.

A precise understanding of how widespread human poisoning from pesticides is globally has never been possible because of a lack of conclusive information on the issue in many countries. The inevitable result of this lack of hard facts is a tendency for the basic pro- and anti-pesticide camps to swing to extremes, and make estimates based on assumptions favorable to their own causes. Independent estimates over the past decade have suggested that between 220,000 and 300,000 people per year are killed by acute pesticide poisoning from over three million severe incidents. These, though, do not include the more difficult to quantify fatalities due to cancers and other longer-term ailments (Hart and Pimentel 2002, Oates and Cohen 2011). In addition, it is widely held that large numbers of poisonings go unreported in the Global South because workers fear it may cost them their jobs, and also because they do not associate such illnesses with their work. Added to this is the problem of actually proving a link between an agricultural worker's illness or death and his/her exposure to pesticides. The death of a man by cancer may be the long-term effect of having worked with carcinogenic sprays a number of years ago, but this is very difficult to prove conclusively.

2.1.1 Intentional Exposure

The first detailed and systematic study of the nature and extent of pesticide poisoning in a developing country was carried out in Sri Lanka between 1975 and 1980. The study showed that approximately 13,000 people were admitted to government hospitals for acute pesticide poisoning per year, of which around 1,000 died. The study also revealed that only a small fraction of the Sri Lankan deaths were the result of the accidental ingestion of the chemicals. Some 73.1% of the patients were admitted after having attempted to commit suicide with the aid of pesticides (Jeyaratnam et al. 1982). Other surveys of pesticide poisonings support the findings in Sri Lanka that the majority of cases are not accidental. It is considered that one third of global suicides are carried out with pesticides, a figure in excess of 250,000. This is a far larger annual death toll than all of the victims of the world’s war and terrorism combined (Bertolote et al. 2006).

The availability of toxic chemicals is a key explanatory factor behind this startling death toll. The phenomenon of suicide by pesticide is most pronounced in Asia where the agrochemical market is biggest and also usually less restrictive in the sale of hazardous formulations. Over half of the world's deaths of this form occur in China. In many Asian countries it is most rife in rural regions and among younger people. Pesticides are generally less available in Africa, but the phenomenon is similar in countries with more intensive agriculture such as in Malawi where 80% of suicides are by pesticides (Dzamala et al. 2006). The high toxicity of pesticides available in developing countries, compared to most developed countries where they have become restricted over time, is an additional factor. Overall, 99% of pesticide suicide cases are from low and middle income countries. In Asia, fatalities from self-poisoning with the herbicide paraquat total 70% while, as a comparison, fatalities in the United Kingdom following suicide attempts with medication is 0.5% (Gunnell and Eddleston 2003).

2.1.2 Unintentional Exposure

Accidental poisoning from agrochemicals can occur in a number of ways. Indirect poisoning, *via* contaminated food and water is considered later as a separate issue, the focus here being on direct, accidental poisonings resulting from pesticide misuse.

2.1.3 Occupational Exposure to Pesticides

The principal victims of accidental pesticide poisoning are, predictably, the agricultural and public health workers involved in their application. Instances of this are highest in the developing world, where workers are often ignorant of the hazardous nature of their work, and management is often negligent in safeguarding the health of their employees. Agricultural workers can be contaminated while mixing or spraying the chemicals, as can those entering fields after spraying, and those working in the formulation of pesticides. This problem is exacerbated by the fact that the pesticides used are the particularly toxic chemicals outlawed or restricted in most developed countries. In addition, it is important to note that the susceptibility of workers in the developing world to pesticide exposure is often higher than their developed-world counterparts, owing to the typically higher temperatures in which they work, and the higher levels of malnutrition and disease to which they are prone. It is widely accepted that occupational poisoning by pesticides can be greatly diminished once the trading of particularly hazardous chemicals is brought under control, and worker safety standards in the developing countries are implemented at levels similar to those in the developed world. The scale of the global death toll from occupational exposure to agrochemicals is unclear, but studies in China have indicated an annual figure of around 17,000 (Phillips and Yang 2004). If China is assumed to have a similar proportion of occupational to suicide victims as in other Asian countries, this suggests a global figure of around 30,000 per year.

2.1.4 Long-Term Health Effects

While acute pesticide poisoning is largely prevented in the developed world, concern remains over the possible long-term health effects of prolonged exposure to pesticides by workers and members of the public. Central to this concern are the possible cancer risks involved in exposure to particular chemicals. Many pesticides have proven carcinogenic in animal testing, and this has fueled enough fear for some governments to restrict or ban chemicals principally on these grounds.

Aside from their potential carcinogenicity, the other long-term health fears associated with pesticides derive from the persistence of the organochlorine chemicals. Chemicals like DDT and dieldrin are also known to possess ‘lipophilic’ characteristics, meaning that they dissolve in fat more readily than water, and as such they are prone to be stored as residues in human tissue. The presence of these residues has been linked to a variety of health disorders. A significant rise in Alzheimers and other forms of dementia through exposure to organochlorine pesticides has been suggested (Hayden et al. 2010). A link between thyroid disorders and organochlorine exposure in women in farming communities of Iowa and North Carolina has also been reported (Goldner et al. 2010).

Restrictions on the use of organochlorines in many countries have not eliminated concern over long-term occupational exposure to pesticide chemicals. Organophosphate (OP) pesticides basically replaced organochlorines in British sheep-dips in the 1980s due to the worries over the persistence of the former types of chemical, but instances of ‘dipping-flu’, where farmers suffer nausea and headaches after treating sheep, have continued. Trade Unions led by the National Farmers Union (NFU) and UNISON, the public service union, finally made headway in the United Kingdom in the 1990s in gaining recognition of the problem and in securing compensation for victims. The appropriately named Robert Shepherd, who worked for the Lancashire College of Agriculture, received £80,000 in an out-of-court settlement in 1998 after having to give up his job due to chronic fatigue believed to be linked to dipping the college’s sheep twice a year in OP pesticides. Other studies have also shown that less direct organophosphate pesticide exposure can impact human neurodevelopment, particularly in young children (Damalas and Eleftherohorirnos 2011).

Overall 81 of the European Union's 276 legally marketed pesticides are known to have negative health impacts; 51 are carcinogenic, 24 are endocrine disrupters, 22 cause reproductive and developmental defects and 28 can be the cause of acute toxicity (Karabelas et al. 2009).

Pesticides applied conventionally on crops may occasionally affect people other than those employed in their application. The primary avenue by which this can occur is as a result of the drifting over residential areas of pesticides originally sprayed on agricultural land. The two principal ways in which the general public has been exposed to pesticides in this manner are by the drift of chemicals used in aerial spraying, and by the drift of vapor following the evaporation of chemicals after application.

The spraying of residents with pesticides dispatched aerially is a commonly recorded complaint in developed countries, and has led to calls for a complete ban on this method of application. Considering that aerial spraying only accounts for a small fraction of all pesticide applications in developed countries, this would seem to suggest that poisonings resulting from this practice are liable to be far more significant in Asia, where aerial spraying is more common and generally less subject to regulation. As is the case with many aspects of the health impact of pesticides, the scale of this problem is impossible to fathom owing to the difficulty of conclusively matching symptoms of poisoning with their causal factors. This is especially so if the effects are long-term. In addition, there is a lack of data from the places where the problem is likely to be greatest, the underdeveloped world.

A landmark legal case in 1997, however, transformed the legal position of people suffering from pesticide exposure of this form, at least in the developed world [1]. A July 31st verdict of the Hong Kong High Court ordered the Swiss-based multi-national corporation Ciba-Geigy to pay Kristan Phillips, an American musician, the equivalent of £19 million in compensation for illness suffered after being contaminated by the organophosphate diazinon in a Hong Kong concert hall in 1987. Phillips was forced to abandon a career as a timpanist with the Hong Kong Philharmonic Orchestra after suffering chronic exposure to the insecticide which was being sprayed on walls of the building during a rehearsal. The key witness at the trial was a British doctor, Goral Jamal, whose testimony on the various effects of organophosphate poisoning, particularly in retarding the nervous system, was accepted by the court and so opened the door to claims for compensation against agrochemical producers throughout the world. The case had particular pertinence because diazinon was at the same time being cited as a potential cause of illnesses suffered by Gulf War veterans in the United States and United Kingdom in long-running legal battles.

Another area of concern is the potential danger from the use of agrochemicals in the home. Despite the growing popularity of 'organic gardening' in Europe and North America, the garden still remains the largest proportional recipient of agrochemicals. While less toxic formulations have gradually come to replace the sorts of insecticides and herbicides available in the 1950s and 1960s, the sheer presence of poisonous chemicals where families live and children play is a source of short and long-term health concern. Approximately 57% of pesticide poisonings in the United States- some 50,000 cases per year- are to children under the age of 6 (Litovitz et al. 2002).

[1] Kristan Bowers Phillips v Initial Environmental Services Ltd. (HCPI 580/1996)

2.1.5 Poisoning Due to Industrial Accidents

Accidental poisoning during the production and transport of pesticides can, of course, affect the health of the general public, in addition to those employed in the industry. This was made most dramatically evident in Bhopal, India, on December 2, 1984, when a gas leak at a plant formulating a chemical for use as a pesticide caused the world's worst ever industrial accident.

The disaster at the Union Carbide plant in Bhopal does appear to have been the culmination of circumstances close to any 'worst-case-scenario' imaginable for a chemical production site. The plant's end-product, the carbamate carbaryl, also known as Sevin™, is not particularly hazardous (category II of the WHO Classification by Hazard), but the chemical methyl-isocyanate (MIC) which is used in its production is extremely toxic. As an intermediate chemical, however, MIC did not feature on the WHO Classification by Hazard and even failed to appear on UNEP's International Register of Potentially Toxic Chemicals. Thus, Indian authorities were completely unaware that the chemical was being stored.

In addition to the fact that nobody was really aware of the nature of chemicals used at the plant, it later emerged that safety standards were also poor. One worker had been killed and three others injured by exposure to phosgene, another chemical used in the processing of MIC in 1981 during Bhopal's first year as a manufacturing unit (phosgene was one of the chemicals used on the battlefields of World War One). In the following year a visiting safety team from Union Carbide's headquarters in the United States described the plants MIC unit in an internal report as possessing, 'serious potential for sizeable releases of toxic materials' (Weir 1987: 40). Such concerns were echoed in the Indian press in a series of reports by local journalist Raj Kumar Keswani, culminating in an article for the Hindu periodical

Jansata just six months prior to the accident. Investigations into the accident later found numerous examples of negligence which aided the tragic gas leak. A refrigeration unit used to maintain MIC at a lower and more stable temperature had been switched off to save money, while temperature and pressure gauges were routinely ignored by workers because of their unreliability.

Added to the ignorance of the nature of MIC and the negligence over safety precautions at the plant, is a third factor accentuating the Bhopal tragedy. Bhopal is a poor city and many thousands of people lived in crowded slums near to the Union Carbide plant. These people were powerless to protect themselves from the escaping fumes which spread over the ground (MIC is heavier than air). David Weir has pieced together eye-witness reports of the Bhopal tragedy to come up with a dramatic account of the night of December 2, 1984.

> *Hundreds of thousands of residents were roused from their sleep, coughing and vomiting and wheezing. Their eyes burned and watered, many would be at least temporarily blinded. Most of those fortunate enough to have lived on upper floors or inside well-sealed buildings were spared. The rest, however, opened their doors onto the largest unplanned human exodus of the industrial age. Those able to board a bicycle, moped, bullock, car, bus, or vehicle of any kind did. But for most of the poor, their feet were the only form of transport available. Many dropped along the way, gasping for breath, choking on their own vomit and finally drowning in their own fluids. Families were separated; whole groups were wiped out at a time. Those strong enough to keep going ran 3.6 to 12 miles before they stopped. Most ran until they dropped* (Weir 1987: 16).

Estimates of the numbers of casualties vary, but it is believed that 200,000 people were exposed to the gas and 17,000 permanently disabled as a result. The immediate death toll could have been anywhere between two and eight thousand, as most of the victims were not formally recorded in any way, and the killing of entire families hindered the identification process. Long-term health effects include various breathing and digestion disorders along with birth defects and spontaneous abortions. After years of legal wrangling, Union Carbide USA and their Indian subsidiaries were finally made liable for prosecution in 1991, opening up the way for compensation payments to 500,000 people and for the setting up of a hospital in the city to deal with ongoing ailments.

The Bhopal disaster, as we have seen, was a consequence of a set of particularly dire circumstances. As such it has been evaluated by many within the chemical industry as a fluke, a one-of-a-kind disaster unlikely to occur again. A speaker at the 'Chemistry After Bhopal' conference in London in 1986 compared the disaster to the sinking of the Titanic, an undoubted tragedy, but not justifying the abandonment of sea-travel (Dudley 1987: x). Many skeptics of pesticide production safety, however, turn the Titanic analogy on its head, as they believe Bhopal, rather, represents the tip of an iceberg, with a vast number of smaller accidents lying submerged from public and political view. Weir, in his book *The Bhopal Syndrome*, argues that the tragedy is continually repeated in 'mini-Bhopals' and 'slow-motion Bhopals' (Weir 1987: ix), in which unseen poisoning occurs. The determination to learn the lessons of the Bhopal tragedy, led to the setup of a 'No-More Bhopals' network at a 1985 Nairobi conference on development organized by the Environmental Liaison Centre and the International Coalition for Development Action.

While it is fair to consider Bhopal as a unique accident in terms of its scale, many examples of 'mini' and 'slow-motion Bhopals' can be found. In 1976, over 500 kilograms of toxic vapor were released after an explosion at a chemical plant in Seveso, northern Italy, after a build-up of pressure. Trichlorphenol and dioxin TCDD, a constituent of the infamous ‘Agent Orange’, used as a jungle defoliant during the Vietnam War, pumped out to form a large cloud around the plant, although no acknowledgement of this was made to nearby villages for four days. Within three weeks pets and crops had died, thirty people were hospitalized with burns or liver pains, and one person had died. The principal health impacts at Seveso were long-term however, owing to the highly teratogenic nature of the released gases. Accurate medical records were not kept in the aftermath of the disaster, but Dr. Alberto Columbi conducted research revealing that even by 1978 birth defects were at a rate of 53 per thousand in the areas around Seveso, compared to an average of below 5 per thousand in the Lombardy region as a whole (Dudley 1987: 107). The Catholic Church became involved in the issue, when some women contaminated by the poison flouted Italian law and had abortions performed.

The fact that tragedies can occur outside the glare of the sort of media interest shown at Bhopal, is seen in the case of the PT Montrose DDT plant at Cicadas, Java. Suspicions that the plant had been secretly burning off waste at night were confirmed by an investigation conducted by WALHI (Indonesian Environmental Forum) and KRAPP (Indonesian Network Against the Misuse of Pesticides) in 1985. It emerged that, over time, 25 villagers had been killed as a result of this action (Weir 1987: 65).

Several major industrial disasters involving fertilizers have also occurred, largely due to the explosive nature of ammonium nitrate, which has also seen such products used by terrorist groups for incendiary devices. The explosion of a ship carrying this fertilizer at port killed 561 in Texas City in 1947, and is one of the worst industrial accidents in history. More recently, 31 people were killed and 200 injured as a result of an explosion in

2001 at a storage hanger at the Atofina Grande fertilizer plant near Toulouse, France, which created a 50 meter-wide crater, and in 2007 at Monclova, Coahuila, Mexico, when a trailer crash left 40 dead.

2.2 Environmental Pollution

The fact that all pesticides are by their nature toxic substances means that any contamination of unintended targets with them is potentially hazardous, and thus undesirable. The most environmentally hazardous organic pesticides and some other organic chemical compounds created for industrial purposes have, in recent decades, come to be known as Persistent Organic Pollutants. These compounds, frequently referred to by the acronym 'POPs', are defined by the United Nations Environment Programme as 'chemical substances that persist in the environment, bioaccumulate through the food-web and pose a risk causing adverse effects to human health and the environment' (UNEP 2009). Fertilizers tend to be less inherently toxic, but can also become significant pollutants if used in excess.

Once again, however, it can be seen that there are different levels of concern over this phenomenon. To some actors, the evidence of environmental damage due to agrochemical use is enough to warrant the outright abolition of their use in any capacity, whereas others merely wish to see them used with some consideration for their ecological consequences. As with human poisoning, the actual extent of pollution by agrochemicals is unclear and disputed by scientists and political actors alike. Traces of pesticides can be found in the soil, in the water, in the air, and in unintended crops and animals, but there is little consensus as to when this equates to pollution at a level at which we should be concerned. Most insecticides and herbicides that are sprayed do not hit their target and, instead, can contaminate the air, water and soil with a variety of environmental consequences. Those pesticides that do hit their intended destination may still end up killing more than that target when they pass down the food-chain and are ingested by other organisms.

Aside from such 'collateral damage' resulting from chemicals accidentally missing their intended target or willfully being employed in ways for which they were not designed, the chemical properties of POPs can cause them to be environmental hazards well away from the fields where they have been applied. Since they are so slow to break down and tend to be stored in fat, POPs can end up deposited in animals thousands of kilometers from where they were used. In a phenomenon known as the 'grasshopper effect' chemicals, like DDT and carbofuran, after evaporating in the warmer climes where they tend to be used, can then be carried around the globe in the atmosphere or water in a series of 'hops' of evaporation and deposition, and then build up in food-chains remote from where they are used. Hence Polar Bears, at the top of Arctic food-chains, have been found to be contaminated by POPs (Tenenbaum 2004).

2.2.1 Forms of Agrochemical Pollution

2.2.1.1 Soil

The soil is the principle recipient of agrochemicals, the source of which may be deliberate or accidental. Unlike the intentional entry of pesticides into the soil, which is usually a precise procedure, accidental or collateral entry is indiscriminate and affects a much wider land area, including areas where their presence may be wholly undesirable. Much of the pesticides intended for crop application clearly will miss their target or wash off the plants into the soil beneath. To this can also be added the entrance of pesticides into the soil from crop residues, leaf-fall and root deposits. A less voluminous but more widespread source of pesticides which enter the soil is by atmospheric fallout. Small amounts of pesticides have been detected in raindrops and atmospheric dust, which are absorbed into the soil on reaching the ground.

Whether the presence of an agrochemical in the soil constitutes an environmental problem or not depends somewhat on its persistence. A quickly degrading chemical will not be likely to disrupt the ecosystem greatly, but a highly persistent chemical may have biological effects beyond the period of its usefulness. Four types of such biological effects can be environmentally damaging. The chemical residues may i) survive long enough to affect succeeding crops, ii) affect soil organisms, iii) leach into water, or iv) cause long-term damage to soil fertility. The effects of residues on living organisms within the soil can also be summarized into four categories. They may a) be directly toxic, b) cause genetic resistance, c) be passed on to other organisms, or d) have sub-lethal effects on behavior or reproduction.

2.2.1.2 Water

As with the soil, agrochemicals may enter water sources either deliberately or accidentally, although instances of the former are far fewer. Relatively tiny amounts of pesticides are applied to streams, ponds, and reservoirs in order to protect fish, attack weeds and algae, and control insects which breed in water. These sorts of practices are generally restricted in the West by firm legislation. In the United Kingdom for example, the local water authorities are required to be contacted before any spraying operations in or around freshwater areas can be undertaken. In some developing countries, though, the deliberate addition of pesticides to freshwater for the purposes of fishing has been reported on a number of occasions.

The unintentional contamination of groundwater remains the more serious problem however. Agrochemical residues can enter water through drift and atmospheric fallout in the same way as they do the soil, but also in a number of other ways. Chemicals in soil may enter nearby water through runoff or be carried there with eroded soil particles. Pesticides also may make up some of the industrial effluent regularly pumped into streams and rivers. They may be the wastes from fabric plants practicing moth-proofing or from the manufacturing, formulating, and packaging stages of production in an agrochemical firm. Similarly, sewage will often contain pesticide traces such as the bactericides found in some soap and cosmetic products. In addition, spills of pesticides into rivers have been known during the storage and transportation of the chemicals. Hundreds of tons of pesticides and other chemicals were washed into the Rhine at a Sandoz warehouse in Basel, Switzerland, in November 1986, after a fire was brought under control with hoses.

The effects of a cumulative input of pesticides into groundwater can also be lethal to the organisms which live there. An increase in the mortality of bacteria, fungi, algae, aquatic invertebrates, amphibians, reptiles or fish will disrupt the food-webs of which they are a part, and their parent ecosystems. The fact that pesticides concentrate in the tissues of aquatic organisms more readily than in terrestrial life-forms exacerbates this problem. Of most concern to humanity is the effect on some fish populations through such pollution, either by direct poisoning or indirectly due to a depletion of their traditional prey. The presence of pesticides in groundwater can also have sub-lethal effects on aquatic life. The raising of water temperature due to pesticide presence, or the entry of chemicals into fish brains or nervous systems can impact their behavior and reproductive capacities. The most serious consequence of this behavioral change occurs when a species of fish develops resistance to a pesticide to which it has been exposed. When this happens, these fish can carry once lethal amounts of chemicals within themselves, and then pass them on to the next organism in the food-web.

The run-off of fertilizers into freshwaters is a key cause of the pollution known as cultural eutrophication resulting from the unnatural accumulation of phosphates, nitrogen and or other plant nutrients. The consequent growth of algae, vegetation or microorganisms on the water surface blocks light and increases oxygen use with sometimes devastating effects on underwater life through the creation of 'dead zones'. The world's largest 'dead zone' is in the Gulf of Mexico into which the Mississippi River empties, and others exist in the Baltic, Black Sea and Lake Eerie.

2.2.1.3 Air

Pesticide droplets have been detected in the atmosphere over most parts of the globe. Clearly therefore, they are capable of falling to earth many miles from the areas where they were originally intended to be applied.

Pesticide vapors enter the atmosphere in many ways. A significant proportion of pesticides may be lost during spraying, by drifting in the wind, or through evaporation. Volatilization can also take place on secondary deposits of pesticides. Some particularly persistent substances, such as DDT and dieldrin, remain long enough as surface residues after falling with rain that they are subject to evaporation again. Other routes by which pesticides enter the atmosphere include the escape of vapors from pesticide manufacture and formulation plants, and the introduction of residues within dust storms originating in agricultural areas.

Though the density of pesticides which fall to Earth from the air is far less of a hazard to man and the environment than the pollution of soil and water, concern remains at the build-up of toxic vapors in the atmosphere. Even with the progressive phase-out of the most toxic of agrochemicals, the persistence of POPs ensures that many used years ago remain in the atmosphere.

A different form of environmental hazard due to the existence of certain pesticides has become apparent over the last twenty years. The soil fumigant methyl-bromide was in 1992 confirmed as a significant agent in the depletion of the ozone layer. A UNEP report concluded that around half of all methyl-bromide applications to the soil are ultimately emitted into the atmosphere, where their capacity for ozone destruction is at least thirty times greater than that of organochlorine compounds, such as the infamous 'CFCs' (chlorofluorocarbons). The report estimated that between five and ten percent of annual global ozone depletion was attributable to methyl-bromide (UNEP 1992).

2.2.1.4 Wildlife

Although water and soil contamination are a known source of faunal exposure to agrochemicals, the greatest route by which wildlife come into contact with pesticides is through the contamination of their food sources. It may be the case that the effects of pesticides on soil-inhabiting organisms are limited, but the impact on some predators by these organisms can be far more profound. Birds are far more subject to taking in pesticide residues in this way as their bodies break down harmful chemicals less readily than do mammals. The birds most vulnerable are those at the top of food-chains, the birds of prey. Persistent chemicals such as DDT and dieldrin end up deposited in these creatures *via* small birds who feed upon contaminated insects in the soil. The birds of prey are left with the biggest deposits from having accumulated the toxic residues of all organisms below them in the food-chain. This process is known as biomagnification. In the United Kingdom, the Eurasian Sparrowhawk (*Accipiter nisus* L.) was made nearly extinct for 25 years because of direct poisoning from their prey and the thinning of their eggshells due to pesticides. The birds began to re-emerge in the late 1970s once the residues of organochlorine pesticides used in the 1950s had finally begun to disappear (Newton et al. 1992: 31).

In the United States alone, where restrictions on chemical use are among the most stringent in the world, it is estimated that every year between 6 and 14 million fish and around 5% of the total honeybee population are killed as a result of exposure to pesticides (Pimentel 2005). Globally, figures substantiating the environmental impact of pesticides are predictably sketchy, but certain well-documented cases give a hint at the scale of damage. For example, forensic analysis has proven that at least 4,000 Swainson's Hawks (*Buteo swainsoni* Bonaparte) in Argentina were killed as a result of eating caterpillars that had been sprayed with a newly imported organophosphorous insecticide, monocrotophos, during the summer of 1995-1996 (Goldstein et al. 1999). In Kenya, hundreds of lions and vultures are known to have been killed between 2004 and 2009 as a result of exposure to a form of carbamate insecticide known as carbofurans, recognized as POPs. Carbofuran products, which are completely prohibited from use in the European Union and highly restricted in the United States, are designed to protect corn and other crops, but owing to their toxicity are also fatal to other animal species and are known to have been used by cattle herders to eliminate mammalian prey by lacing animal carcasses and leaving them as traps (Howden 2009).

2.2.1.5 Crop Losses

Pesticides may also be responsible for damaging farm crops when the chemicals become volatile, or unintentionally come into contact with crops other than those they are intended to protect. The drift of vapor from neighbouring crop fields, the effects of herbicide residues which have remained in the soil after application on a different crop in a previous season, or changes in the nature of a pesticide due to climate can all be causes of crop losses. Pimentel (2005) estimates that beneficial crop losses amounting to $1.5 billion occur every year in the United States.

It can be proven that pesticides and fertilizers sometimes pollute the environment and poison the organisms that inhabit it, but the overall significance of this to the natural world is still open to debate. The influence of agrochemicals is one of many inputs determining the balance of nature, alongside far less contentious human practices such as building reservoirs and dams or fishing. While the wholesale contamination of the environment by care-free pesticide or fertilizer application is clearly undesirable, minor changes to an ecosystem need not necessarily be viewed as ecologically damaging. Yet, judging whether the net result of such change is desirable is difficult to discern and subject to dispute by the political actors affected by environmental agrochemical pollution.

2.3 Agrochemical Residues in Food

Human poisoning by agrochemicals can also occur indirectly, through the consumption of contaminated foodstuffs or drinking water. As with all areas of agrochemical pollution, the extent to which the presence of residues in food represents a threat to human health is unclear and hotly disputed between competing stakeholders. High doses of agrochemical toxins have been responsible for a number of acute poisonings and even deaths of people eating the contaminated produce. The worst food poisoning epidemic of all time occurred in Iraq in 1971-1972 due to the consumption of bread made from wheat grain treated with an organochlorine fungicide. In total, 6530 local farmers and members of their families were admitted to hospitals with varying symptoms and 459 died. The fact that the symptoms took at least 60 days to appear contributed to the size of the catastrophe (Al-Tikriti and Al-Mufti 1976).

Direct poisoning of this sort results from an ignorance of the hazardous nature of pesticides. Reports from developing countries abound with stories of farmers continuing to spray right up until harvesting time in the face of heavy pest infestation. Pesticides have even been known to be used in fishing. Alongside the effects of such wanton misuse of pesticides, food produce can also be contaminated accidentally by spray drift or by a leakage of the chemicals during storage.

Such cases represent extreme instances of poisonings resulting from malpractice, but the subtler health impact of agrochemical residues remaining in foodstuffs after their normal application has emerged as a major health and consumer issue over the last fifty years. The rise to prominence of organic food, grown without the aid of any chemical pesticides or fertilizers, is testament to public concerns about the presence of potentially toxic residues in their food.

Agrochemicals can also enter the human body *via* drinking water from two forms of contamination. First, agrochemicals applied deliberately or accidentally to rivers and lakes may be carried into aquifers. Second, pesticides or fertilizers can gradually leak into groundwater supplies *via* the soil. As with occupational exposure, the long-term health impact of consuming small traces of agrochemical residues remains a concern. Excessive concentrations of nitrates in drinking water have been linked in studies to the potentially fatal infant condition known as 'blue baby syndrome' (McIsaac 2003). Pesticide residues that are carcinogenic or linked to birth defects and other ailments do remain in foodstuffs, but generally at levels too low to produce scientific certainty on a causative link (Oates and Cohen 2011, Hamilton and Crossley 2004). Another area of concern is the 'cocktail effect' of different combinations of agrochemical residues. Pesticides are often used in combinations and it has been shown that chemicals that are comparatively safe individually can acquire dangerous properties when combined with other chemicals in a process known as *synergism*.

Some pesticides are used not to save a crop from pest destruction, but merely to maintain its appearance to a particular standard. Consumer expectations ensure that retailers demand blemish-free products from farmers and exporters, although there are no discernible health risks inherent in partially brown bananas or lettuces containing a few holes in their leaves. Maintaining the cosmetic value of products leads to the spraying of crops until close to harvesting, a practice which increases the likelihood of residues in the final product. Similarly, consumer demand for fruits and vegetables out of season means that chemicals are often used on stored produce to avoid insect or fungus attack. The residues of hormones given to promote growth in cattle are also prominent health concerns, often linked to cancers and reproductive problems. Steroids used in beef have been linked to the lowering of sperm counts (Swan et al. 2007). The threat posed by hormones is taken very seriously in Europe, where extensive national and European Union restrictions are in place, but has not prompted the same level of political response in North America where their use remains prominent.

The human health significance of traces of agrochemicals that remain in foodstuffs is subject to great debate. The agrochemical industries defend themselves by pointing to rigorous testing procedures for new products. As well, they argue that national legislation on permissible levels of residues on imported and home-grown foods is also rigorous and more than sufficient to ensure consumer safety. Prominent United States scientist Bruce Ames has argued that excessive caution over the carcinogenicity of pesticide residues is absurd given that fruit and vegetables naturally contain carcinogenic chemicals that can even be counterproductive, given that resultant public fear leads to lower consumption of such foods which leads to greater cancers and other ailments (Ames 1984). This argument is, though, disputed by others who observe that human exposure to natural carcinogens in food cannot be compared to that from added synthetic chemical residues because it has been an ongoing process for over a million years, allowing for adaptation (Richter and Chlamtac 2002).

2.4 The International Trade in Agrochemicals

The introduction into the Third World of Western agricultural technology in the 1960s and 1970s, known commonly as the 'Green Revolution', created a dependence on pesticides produced in the West and opened up a massive new trade, flowing from North to South. Despite the growth of Asian agrochemical production, most of the Global South's pesticides are still imported from the big chemical corporations based in the North.

International regulation of pesticide trading has, until recently, been extremely lax and certainly not kept in step with municipal law in the developed states. Awareness of the hazardous nature of many substances used for pest control has gradually seen the most toxic chemicals becoming banned or restricted in the West with rigorous safety guidelines for their application developed. Many pesticides that are banned and withdrawn from use domestically in the developed world, however, have continued to be marketed to the Global South where many states have weak regulatory procedures or lack the resources to efficiently enforce those that do exist. The response of many agrochemical firms to greater scrutiny of their produce by health and environmental groups in the West has been to redirect their goods to such less restrictive markets. Following the banning of DDT in the United States because of its carcinogenic qualities, some chemical companies turned to Third World trading partners to stave off losses from accumulated stocks of the chemical. Weir and Schapiro (1981) revealed that over 25% of the exported pesticides from the United States were unregistered, with their destination invariably being a less developed country. Often the main importers of such products are subsidiary bodies of the companies manufacturing them in the first place.

The flood of particularly toxic pesticides into the Global South, backed up by persuasive advertising, has accentuated the problems which arose when such products were used widely in the West, as specialized knowledge on pesticides is much scarcer and levels of illiteracy prevent workers from even reading safety instructions printed in their own language. A clear theme which emerges from this study is that the 'side-effects' of pesticide use, human poisoning, environmental pollution and food contamination, are at their most damaging in the underdeveloped world. As these costs have become apparent, the view that the international trade in pesticides needs to be controlled has developed. Acceptance of this norm has been influenced by the realization in the West that trading in deadly toxins ultimately hurts them too. Pesticides profitably dumped on the Third World market can return to Western consumers in their food imports from the same countries, a process which has been labeled the 'circle of poison' (Weir and Schapiro 1981).

3 Limiting Agrochemical Use - Integrated Pest Management

3.1 The Rise of Integrated Pest Management

In light of the damage that can be done to the environment and human health by the misuse of chemical pesticides, many people have called for a more limited use of these substances in general, going beyond trade restrictions. A body of opinion has steadily emerged which would like to see all uses of manufactured pesticides ended, in favor of alternative practices of pest control. Even more conservative voices within the world of agrochemicals have come to aspire towards a situation in which reliance on chemicals is replaced by a multi-faceted approach to the problem of crop-protection in agriculture - Integrated Pest Management. This middle ground, of maintaining agrochemical use but in a much more limited and sustainable manner, represents a clear expression of agroecology and has gathered momentum in parts of the world where principles of environmental sustainability have taken root.

Several governments have implemented legislation reducing pesticide use in this way. In 1972 President Nixon, riding the wave of public concern induced by environmental pollution from DDT and Agent Orange, gave rhetorical support for IPM schemes in the United States. The governments of Denmark, the Netherlands and Sweden in the late 1980s launched schemes to cut pesticide use by 50% before the end of the century. The Dutch government has continued to advocate IPM in a series of initiatives since then (Boorma 2008) and the United States in 2004 launched the National Road Map for IPM, promoting the exchange of information on implementing such schemes. In possibly the world's first binding legal IPM provision, the 2008 German Plant Protection Law insists that IPM procedures are followed in plant protection (IITA 2008). IPM has also received advocacy from the European Union 2009 Sustainable Use Directive.

The inclusion in the FAO's Pesticide Code of Conduct of Article 3.8 stating: ‘Governments and the pesticide industry should develop and promote integrated pest management’ (FAO 1986), signified that the principle that agrochemical usage be kept to a minimum has developed the status of an international norm. This was reaffirmed in 1992 when IPM was cited as good practice at the United Nations Conference on the Environment and Development (UNCED) spawning the Consultative Group on International Agriculture’s ‘Research Programme on IPM’ in 1996 and a Global IPM Facility, jointly sponsored by the FAO, UNDP and World Bank the following year.

The agrochemicals industry has noted this, and made efforts not to appear out of line with such opinion. As far back as 1983 a report from Shell Chemicals on their agrochemical business acknowledged that:

> *Environmental and economic arguments as well as sound biological principles support a trend to integrated pest management (IPM), by which is meant the coordination of agricultural practices and biological and chemical control of pests* (Shell Chemicals 1983).

The report goes on to stress that IPM ultimately must still be dependent on chemical applications. The acceptance of the role of other methods of pest control, however, indicates a tacit acknowledgement of the norm for minimizing chemical use. The agrochemical industry’s international mouthpiece, the Global Crop Protection Federation, for example, has a working group dealing specifically with IPM implementation.

The development of this norm of limiting agrochemical use has its roots not only in the problems of environmental and human poisoning referred to earlier, but also in the growing realization that over-reliance on chemicals in agriculture has its own pitfalls. While crop yields undoubtedly improve with the initial application of pesticides, these yields are difficult to sustain because pests often develop resistance to a particular toxin after prolonged exposure to it. By the end of the twentieth century, the number of insects known to be resistant to pesticides rose and has increased tenfold since the 1950s to over 500 and 124 species of weeds were known to be resistant to herbicides (Cox 2004: 85, Heap 1997). The physiological adaptation of insects to a pesticide can take on a number of forms. Some insects have been known to evolve a layer of their body which is impenetrable to a pesticide, while others develop systems which can store insecticides and then detoxify them. In Malaysia, the mosquito *Aedes aegypti* (L.) has developed the capacity to excrete an insecticide which was once fatal to it, before it can be absorbed. Research in Malaysia has also revealed that pests can sometimes develop resistance to types of insecticides other than the one which has actually been used against it. The 'diamondback' moth [*Plutella xylostella* (L.)] became immune to the effects of both organophosphate and carbamate pesticides, despite never having been exposed to the latter form of chemicals (Sahabat Alam Malaysia 1984: 35).

In addition to this problem of pest resistance is the phenomenon of pest resurgence in the face of continued pesticide exposure. Pesticides often eliminate natural predators of the targeted pest, which can lead to the pest actually flourishing after a while. The response of farmers to pest resistance and resurgence is often to increase the dosages of pesticides, which merely serves to exacerbate the problems of pollution, poisoning and food contamination, while ultimately not improving yields. The effect of increasing pest resistance has been to make the issue of minimizing the use of pesticides and fertilizers salient to the industries that manufacture them. The realization from the agrochemical industries that it is in their best interests to discourage the overuse of their products is, of course, a position far removed from that of the environmentalists, some of whom call for an outright end to pesticide use, but some consensus has been able to emerge among them.

3.2 The Alternatives to Chemical Pesticides

3.2.1 Biological Control

The most widely used alternative to chemical pesticides in agriculture is the practice of mobilizing the natural predators of a pest in order to control it. This usually involves the introduction of a natural enemy somewhere where it does not naturally occur. For such predators to become established in their new habitat, however, a small pest population must be maintained in order for them to continue suppressing the pest. Careful research is required before such action is taken in order not to upset the ecosystem and create new, unforeseen problems. If a predator is introduced which also attacks crops or beneficial insects it can become a pest in its own right, as happened when Sri Lankan crows (also known as Indian House crows; *Corvus splendens* Vieillot) were introduced to Malaysia by British colonialists in the early 20^{th} Century with the intention of controlling coffee caterpillars (Sahabat Alam Malaysia 1984: 40). An alternative to introducing new species to a habitat is to augment an existing pest predator by providing it with food and facilities for breeding.

The most common form of biological control is the use of insects to control other insects. This technique has been employed successfully in the protection of cassava crops in Central Africa by the International Institute of Tropical Agriculture (IITA), an internationally funded center based in Ibadan, Nigeria. IITA research discovered a number of predators to the mealy-bug [*Phenacoccus manihoti* Mat.-Ferr. (Horn., Pseudococcidae)], the cause of considerable depletion in cassava yields, and launched, in the 1980s, the world's largest biological control program based around the parasitic wasp *Epidinocarsis lopezi* (De Santis). The parasite quickly became established in much of the 'cassava belt', which stretches from Senegal to Mozambique, and helped reverse a crisis which was costing around $2 billion annually in losses. The mealy-bug was brought under control in all nineteen countries in which the wasp was released and crop losses fell from 50% to below 20% (Gikaru and Ajayi 1990: 33).

Biological control can also include the use of microbes as pathogens against a variety of pests. Some well known examples of this include *Bacillus thuringiensis*, used by organic gardeners to control caterpillars and *Trichoderma viride* Pers., which attacks silver leaf fungus on fruit trees. The advantage of microbes over insects in biological control is that they are usually more specific predators and are less prone to infest beneficial crops or insects. The field of biopesticides has been boosted by the development of techniques to genetically increase the capacity of microbes to kill their insect hosts, such as implanting genetic fragments from the venom of scorpions and mites into the genome of insect-specific baculoviruses, greatly increasing their deadliness when infecting insect hosts. Biopesticide sales in the United States grew by 20% per year in the 2000s (HighBeam 2012).

3.2.2 Resistant Plants

Another means of reducing dependence on pesticides in agriculture is to breed strains of crops which are inherently resistant to their normal predators. Many voices within agriculture have come to advocate a switch from the traditional practice of breeding plants for maximizing yields, as the ‘Green Revolution’ had taught the Third World, to focusing on producing hybrid species requiring less chemical protection. Once again, economic arguments have been critical in altering perspectives within the agricultural community. The risks to human health and the environment from excessive pesticide use have been well documented, but the appeal of this form of crop protection lies in the fact that it reduces production costs and offers better guarantees of regular, albeit smaller yields.

Probably the most significant research in developing resistant strains of plants is being carried out by the IITA on the banana and its close relative the plantain. These fruits, which represent a staple food for over 60 million Africans, have increasingly fallen victim to a fungal disease known as Black Sigatoka [*Mycosphaerella fijiensis* (Morelet)], first discovered in 1973 in Zambia. The natural resistance of bananas to disease is negligible, owing to a continual history of selective breeding which has produced extremely low levels of genetic variability between fruits. Big plantations, responsible for providing the West's supply of bananas, have overcome this problem with the aid of chemicals, but this is an option not open to Africa’s many subsistence farmers. Hence, the IITA has developed resistant genotypes from wild bananas being propagated in the laboratory to produce new hybrid strains of banana. A process of evaluation is now being implemented to determine which new strain of banana/plantain is most appropriate to be bred for agricultural use (IITA 2012).

Much research in the field of plant resistance has concentrated on isolating the genetic traits responsible for resistance, so that they can then be bred into other plants not possessing such a capacity. The pioneer in this new era of genetically engineered crops was a strain of tomato which was interbred with a gene from the bacterium *Bacillus thuringiensis*. This bacterium kills caterpillars and its toxin, if introduced into a plants genetic architecture, can make the plant resistant to caterpillars and other common pests. As in the domain of hormone residues in food, a clear difference in attitudes to genetically modified crops has emerged between Europe and North America. They have been embraced in the United States, but not in more risk-aversive Europe through fears of the potential health and pollution consequences of meddling with nature in this way.

3.2.3 Semiochemicals

There exist a number of ways to help protect crops from pests involving chemicals, but which fall short of directly killing the pest. The chemicals used are less toxic and consequently less hazardous to man and the environment than traditional pesticides.

Probably the best researched of these chemical control methods involves the use of insect sex pheromones which can be applied so as to disrupt the mating of insects or lure them into traps. Such methods are now commonly used in orchards (Chandler et al. 2011). A different method of controlling insects by disrupting their reproductive activities is to use chemicals known as chemo-sterilants to sterilize the males of a pest species. These chemicals, though, can have the disadvantage of being mutagenic to the pest, permitting the target organism to genetically develop resistance in the same manner as many have to conventional pesticides.

3.2.4 Cultural Controls

Not all of the non-chemical forms of crop protection are procedures rooted in technology, however. During the latter part of the twentieth century, cultural controls (limiting pests by affecting their habitats) have re-emerged as general techniques employed by farmers to protect their crops before dependence on pesticides sets in.

Returning to the age-old practice of crop rotation is one such form of cultural control. With the advent of the Green Revolution, crop rotation was largely abandoned in favor of monoculture, which allows for more economical harvesting and sowing, but at the same time permits pests to flourish. Multi-cropping, on the other hand, provides pests with only small areas of host crops to inhabit, while the practice of having fallow seasons within the cycle breaks up any pattern of gradual pest proliferation.

Another traditional farming practice which has been rediscovered as a means of culturally controlling pests is the destruction of crop residues after harvesting. Burning or ploughing fields after they have been harvested removes any remaining pest habitats and eggs that may otherwise flourish when the next growing season begins. Inter-planting a cash crop with plants or flowers which deter its pests is another old-fashioned agricultural technique which is beginning to find favor again, especially with the rise in consumer demand for organic produce in the West. Planting orange marigolds (also known as French or Aztec marigolds; *Tagetes erecta* L.) among crops of cayenne peppers (*Capsicum annuum* L.), for example, attracts pollinating insects to the flowers while simultaneously repelling other potentially harmful insects with their scent. Similarly, the application of natural products such as lemon-rind, tobacco plant stems, and ash is effective in killing some insects or at least in deterring them.

The use of physical controls against pests can sometimes be an effective means of limiting their damage without resorting to chemicals. Placing metal barriers in the ground around a crop field is a way of deterring termites or rodents, for example, while utilizing yellow boards covered in glue can serve as a means of trapping whiteflies (Hemiptera: Aleyrodidae). Projects in the United Kingdom, Norway and Sweden in the early 1990s explored the benefits of creating banks of grass in the middle of crop fields, providing habitats for spiders and beetles which are the natural predators of aphid pests (Hawkes 1992). The premise behind this simple procedure, created by exempting field tracts from ploughing, is to reverse the effects of a gradual increase in the size of crop fields which has resulted in fewer hedgerows and with it fewer aphid predators.

3.2.5 Integrated Pest Management

Integrated pest management (IPM) utilizes the various pest control techniques mentioned previously, in line with the norm that chemical pesticide use should be optimized. The FAO/UNEP Panel of Experts have defined the concept as follows:

> *A pest management system that in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing them injury* (FAO 1967).

This represents a very holistic approach to pest control, as the whole ecosystem of which the plant and pest form a part is always considered. This is a total change in approach to traditional pest control, where each pest is treated as a separate problem, and any interrelationships are not considered. Thus, for instance, a fundamental principle behind IPM is the idea that the targeted pest should never be completely eliminated, but rather maintained at an acceptable level whereby damage to the crop is not economically significant.

The conception of this economic threshold indicates that IPM is rooted in more than merely the desire to restrict pesticide use for the good of the environment and human health.

It becomes apparent that, what are at first seemingly contradictory norms, form the framework on which the system is operated. The value on which traditional agrochemical use is guided, namely the optimization of profit by increasing yields and decreasing damage, is still influential under IPM, but is reconceptualized. By operating a system in which the aim is to satisfy all of these norms, the idea of an optimum yield becomes understood both in terms of economic profit and the human and environmental costs. Balancing these disparate aspirations requires that systematic research be undertaken before the appropriate remedies are integrated into the economically deficient ecosystem in question. At a simple level this may just mean taking time to estimate levels of pest infestation in a region prior to applying appropriate crop protection techniques, rather than applying pesticides immediately as a preventative measure. This sort of action will be likely to cut the farmers input costs, while simultaneously lowering the risk to the environment. The ultimate projection of this idea is to refine the deduction of the optimal yield with the aid of computer technology. Computer models can be made of the complex ecological interactions making up the system under consideration, to determine which measures of pest control represent the most appropriate long-term methods of obtaining an optimal yield.

3.3 Problems Associated with IPM

While the attraction of a scheme in which the environmental and human hazards of agrochemical use are reduced at the same time as economic profits are maximized is obvious, IPM is not without its drawbacks as a pest control scheme. The proposed alternatives to pesticides for use in crop protection also possess flaws which can become apparent if they are not carefully operated. Intensive research is required before biological control schemes can be enacted to ensure that the ecosystem is not undesirably disrupted by the introduction of a pest predator. It needs to be ensured that the predator is specific to the pest it is intended to control, or else it may become a pest in its own right by attacking crops or beneficial insects. The introduction of Cane toads [*Bufo marinus* (L.)] to Australia and of crows to Malaysia to control coffee caterpillars are cases in point. In both instances the introduced species' are accepted as having caused more harm than good to the crops they were intended to protect (Sahabat Alam Malaysia 1984).

The augmentation of advances in genetic engineering to the field of biological control, creating what are known as biopesticides, has created great excitement in the scientific world, but has not taken off as much as many anticipated in the 1980s. Biopesticides by 2011 had only secured around 2.5% of the pesticide market since they are highly selective, less straightforward to utilize and still comparatively unfamiliar to most farmers (Chandler et al. 2011).

Developing a means of pest control without resorting to chemicals or pest predators, by breeding pest resistant crops, also has its weaknesses. For a start, it is possible that the crop variety with the best resistance may have a yield that is too low to make it economically viable, or that its quality may be below what is expected by consumers. Only a limited number of resistant crops will be able to match these essential criteria. It is also known that a side-effect of increasing a crops resistance to a particular pathogen can be to reduce its resistance to another. Great concern has also been aired regarding the ramifications of manufacturing genetically engineered crops that are resistant to pests. Evidence that some insects have become resistant to *Bacillus thuringiensis*, the toxic genes of which have been incorporated into cotton plants, suggests that this form of pest control is prone to the same Achilles heel that has basically called pesticide use into question (Tabashnik et al. 2008).

Perhaps the biggest fear concerning this technology, however, is that ultimately it may actually provide a new and bigger stage for pesticides to act on and thrive. It should be remembered that it is agrochemical businesses that own the vast majority of plant breeding companies, and the concern of many is that, far from using resistant crops as an alternative to chemicals, they are exploited as a means of allowing more intensive pesticide use. Crops have been developed which are resistant to particular herbicides rather than weeds, allowing greater quantities of such herbicides to be used against the weeds without harming the crop. An empirical study by organic farming lobbyists in the United States, but based on agriculture department statistics, found that national levels of herbicide use had significantly increased since the augmentation of GM crops in the country (Benbrook 2009). The potential environmental consequences of this trend do not need to be spelled out, suggesting that the technology of inducing greater crop resistance is in the wrong hands and could exacerbate a problem it was hoped it could help solve.

The mutagenic effects of chemicals used to sterilize male pests have already been discussed, and it is clear that all forms of 'indirect' pesticides are still in their infancy as crop protection alternatives. At the same time, it is a common delusion that natural chemicals are inherently safer than their synthesized counterparts and so more preferable for use as pesticides. The use of tobacco-based solutions is frequently cited as a traditional pest control agent which can be rediscovered as an alternative to modern insecticides, but nicotine is as equally hazardous as most synthetic chemicals owing to its high mammalian toxicity.

The use of IPM as a package of pest control measures has had its successes, as has been illustrated, and it has been enhanced through the application of information technology. Extensive national pesticide reduction schemes have thus been implemented in many developed countries but its impact in the Global South has been much more limited (Cuba and Indonesia are notable exceptions). IPM's applicability as an antidote to all the ill-effects associated with pesticide use does, therefore, need to be qualified. The bulk of environmental and human tragedies occur in the Global South, where the application of such substances is comparatively unregulated. IPM does not always represent a viable alternative in these states because it is more complicated and, ultimately, rooted in advanced technology. An extensive empirical study by proponents of such measures, for example, concluded that ‘introducing IPM in South East Asia through the conventional transfer of technology oriented transfers simply does not work’ (Chowdhury and Ray 2008: 226). Returning to age-old methods of pest control may be less hazardous for Global South workers, but it should be remembered that it was the inadequacy of such measures to protect crops that led to the Green Revolution and chemical control in the first place. An economically viable IPM system requires sophisticated technology and a well-trained workforce able to analyze the ecology, geology, and agronomy of a region and prescribe the appropriate solution. These prerequisites are clearly not to be found in most Global South countries. This problem is recognized by the epistemic community who continue to advance IPM principles to developing countries with some successes, but progress is slow.

4 The Politics of Agrochemicals

4.1 The Emergence of Agrochemical Politics

The production and use of agrochemicals thrived from the late 1940s to the 1960s, when food yields soared and many tropical diseases appeared to be being brought under control through their use, but then the rise of political ecology brought numerous side-effects into focus. The issue of pesticide-induced environmental pollution was, in many ways, the catalyst for the emergence of the whole issue of environmental change on the international political agenda in the 1960s. The publication in 1962 of *Silent Spring* by Marine Biologist Rachel Carson from the United States, despite concerted corporate attacks on its scientific authenticity, is widely recognized as having helped fuel the take-off of environmental politics. The book's title alludes to a future world in which birdsong could no longer be heard, drawing on evidence that organochlorine pesticide use was damaging eggshells. It was this ecocentric message which prompted a backlash in the United States and much of the West against what was undoubtedly a profitable and, in some cases, life-saving technology, although the book did also highlight human health hazards associated with organochlorine pesticide use (Carson 1962). The controversial use of the jungle defoliant 'Agent Orange' (a trade name of the herbicide 2,4,5-T) by the United States during the Vietnam war also served to heighten anxieties about pesticides. At that point the use of such chemicals even entered the world of 'high politics' when Swedish Prime Minister Olaf Palme denounced the applications of Agent Orange by the United States as 'ecocide' at the 1972 United Nations Stockholm Conference on the Human Environment, prompting a diplomatic spat between the two countries. As with other environmental issues, the 1960s and early 1970s saw the entire arena of agrochemical production, trade and use at the international level move from being a relatively unchallenged and heralded technological development to a highly politicized set of issues.

The rise in concern at the effects of organochlorine insecticides on wildlife since the 1960s has contributed to the banning of, or severe restrictions on, the use of DDT, dieldrin and other notorious chemicals in most developed countries. The United States government enacted legislation restricting DDT use in 1969 and then outlawed its use altogether in

1972. Pesticides continue to arouse a certain amount of political controversy in the domestic political arenas of the developed world, but the phasing out of the most carcinogenic and polluting chemicals and their replacement with less toxic formulations, alongside the establishment of stringent consumer standards and health and safety regulations has significantly reduced environmental and health concerns. There have been some notable environmental benefits from these domestic legal changes, such as the return of Sparrowhawks in the United Kingdom since the 1970s after coming close to disappearing. However, as the United States figures referred to earlier indicate, there continue to be some significant pesticidal impacts on wildlife.

Since the 1960s, however, it has been transnational issues of pesticide use, production and trade that have commanded most social, environmental and political significance. The 'Green Revolution' saw many chemicals withdrawn from domestic use in the developed world continue to be marketed to the Global South where regulatory standards tend to be more lax. The monocrotophos used in Argentina, referred to earlier, was imported from the United States, where its use is prohibited. The response of many agrochemical firms to greater scrutiny of their produce by health and environmental groups in the North has been to redirect their goods to much less restrictive markets in an 'industrial flight' or 'race to the bottom'.

Chemicals were first legally restricted in a number of developed countries in the late-1960s and 1970s chiefly because of their proven effects on birds and other wildlife but this, in itself, has never proved a sufficient basis for global rules to develop. Global regimes which have emerged in the governance of pesticides have only crystallized once vested industrial and governmental interests have also come to see some advantage in regulation due to the consequent harmonization of trading standards.

It was the 1984 Bhopal disaster that served as the catalyst for a campaign involving numerous environmental and consumer activists aiming to regulate the global production, trade and use of pesticides led by a purpose-built global pressure group the Pesticides Action Network (PAN) formed two years earlier. The Bhopal disaster served to highlight concerns over pesticide toxicity beyond that which had been possible in the countless smaller-scale disasters that had occurred before 1984. Bhopal also served to expose a clear International Political Economy dimension to the pesticide industry since safety standards at the plant were found to be much more lax than those at the home-base in Virginia.

Crucially, self-interest as well as compassion in the Global North came to favor the regulation of the pesticide trade in the 1980s and 1990s as governments came to see that domestic legislation was insufficient for protecting their citizens. Pesticides profitably dumped on the Global South market can return to Northern consumers in their food imports from the same countries, or through long-range atmospheric pollution due to the 'grasshopper effect'. Additionally, chemical firms needed to improve their reputations after Bhopal and came to see that global standards would be less costly than further domestic legal restraints on their industry, and even advantageous in the long-run. Thus, the powerful players in pesticide politics, the chemical companies and Northern governments, have gradually been persuaded of the need for regulation, paving the way for the development of international law in the 1990s.

Contemporary global governance with regards to agrochemicals is focused on four areas: 1) regulating permissible amounts of residual chemicals in traded food, 2) regulating the export of certain pesticides, 3) outlawing the use and production of the most toxic chemicals, and 4) targeting a specific pesticide as part of the ozone regime.

4.2 The Politics of Agrochemical Residues in Traded Food

The origins of global policy on agrochemicals can be traced back as far as 1963 when the Food and Agricultural Organization and World Health Organization co-launched a body intended to "protect the health of consumers and to ensure fair practices in the food trade" (Codex 1989, 31). The Codex Alimentarius Commission, the implementing machinery of the FAO/World Health Organization Food Standards Programme, has a Committee on Pesticides Residues (CCPR) which sets global standards for recommended maximum levels of pesticide traces in traded foodstuffs, initially intended to be no more than voluntary guidelines. A Codex Committee on Additives similarly deals with traces of veterinary drugs or fertilizers.

Environmental and consumer groups have long suggested that Codex standards are more informed by the latter of its two stated aims and cannot be relied upon to guarantee consumer safety since the body is not impartial in its judgments and is chiefly motivated by the desire to harmonize national food standards to an agreed minimum in order to facilitate international trade. The membership of Codex is open to any member-state or associate member of the FAO and WHO who can then vote on a majority basis for the adoption of draft standards for food quality issues. The commission has always been far closer to the FAO than the WHO, owing to the latter's broader portfolio of responsibilities, and has attracted similar sorts of criticism to its closer parent of being over-influenced by Multi-National Corporations linked to the food industry (Avery et al. 1993). For example, of the twenty-three 'international non-governmental organizations' listed as participants at the Thirty-ninth CCPR meeting in July 2007, all were business representatives (Codex 2007).

This concern at excessive corporate influence was heightened with the creation of the World Trade Organization (WTO) and the sudden elevation of Codex's technical standards to quasi-international law. The 1995 WTO Agreements on the Application of Sanitary and Phytosanitary Measures (SPS) and Technical Barriers to Trade (TBT) cite Codex standards as the benchmark for determining whether state food standards are being used by members as an unfair barrier to free trade. The United States and Canada have accused the European Union of this in relation to hormone residues in beef, but a leveling down of international residue standards has not yet happened. Food in the Global North generally still continues to be produced in accordance with national pesticide residue standards since lowering consumer safety standards in democracies with active civil societies and a press is politically infeasible.

Codex standards for agrochemicals, though less stringent than the domestic standards of many developed states, are presently almost certainly sufficient to safeguard against significant pesticide risks to human health. Despite high levels of corporate influence, the CCPR's standards are drawn largely from the findings of the Joint Meeting on Pesticide Residues (JMPR), a respected WHO/FAO forum of scientists and academics without any corporate representation. JMPR recommendations on acceptable residue limits in foodstuffs, though less stringent than some domestic standards, are very much informed by the precautionary principle with levels set much lower than are known to be dangerous to health.

As with many other environmental and health issues there has been some breaking of the ranks on the appropriateness of the precautionary principle in spite of its apparent legitimization by all governments at UNCED in 1992. This was most notable in 2001 when the United States delegation at the 16th session of the Codex Commission on General Principles led a walk-out in protest at attempts to develop further use of the principle in Codex standards, arguing that this would represent a "non-scientific" trade barrier. The United States government and global chemical industry representatives have since focused on lobbying for a global harmonization of Codex Maximum Residue Limits (MRLs), but to date the right of states to fix their own- even more precautionary- MRLs has remained. Where Codex pesticide residue limits have been most influential is in providing a standard for developing countries lacking any MRLs of their own. Hence, Codex standards have not levelled-down standards with regards to pesticide residues in traded food and, despite extensive corporate lobbying and being co-opted by the WTO, have instead levelled-up standards and served to enhance public safety around the world. The precautionary principle has so far held sway and, at the moment, the pesticide residues regime represents something of a "bootlegger and Baptist coalition"[2] (Yandle 1989) with its rules developed from principles emerging from an epistemic community committed to safeguarding human health, with the economic interests of industry brought on board.

Significant national differences can be seen with regards to traces of growth hormones in traded meats. The European Union has banned the use of such products since 1985 in contrast to the United States and Canada, leading to a series of trans-Atlantic trade disputes once import restrictions were introduced in 1989.

4.3 The Methyl-Bromide Regime

An international regime has emerged since the early 1990s, regulating releases into the atmosphere of the soil-fumigant methyl-bromide which is used extensively in the farming of tomatoes and strawberries, particularly in the United States. Concerns had been voiced about the environmental effects of methyl-bromide for years (the Netherlands government phased

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[2] The term is derived from the days of alcohol prohibition in the United States when both the church and the illegal 'black market' gained in different ways from the law.

out its use in 1992), but it took the realization that the chemical posed a threat to human life for it to be made subject to any international regulation. The discovery that methyl-bromide was a significant ozone-depleting agent saw a global agreement concerning methyl-bromide use and production reached in November 1992 in Copenhagen as part of the *Montreal Protocol on Substances That Deplete the Ozone Layer*, the key treaty dealing with the issue of ozone depletion.

The Copenhagen meeting decreed that methyl-bromide production and consumption levels should be frozen at 1991 levels from the start of 1995. In September 1997, the 9th Meeting of the Parties to the Montreal Protocol committed 160 governments to a timetable for a complete phase-out of methyl-bromide production and use. In line with the 'common but differentiated responsibilities' principle agreed upon at UNCED, developed countries agreed to end use of the chemical by 2005 after a series of intermediate cuts, while developing countries agreed to a deadline of 2015 to eliminate its use following a freeze in 2002. As with other areas of environmental and humanitarian global governance, however, the United States position backtracked under the Bush Junior administration from seeming to support a complete phase-out, and they have maintained a significant level of methyl-bromide use since 2005 by exploiting a 'critical use exemptions' clause to the agreement far more than had been anticipated. The California strawberry industry, mindful of the costs of switching to alterative soil fumigants, lobbied hard for United States delegates to argue that previously agreed upon alternative fumigants were not adequate for the West Coast climate, much to the irritation of most other Montreal Protocol parties (Gareau 2008). Hence, methyl-bromide continues to be used, principally in the United States, but also in several other countries. A global phase-out is still proceeding, albeit more slowly than was originally envisaged.

4.4 Prior Informed Consent in Trading Chemicals

Probably the most significant development in the global governance of chemical pollutants was the 1998 *Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade* which came into force in 2004. The Rotterdam Convention sets out legally binding commitments constraining governments attempting to export chemicals banned in their own countries through the Prior Informed Consent procedure (PIC). The chemicals PIC regime stands as an example of how private governance can form the basis of more stringent consumer-focused regulation. The Rotterdam Convention made legally binding Article 9 of the FAO's 1986 *International Code of Conduct on the Distribution and Use of Pesticides*, a voluntary set of safety standards for the handling and transport of pesticides.

The PIC was initially resisted by displays of corporate power, but eventually was able to overcome such vested interests. The relevant PIC provision in Article 9 was withdrawn during the lead-up to the FAO Code's ratification in 1985 despite appearing on seven of its eight drafts in the face of strong persuasion from the United Kingdom and United States, motivated by a chemical industry lobby alarmed at the prospect of restrictions on their trade. No national delegation officially requested the deletion of the PIC provision and 30 countries protested its removal, but it appears that covert pressure convinced delegates at the ratifying conference that the Code as a whole would be at risk if a compromise over Article 9 was not accepted (Hough 1998: 113-120). Led by the Pesticides Action Network (PAN) and OXFAM, a campaign to re-incorporate PIC into Article 9 of the FAO Code and advance the principle carried on, regardless of the 1985 ratification. The Netherlands became the first country to formally embrace PIC into domestic legislation in 1985 and the European

Community made moves towards adopting the procedure for all its member states before eventually absorbing the whole FAO Code of Conduct, including PIC, into European law in the 1990s [3].

The establishment of the principle of PIC as a binding international rule was sealed by eventually gaining the support of the chemical industry in the early 1990s. The agrochemical industry's global political mouthpiece at that time, the *Groupement International Des Associations de Fabricants de Produits Agrochemiques* (GIFAP), announced in its annual report for 1991 that one of its aims for 1992 would be to "continue to cooperate with FAO/UNEP on the implementation of PIC" (GIFAP 1991: 11). The reason for this apparent "U-turn" on PIC appeared to be a fear of the alternatives, such as an outright prohibition of the export of certain pesticides. The drafting of a bill in the United States during 1991-1992 proposing the introduction of export controls for pesticides raised alarm in the agrochemical industry and prompted GIFAP to take the extraordinary step of criticizing the bill on the grounds that it was contrary to the very article of the FAO Code of Conduct it had so vehemently opposed:

> A major concern ... is the appearance of a draft Bill on pesticide export control in the USA which is very much at variance with PIC in the FAO Code, namely that this draft legislation is export rather than import control orientated (GIFAP 1991: 13).

GIFAP here saw an opportunity to ensure that any chemical trade regulations that did emerge would be based only on import rather than export restrictions. In a choice between PIC and export restrictions of the sort discussed in the United States Congress, the chemical

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[3] EC Directive EEC2455/92

industry came to accept the principle because it represented the lesser of two evils in the pursuit of their main goal of maintaining free trade. Thus, again, an agrochemical regime came to be formed through a 'bootlegger and Baptist coalition' of actors agreeing to cooperate to enforce norms in the name of differing values: safeguarding human health and maximizing economic returns, with the former the primary influence.

The Rotterdam Convention obliges parties exporting any chemical restricted by their own domestic legislation to send Decision Guidance Documents (DGD) to importing authorities detailing the basis of such restrictions. The process also ensures DGDs are automatically circulated to all parties for chemicals listed under Annex III of the Convention. A Chemical Review Committee (CRC) considers proposals from parties for including new chemicals in the automatically triggered PIC list (Annex III). By 2012, there were 43 chemicals, including 32 pesticides, contained in Annex III[4]. The CRC considers the reliability of the evidence provided and the significance of reported effects in comparison to the quantities used, and then discerns whether any reported ill-effects could be prevented by

[4] List of Pesticides subject to PIC Procedure: 2,4,5-T; Alachlor; Aldicarb; Aldrin (HHDN); Binapacryl (Endosan); Captafol; Dustable powder formulations containing a combination of at least 7% Benomyl, 10% Carbofuran, and 15% Thiram; Chlordane; Chlordimeform; Chlorobenzilate; DDT; Dieldrin (HEOD); DNOC and its salts; Dinoseb and dinoseb salts; 1,2-dibromoethane (EDB; Ethylene dibromide); Endosulfan; Ethylene dichloride; Ethylene oxide; Flouroacetamide; HCH; Heptachlor; Hexachlorobenzene; Lindane; Mercury compounds; Pentachlorophenol; Monocrotophos; Methamidophos; Phosphamidon; Methyl-parathion; Parathion; Toxaphene (Camphechlor); Tributyl tin compounds.

proper application of the chemical. The Secretariat is able to take up reports from NGOs in addition to those from governments. This practice was established under the voluntary scheme due to PAN pressure in highlighting health problems peculiar to developing countries resulting from the use of some pesticides. The contentious issue of whether the rules of the Convention could be overruled by World Trade Organization provisions on free trade in the event of any clash was fudged by removing a get-out clause to this effect, which was supported by the United States government (who has not ratified the Convention). In its place a number of governments were permitted to include in the preamble a statement that the Convention will not 'prejudice their respective positions in other international forums and negotiations addressing issues related to the environment and trade'. There was some opposition to including the word "environmental" in the negotiating of the Convention, but it was eventually agreed that PIC would be extended to any:

> ...chemical formulated for pesticidal use that produces severe health or environmental effects observable within a short period of time after single or multiple exposures, under conditions of use.
>
> (Rotterdam Convention, Article 2d)

Even for those chemicals able to make Annex III, whether PIC does lessen the problems associated with their trade is, though, open to debate. The procedure provides for information to be provided to importers, but does not actually prohibit the trade in hazardous chemicals. Further, some have expressed concern that, far from empowering Global South importing countries, the PIC procedure has actually served to reinforce dependency since the scientific assessments used are from the Global North (Barrios 2004, Karlsson 2004). The enshrining of

PIC as a rule for the trading of hazardous chemicals is an important step forward for global governance but does not, in itself, represent the realization of environmental and consumer focused safety standards comparable to those that have become established in many countries of the developed world since the 1960s.

4.5 The Politics of Persistent Organic Pollutants (POPs)

Inspired by the progress achieved with the PIC regime, but also by its practical limitations, a global campaign aiming to eliminate the use and production of the most toxic and persistent chemicals worldwide emerged following the formulation of the Rotterdam Convention. UNCED (Chapter 19, Agenda 21) raised the profile of a pressure group campaign, supported by a WHO-based epistemic community, culminating in a treaty similar to the methyl-bromide convention, but for a range of chemicals including notoriously hazardous pesticides like DDT, aldrin and dieldrin. After endorsement by UNEP's Governing Council in 1997, the Intergovernmental Forum on Chemical Safety (IFCS), set up by UNCED, was charged specifically with the task of implementing the proposal which it duly adopted as the chief of its "Priorities for Action" at its first meeting.

Once again the development of a new regime can be seen to have emerged from a lengthy process of pressure group campaigning and United Nations agency-led epistemic cooperation. WHO Expert Committees have been at the forefront of developing global standards for measuring chemical toxicity since the 1950s and their "Classification by Hazard Scheme", launched in 1975, is the key reference point for the FAO's "Code of Conduct on the Use and Distribution of Pesticides" and the Rotterdam Convention. On the back of their success in getting the FAO Code ready for signature, PAN in 1985 launched their "Dirty

Dozen" campaign calling for the outright prohibition of many of the same chemicals which subsequently formed the basis of the POPs. Sixteen years later many of the dirty dozen formed the basis of the International Legally Binding Instrument for Implementing International Action on Certain Persistent Organic Pollutants (POPs Treaty) which was signed by 127 governments at a diplomatic conference in Stockholm in May 2001 and entered into force in 2004 (Table 1).

Table 1 Pesticides subject to the Stockholm Convention

Intentionally Produced	
Aldrin Chlordane Chlordecone Dieldrin Endosulfan Endrin Heptachlor Hexachlorobenzene (HCB) Lindane Mirex Pentachlorobenzene Toxaphene	*use and production banned apart from laboratory-scale research*
dichlorodiphenyltrichloroethane (DDT)	*use restricted to disease vector control*

Unintentionally Produced	
Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD 'dioxins' / PCDF 'furans') Hexachlorobenzene (HCB) Pentachlorobenzene	*use and production minimized with aim of elimination*

Under Article 8 of the Convention, a Persistent Organic Pollutants Review Committee appraises proposals to add new chemicals to the list[5]. The Stockholm Convention is explicitly linked to its UNEP sibling the Basel Convention on Control of Transboundary Movements of Hazardous Wastes and their Disposal with measures calling on parties to minimize the generation and movement of waste POPs. The Convention is an example of 'soft international law' in that it is legally binding, but contains no enforcement measures.

The production and use of the outlawed chemicals has long ceased in most developed countries but their properties ensure that they remain a domestic hazard to their populations. Due to their slowness to break down and propensity to travel, the sterility, neural disorders and cancer in peoples of the developed world can be attributed to the use of POPs in other parts of the planet. The political significance of this is such that even President George W. Bush, shortly after his government's revocation of the Kyoto Protocol on Climate Change in

[5] For example, among chemicals proposed for inclusion by the parties are Hexabromobiphenyl (HBB) and Polycyclic aromatic hydrocarbons (PAH) which have been banned in Europe by the UNECE Protocol on Long-Range Transboundary Air Pollution since 2003.

2001, declared the United States would support international environmental cooperation on POPs. That the POPs regime is not fundamentally driven by ecocentric values is evidenced by the fact that the infamously environmentally-unfriendly DDT is exempted from prohibition by governments signing-on to the POPs regime declaring that they require the use of the chemical to combat mosquitoes in the fight against malaria and other diseases borne by this group of insect vectors (e.g. dengue). This qualification follows a concerted campaign by public health specialists. Again, the value of safeguarding human health and the coincidental satisfaction of corporate interests has been the driving force for political action rather than environmental values.

The chemical industry, represented at Stockholm by GIFAP's successor the Global Crop Protection Federation (GCPF) and other global lobby groups, again gave their backing to an agreement which constrains their freedom of action in order to prevent something more restrictive emerging. The chemical industry presence at the Stockholm negotiations was more low-key than at other conferences on global chemical trade issues and they were largely receptive to environmental/consumer group demands. The POPs pesticides were not worth fighting for as they were by now rarely produced by the big agrochemical companies of the Global North since their patent protection had mostly expired and cheaper generic versions were being produced by small companies in the Global South. Hence, a global ban on POPs could even serve the interests of the agrochemical giants since it would give them an opportunity to corner the market in new, alternative and patent-protected pesticides. Hence, at Stockholm the chemical lobby concentrated on ensuring that the list of chemicals making up the POPs list be limited to the older organochlorine pesticides (Clapp 2003). The chemical industry and the United States delegation at the negotiations of the Stockholm Convention fought hard to ensure that the term 'precautionary principle' did not appear in the final text and it was eventually replaced with the more ambiguous compromise phrase ‘precautionary approach’, which the industrialists hoped would open the door to less expansive ‘scientific’ toxicity assessments (Olsen 2003: 99-100). The significance of such semantics is clear from considering the Bush administration’s pronouncements on the principle previously accepted by the United States government at UNCED; “the US government supports precautionary approaches to risk management but we do not recognize any precautionary principle” (Graham 2002). By 2012, the United States had still not ratified Stockholm with Washington’s initial enthusiasm curbed by the inclusion of furans and dioxins on the list which are significant by-products of the large chlorine industry in the United States.

5 Conclusions

The advent of agrochemicals epitomizes the dilemmas that industrialization and economic development present to humanity; progress, but at a price. They have contributed greatly to the invaluable task of increasing the world’s food supply, helping avert environmentalist’s fears of overpopulation in the 1960s and 1970s through the ‘Green Revolution’ and could still prove crucial in averting future food shortages. In the 1940s and ‘50s the use, production and trade in pesticides and fertilizers was essentially uncontroversial and they appeared to vindicate the view that human ingenuity and scientific progress could defeat global problems like poverty and disease. The emergence, from the 1960s, of evidence that agrochemicals- particularly pesticides- also affected the world negatively through human poisoning and environmental pollution has, though, made their use more contentious and very political. Since then, principles of agroecology have taken root with the growth of stringent, precautionary domestic legislation in most industrialized countries leaving the greatest political dilemmas for the Global South where agrochemicals are most needed, but at the same time, are most dangerous.

Global rules have emerged dialectically from a dialogue between rival interests, led by chemical corporations and environmental pressure groups with governments somewhere in-between and often divided themselves[6]. The regulation of pesticides became part of the global agenda due to the action of pressure groups and epistemic communities, promoting agroecology, coordinated by UNEP and the WHO. Powerful governments and business interests tried to resist, but were eventually persuaded, through fear of being exposed as immoral to their electorates/consumers to come to the negotiating table. Pressure groups, led by PAN, have successfully helped put agrochemical issues on the global agenda and advanced the values of environmental conservation and safeguarding human health. The rules that have emerged from this process are not, however, driven purely by social and environmental concerns and are 'tempered' by the competing interests of the chemical industry who generally have greater influence on the governments signing and ratifying the international agreements. Governments in international politics are still more likely to be driven by economic national interests than by domestic affairs, where consumer rights and ecocentric policies can hold them to account (at least in developed democracies). Global governance in the area of agrochemicals is as yet, therefore, limited in comparison to domestic,

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[6] The United States government represents a classic case of 'transgovernmental relations' when dealing with global pesticide issues with the position of delegates at the Codex, PIC and POPs regime meetings promoting international harmonization and less precautionary approaches to classifying chemical toxicity which are often at odds with the standards of the Environmental Protection Agency.

environmental and health policy in much of the Global North, and insufficient in providing hope for the eradication of the occurrences of environmental pollution and human poisonings which still blight much of the Global South in particular.

The first steps taken in global pesticide governance may be small ones, but they are still significant. Norms once established cannot easily be erased. Unraveling agreements clearly made with regard to human and environmental interests is more difficult than preventing them in the first place since the selfish pursuit of profit is more clearly exposed as such and reputation does count for something in the contemporary interdependent world. The precautionary principle cannot be wished away by the United States or the chemical industry. Methyl-bromide is still going to be phased out despite the increasingly desperate rear-guard action fought by the United States government. Codex standards are still based on precautionary calculations of human toxicity even if they are being exploited by big business as a means of circumventing more stringent domestic standards. The POPs regime is currently limited in what it can do, but now in force, it can only broaden and deepen. The Stockholm Convention Conferences of the Parties have discussed a working compliance mechanism to improve implementation and new chemicals have been added to the original POPs list thanks to concerted lobbying by PAN and many other groups present as observers at the Review Committee meetings and independent assessments by an epistemic community representing no vested interests.

The chemical industry has no direct interest in curbing its freedom to trade in pesticides as it chooses, but the Bhopal disaster and public fears of continued exposure to presumed obsolete chemicals brought them to a negotiating table laid by civil society actors. Once at the table the industry has been able to negotiate from a position of strength and further their own interests, but the fact that they have had to come to the table is still an important breakthrough in the development of global governance. Ultimately, the global governance of agrochemicals is in the interests of both sides at the table, even if their motivations for being there are different. Actors driven by different values can, nevertheless, reach mutually beneficial agreements. Just as ‘bootleggers and Baptists’ supported alcohol prohibition in the United States, environmentalists and the chemical industry have found themselves’ seeing global pesticide regulatory measures as means to very different ends.

Agrochemicals are here to stay as their benefits are still apparent to food producers and the side-effects tolerated by most farmers and consumers. Agroecology informs agrochemical use in much of the developed world but the application of more sustainable strategies remains limited in the industrializing world. The demand in the West for organic food continues to grow, but so does the global demand for food. However, the side-effects of agrochemical use are sufficiently apparent that their production, use and trade will also continue to be brought under tighter scrutiny and regulation. As with ecological principles in general, many farmers, citizens and regulators in industrializing countries need to be convinced that sustainable agrochemical use does not compromise their economic development. This is the challenge for proponents of agroecology.

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Comment [BC1]: Please ensure that all of the journal abbreviations are officially correct.

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