Use of agrochemicals in Thailand and its consequences for the environment

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Summary

Farming is still by far the most common form of employment in Thailand, representing 65% of labour force in 2006. The Thai population continues to be mainly rural, with about 68% of the population living in rural areas and 32 % in urban areas. The arrival of the Green Revolution dramatically changed the Thai countryside after the 1980s, starting with the use of new varieties of crops that depend on agrochemicals to produce high yields. The new varieties were often susceptible to insect and disease and so insecticides and fungicides had to be introduced to combat pests. The use of agrochemicals has been steadily increasing in the country during the 3 last decades, and continues to grow in recent years.

The total land under cereal production in Thailand almost doubled from 1961 to 2005 (from 6.5 to 11.5 million hectares), and the total cereal production tripled in the same period (from 10.8 to 31.5 million tonnes). Thailand is presently the world's largest exporter of rice. The expansion of agriculture into fertile land areas, plus the widespread use of irrigation, agrochemicals and new seeds help explain this large rise in agriculture production, but this model of agricultural growth is fatally flawed because of declining crop yields and massive environmental impacts. All fertile land is currently under cultivation in Thailand and the long term use of high levels of agrochemicals to boost yields have made it very difficult to sustain the same rate of productivity growth, and yields approach the economic optimum levels.

Environmental pressures are increasing as existing land and water resources come under threat from rapid urbanization. Land is being withdrawn from agricultural production, creating additional pressures for the reallocation of water now used in agriculture. Furthermore, the need to use large amounts of fertilizers and pesticides to control pests and weeds has raised environmental and human health concerns. Agrochemicals pollute rivers, lakes and underground water and pose risks for human health and the environment. There are proven alternatives to this dangerous and expensive agriculture system: farmers are already fertilizing soils and protecting crops with organic and sustainable techniques that work with nature, not against it, and can provide food for all.

The use of chemical fertilizers in Thailand started to increase exponentially in the 1970s; between 1961 and 2004 fertilizer use increased more than 100 times, a spectacular increased from 18 thousand tonnes in 1961 to 2 million tonnes in 2004. But in spite of this massive increase in chemical fertilizer use, the yield of rice and maize increased barely 1 time,

doubling in 45 years. This indicates a tremendous loss of fertilizers into the environment due to their imbalance use and poor management.

Most pesticides used in the country are imported, and the quantity of pesticide imports has increased 3 times from 1994 to 2005, reaching more than 80 thousand tonnes in 2004. Pesticides are applied in the highest quantity in vegetable and fruit farming, where market pressure for appearance is higher. More cash crops, reduction in pesticides price, lack of knowledge about correct use among farmers and the Government promotion of pesticide use all are factors that relate to this rapid rise in pesticide use in Thailand.

Around 95 % of freshwater in Thailand is withdrawn to irrigate the more than 5 million hectares of irrigated agriculture. In rural areas, which accounts for nearly 70 % of the population, there are still many problems related to water quality due to microbiological and chemical contamination in both surface and groundwater sources. According to the Pollution Control Department, in recent years more than 40% of Thailand's surface waters and about 33% of coastal waters were in "poor" or "very poor" quality.

Agriculture contributes directly to water pollution through agrochemicals runoff from farms. Water pollution with nitrates derived from fertilizer runoff is more widespread in Thailand than previously thought. A recent survey done by Greenpeace found that in asparagus farms in the Central Plain, 55% of the tested groundwater wells had nitrate levels above the WHO drinking water safety limit of 50 mg/l NO_3^-, in some cases 2 times higher than the safety limit (>150 mg/l NO_3^-). Other studies done by Thai scientists in Nakhon Pathom province have also shown high nitrate pollution in 46% of the underground water wells tested in asparagus farms under contract with a Japanese agribusiness company. These examples of nitrate pollution are directly related to excessive application of synthetic nitrogen fertilizers; in many cases up to 95% of the fertilizer applied is not used by the crop and thus lost to the environment. Another consequence of this excessive use of fertilizers is the accumulation of nitrate in the vegetable crops themselves; Thai scientists found unhealthy levels of nitrates in 90% of the Chinese kale sold at markets around Bangkok from May to July 2001. These high levels of nitrates in drinking water and vegetables could have serious health effects for the local population, especially for children.

Lakes and coastal areas polluted with nitrates cause major problems by eutrophication and massive growth of harmful algae. Recent studies in reservoirs in Chiang Mai and Nakhon Pathom Province have found blooms of algae producing the potent liver toxin microcystin. In the Gulf of Thailand the occurrence of algae blooms has been increasing in the last decades, accompanied in occasions with massive fish kills and paralytic shellfish poisoning in people after consuming contaminated seafood, causing even human deaths.

Toxic pesticide residues can also pollute water bodies used for drinking, are toxic to fish and can accumulate in many aquatic organisms. From 1993 to 1999 a survey in the main rivers in Thailand found pesticides residues in about 40% of the samples. From 1999 to 2001, another survey in the three major rivers along paddy field areas found the highest residues of the insecticide endosulfan in the Thachin River, followed by the Chao Phraya and Bangpakong Rivers. In all cases, the levels of pesticide residues were above the safety limit set by the European Union (0.1 µg/l). Groundwater is also susceptible to pesticide contamination, during 2001, 68% and 71.2% of the groundwater samples analysed in the lower Central and lower Northeastern region, respectively, were contaminated with endosulfan and other insecticides.

Pesticides can have acute and chronic toxic effects in humans. Pesticide self-poisoning is the most common form of suicide in rural Asia, accounting for 60 % of deaths. In spite of Government legislation to control pesticide use, cases of pesticide poisoning of Thai farmers are common; in 2003 2,406 cases of pesticide poisoning were reported. In addition to acute effect, chronic effects of pesticides can also deteriorate the health of people living in rural communities. However, not only farmers and rural communities are affected, the effect of pesticide application also affects other population who consume contaminated food and water. Pesticide exposure can trigger chronic eye, skin, pulmonary, neurological and renal problems in people that manage pesticides or are exposed to them.

The future of farming lies in a modern type of agriculture that works with nature and with people, not against them. Millions of farms on all continents already prove that organic and sustainable agriculture can provide sufficient food, increase food security, replenish natural resources and provide a better livelihood for farmers and local communities. The time has come to recognise the false promise of the Green Revolution and for governments to support the real revolution in farming that meets the needs of local communities and the environment, restores the land and enables the poor to combat hunger, displacement and depletion of their resources and culture.

1. Agriculture in Thailand

Once a predominantly agricultural country, agriculture growth in Thailand has slowed down during the previous decades. In the last 20 years, the contribution of agriculture to the national economy has dropped from 25% to less than 10% (Reunglertpanyakul, 1993). However, farming is still by far the most common form of employment in the country (65% of labour force in 2006). Population is still mainly rural, with about 68% of the population living in rural areas and 32 % in urban areas.

Thailand is a country rich in natural resources and has a long history of exporting agricultural produce. The Thai government has historically recognized agriculture as the principal driving force of economic growth in Thailand. Starting in the 1960s the government economic plans aimed at developing agriculture infrastructure for irrigation, transport and agriculture credits. In the 1970s the economic plans promoted the use of agrochemicals (fertilizers and pesticides) and farm machinery with the development of credits to help boost agriculture growth. The arrival of the Green Revolution dramatically changed the Thai countryside. The Green Revolution promoted the use of new varieties of crops that depend on agrochemicals to produce higher yields. The new varieties were often susceptible to insect and disease pests and so insecticides and fungicides had to be introduced to combat pest.

The total land under cereal production in Thailand almost doubled from 1961 to 2005 (from 6.500 to 11.5000 thousand hectares), and the total cereal production tripled in the same period (from 10.769 to 31.490 thousand tonnes) (FAOSTATS 2007). Thailand is presently the world's largest exporter of rice (FAO, 2004). Food availability (measured as calories available per person per day) increased from 2,200 in 1990-1992 to 2,414 in 2001-2003 (FAO, 2006).

The expansion of agriculture into fertile land areas plus the widespread use of irrigation, agrochemicals and new seeds have largely increased agriculture production, but this model of agricultural growth is fatally flawed because of declining crop yields and massive environmental impacts. The future of farming lies in a modern type of agriculture that works with nature and with people, not against them. Millions of farms on all continents already prove that organic and sustainable agriculture can provide sufficient food, increase food security, replenish natural resources and provide a better livelihood for farmers and local communities (Badgley et al. 2007).

2. Agrochemicals

The current industrial agriculture system promotes the reliance on agrochemicals, both synthetic fertilizers and pesticides, while neglecting to consider their negative effects on the economy of local communities, human health and environment. The long term use of high levels of agrichemical to boost yields has made it difficult to sustain the same rate of yield growth, and yields approach the economic optimum levels. Environmental pressures are increasing as existing land and water resources come under threat from rapid urbanization. Land is being withdrawn from agricultural production, creating additional pressures for the reallocation of water now used in agriculture. Furthermore, the need to use large amounts of pesticides to control pests and weeds has raised environmental and human health concerns. Agrochemicals pose health and environmental risks, and they can pollute rivers and lakes through runoff and groundwater through leaching. There are proven alternatives to this expensive agriculture system: farmers are already fertilizing soils and protecting crops with organic and sustainable techniques that work with nature, not against it, and can provide food for all (Pretty et al. 2003, Badgley et al. 2007).

Fertilizer use

The use of chemical fertilizers in Thailand started to increase exponentially in the 1970s; between 1961 and 2004 fertilizer use increased more than 100 times, an spectacular increased from 18 thousand tonnes in 1961 to 2 million tonnes in 2004. But in spite of this massive increase in chemical fertilizer use, the yield of rice and maize increased barely 1 time (doubling in 45 years) (Figure 1). This indicates a tremendous loss of fertilizers into the environment due to their imbalance use and poor management. Moreover, the total area dedicated to cereal crops also doubled during this period, reaching almost 12 million hectares in 2005.

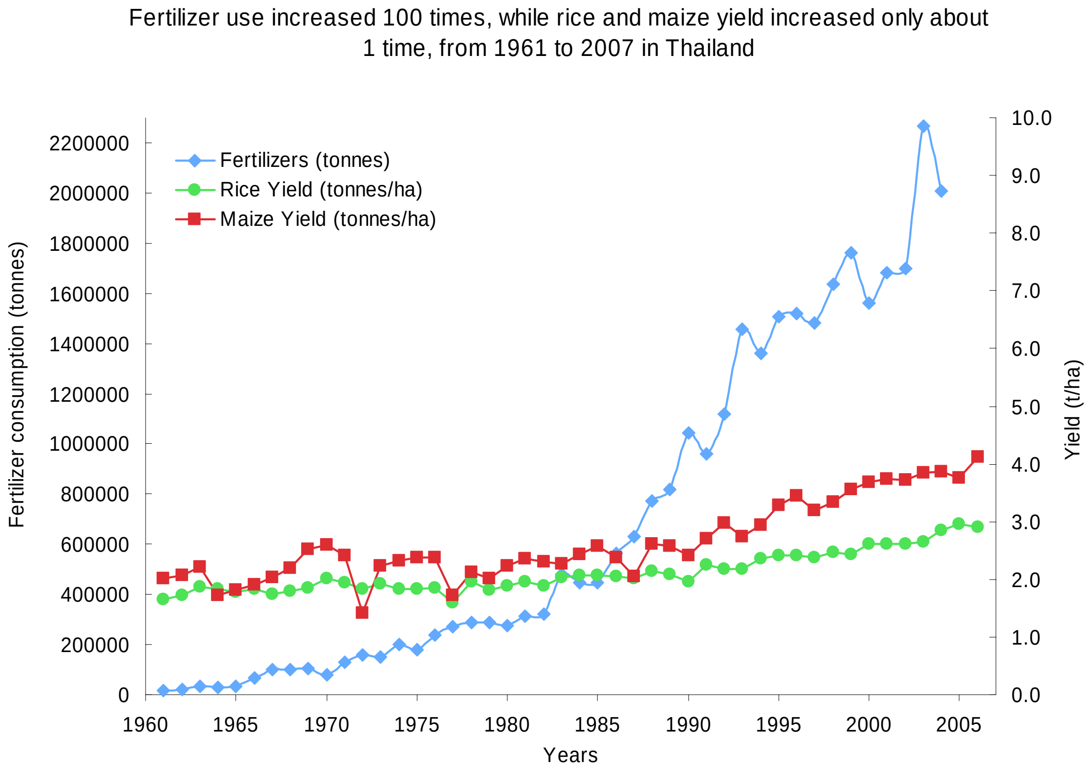

Figure 1. Fertiliser consumption (left axis) and rice and maize yield (right axis) in Thailand from 1961 to 2005. Data source FAOSTAT, 2007.

The country production of major crops has increased considerably with the rapid expansion of planted areas over the last 30 years (doubled of land under cereal crops and tripled of total cereal production). However, the yield (production per unit of land) of major crops has not increased, and yield of some crops have actually decreased. Almost all land with good soil fertility has now been converted into cultivated areas, and the continuous cultivation with limited recycling of plant nutrients has caused rapid soil fertility lost in most cropping areas (Chaiwanankupt, 1983, Kuneepong 2002).

The expansion of cultivated area has now been restricted by government policy; therefore, the only means available to increase national agricultural production to meet the demand for exports and for domestic consumption is by increasing the crop production per unit of land. The Government has encouraged the intensification in the use of chemical fertilizers as the approach to increase crop production. However, Thai farmers have increased fertilizer use at high rates without seeing a corresponding increase in yield, and there are now examples of overuse and inadequate use of fertilizers in Thai agricultural systems.

Pesticide use

Since pesticides were first imported into Thailand under the "Green Revolution Policy" as part of the 1st National Economic and Social Development Plan in 1966, the total amount of imported pesticides has dramatically increased year by year. Most pesticides used in the country are imported (Department of Pollution Control 2005), and the quantities of imported agricultural pesticides have increased 3 times from 1994 to 2005, reaching more than 80 thousand tonnes in 2004 (Figure 2). Pesticides are applied in the highest quantity in vegetable and fruit farming, where market pressure for appearance is higher. In 2000, organophosphates contributed the majority of imported pesticides followed by carbonates and organochlorines; most were herbicides, followed by insecticides, disease control agents and plant growth regulators (Department of Pollution Control 2002). Using WHO hazard categories, 54% of imported insecticides fell into the extremely hazardous category (Ia) and highly hazardous (Ib) category (Pingali and Rosegrant, 1993).

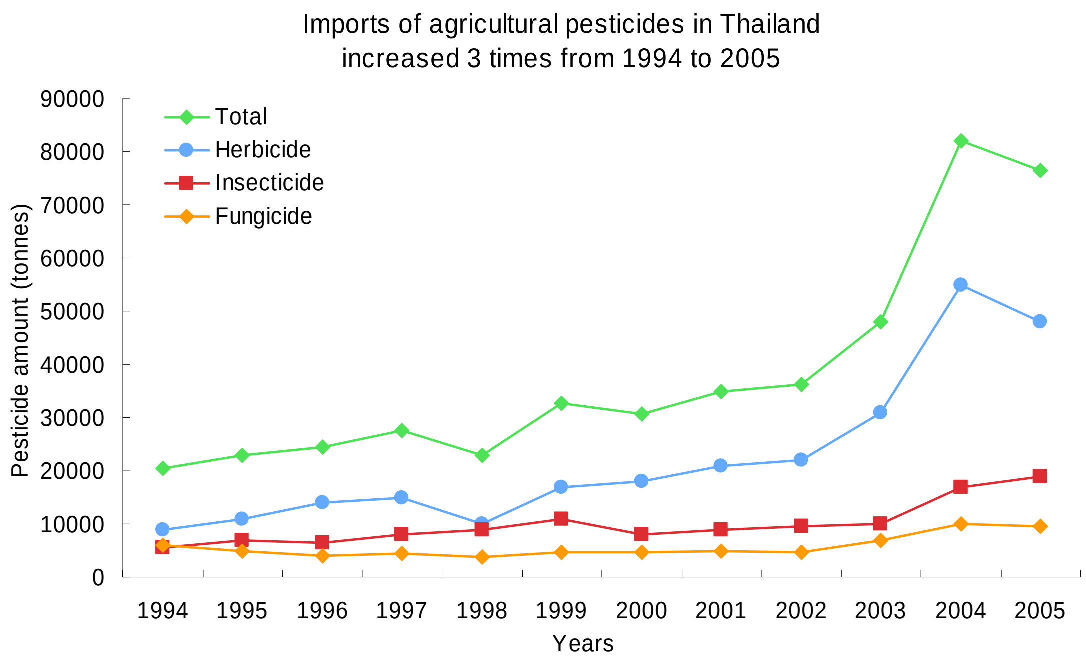

Figure 2. Tonnes of pesticide imported in Thailand between 1994 and 2005. Most pesticides used in Thailand are imported.

Initially, importation of pesticides was mostly in the form of finished products. Currently there are three categories of pesticide forms imported in Thailand: active ingredients, additive chemicals and separated packaging (Office of Industrial Economics, 2002). Because pesticides are often overused, Thai farmers' current use of pesticides is highly inefficient and has led to chemical poisoning. For instance, in order to save labour costs associated with spraying, farmers often mix pesticides themselves, creating a “cocktail” of several chemicals without considering their synergistic effects (Chaiwanankupt, 1983).

The rapid increase of pesticide use in Thailand may be accounted for in several ways:

- **Increase in cash crops**: Thailand’s most pesticide-intensive crops, vegetables and fruits, are also its highest cash value added crops. As farmers have gradually switched from low value added to high value added crop production, the overall consumption of pesticides has naturally increased.
- **Higher application rate**: in order to raise yield, farmers have intensified pesticide use in the production of all crops. This is reflected in the increasing share of pesticide costs in total production costs.
- **Lower pesticide price**: along with an increased in the number of manufactures from 1986 to 1996, the average nominal retail price of Thai pesticides actually fell by 45 % in that decade. For example, the real price of the highly hazardous methyl-parathion fell by 23 percent (Ruhs et al 1997).
- **Farmers uncertainly in correct use**: the great gap between registered trade-names and generic names (3,058 trade-names and 247 widespread product adulteration (Sombatsiri, 1997)) have considerable increase farmers’ uncertainly regarding the effectiveness of pesticides, which is widely agreed to be a major factor inducing pesticide use.
- **Government policies**: a number of public policies have encouraged pesticide use (Chaiwanankupt, 1983), and continue to do so.

3. Water pollution

Around 95 % of freshwater in Thailand is withdrawn to irrigate the more than 5 million hectares of irrigated agriculture (FAOSTATS 2007). Due to the high use of agrochemicals in Thailand in the last years, there is a high potential for pollution of water sources through irrigation runoff, return flows and infiltration. For example, the high application rate of chemical fertilizers and pesticides in home gardens and commercial farms in the Rattaphum Catchment of Thailand in 2005 led to the accumulation of nitrates in the top-soil, and contribute to the high potential for agrochemicals contamination in the groundwater in the area (Chatupote and Panapitukkul 2005).

In Thailand, surface water and groundwater are the water sources for tap water and drinking water for the Thai people (National Statistical Office). Water supply is available to over 98 % of the Thai population and provision for sanitation has also reached nearly universal coverage within the country. According to WHO data, between 1970 and 2002 (2006 update), the fraction of the population with access to safe drinking water for the entire country was 85% (95 % of urban and 80% of rural). However, there appear to be still many cases of water pollution with agrochemicals throughout the country. In rural areas, which accounts for nearly 70 % of the population, there are still many problems related to water quality due to microbiological and chemical contaminations from both surface and groundwater sources.

Surface water quality

The Pollution Control Department (PCD) monitors the water quality in the major rivers and lakes in Thailand. The major causes of water pollution in the country are related to fecal coliform bacteria, high solids, organic matter and nutrients (phosphates, ammonia and nitrates) (Simachaya, 2002).

According to the Pollution Control Department, in 2003 around 60% of the water bodies surveyed were suitable for agriculture and general consumption ("good" and "moderate" quality). However, more than 40% of Thailand's surface waters were in "poor" or "very poor" quality. No surface water was categorized as "very good" quality (extra clean water which is suitable for aquatic animals and human consumption after normal treatment), and the surface water quality appeared to be slightly worse than in previous years in terms of dissolved oxygen and total coliform bacteria indicators.

The Pollution Control Department also monitors coastal water along the coastline and islands. In 2003, 68% of the sampling stations showed "very good" or "good" quality, while 33% showed indicated "fair" or "poor" quality. Compared to previous years, coastal water quality had deteriorated, especially in the areas where the four main rivers flow.

Groundwater status

Groundwater in Thailand is a source of drinking water within households and supplements surface water for agriculture and livestock uses. Groundwater is used for public water supply in 20% of the nation's towns and cities and for half of the sanitary districts. It is estimated that 75% of domestic water is obtained from groundwater sources and that they service some 35 million people in villages and in urban areas. Increasing demand for water has led to a growing unsustainable reliance on groundwater. Moreover, groundwater pollution is occurring from a number of sources and urgently needs to be controlled.

Nitrates pollution

Agriculture contributes directly to water nitrate pollution through fertilizer runoff. Often, too much nitrogen fertilizer is applied to crop soils, and the excess that is not used by the plants runs-off polluting groundwater, rivers, and finally coastal areas. Drinking water polluted with nitrates poses health risks, especially to children.

Approximately 95% of surface water withdrawn in Thailand is used by the agricultural sector, particularly for paddy rice, which is the major crop in the country (FAOSTAT 2007). Water pollution resulting from discharges from paddy fields is becoming more serious, particularly in river basins where rice is the main economic crop (Tougkasame 2007). Discharges of nitrogen, phosphorus and pesticides are the main pollutants from paddy rice farming affecting water quality. Water pollution caused by rice farming also affects the natural populations of fish and other aquatic fauna. In Pranburi Irrigation Project area (Prachuab Khiri Khan province) the density of fish and benthic faunas in 2005 was less than half in the section downstream of the paddy irrigation area compared to that in the upstream section (away from the influence of rice farming).

A study in a pilot rice paddy field located at the Asian Institute of Technology (AIT campus, Pathumthani) showed that 20% of the nitrogen applied as fertilizers to paddy fields found its way into the river basin through surface runoff and percolation. The nitrate concentration in the groundwater increased more than 3 times after fertilization (from 1.8 mg l^{-1} to 7.2 mg l^{-1} NO_3^-). Contamination of groundwater is therefore a concern especially if these practices (like application of excess fertilizers) are continued over long time periods (Pathak et al 2006).

A recent survey done by Greenpeace found examples of water pollution with nitrates in intensive farming areas in the Central Plain (Kanchanaburi and Suphanburi) (Tirado 2007). In Suphanburi, two of the five wells sampled in farms had nitrates levels higher than the safety limit established by the World Health Organization (50 mg/l NO_3^-). In Kanchanaburi, the study found a clear example of heavy fertilizer use related to water pollution with nitrates in contract asparagus farms: in 55% of the asparagus farms, nitrates levels in groundwater wells were above the WHO drinking water safety limit of 50 mg/l NO_3^-, in some cases 2 times higher than the safety limit (>150 mg/l NO_3^-).

Other studies have also shown contamination from heavy application of fertilizers in asparagus farms in Nakhon Pathom province (Phupaibul et al. 2004). Asparagus are cultivated under contract farming with a Japanese agribusiness company, which also provides guidelines for the use of fertilizers, pesticides, etc. Farmers follow these guidelines and end up applying fertilizers in great excess: 840 kg N and 286 kg P ha^{-1} $year^{-1}$, from which less than 5% of the applied nutrients are recovered in the harvested crop. As a result of these practices, these excess agrochemicals runoff from the farms and accumulated in the soil and the underground water. In 46% of the monitored groundwater wells the nitrate concentration were high and well above WHO safety limits. These high levels of nitrates in drinking water could have serious health effects for the local population, especially for children.

Excessive application of nitrogen fertilizers also increases the accumulation of nitrates in vegetables, especially in green leafy vegetables. Scientist in the Kasetsart University in Bangkok analysed the concentration of nitrate in Chinese kale grown in Thailand and sold at markets around Bangkok during May-July 2002 (Phupaibul et al. 2002). About 90% of all the Chinese kale analysed contained nitrates in high concentrations (>3000 mg/kg): a 60 kg person eating only about 100 g of this Chinese kale in a day would excess the daily intake of nitrate considered safe by the World Health Organization (0–3.7 mg per kg of bodyweight).

Algal blooms

Lakes and coastal areas polluted with nitrates cause major problems by eutrophication and massive growth of harmful algae. Nutrients from agricultural and domestic waste sources have resulted in eutrophication of major water bodies worldwide. Eutrophication causes loss of productivity due to low dissolved oxygen concentrations in water, but of particular concern is the explosive growth of algae (cyanobacteria) and toxins production. Global warming may exacerbate the occurrence of harmful algal blooms in future years, since higher temperatures may increase algal growth and favour toxic algal species (Chu et al. 2007).

Recent studies in Thai reservoirs have found blooms of toxin-producing algae in the water bodies (Peerapornpisal, 2006). Earlier studies in the Mae Kuang Udomtara Dam reservoir in Chiang Mai found proliferation of the blue-green alga *Microcystis aeruginosa*, which secretes the potent liver toxin microcystin. The explosive growth of this alga is related to nutrient enrichment, particularly phosphates (Peerapornpisal et al 1999). In 2001 and 2002 the same toxic blue-green alga *Microcystis aeruginosa* was found in every sample taken in Mae Kuang Udomtara reservoir in Chiang Mai, although at lower concentration than the indicative of a harmful bloom (Chanttara et al 2002). Other potent toxins produced by algal blooms were found in the Bang Phra Reservoir in Thailand (Nakhon Pathom Province), associated with high nutrient levels in the water body. In particular, nitrogen and phosphorus are the two major nutrients driving growth of algae in the reservoir (Wang et al. 2002).

The Gulf of Thailand has been a major marine resource for Thai people during centuries. However, recent agricultural and industrial development has exerted considerable stress on the marine environment. Eutrophication is the most serious problem of the inner Gulf of Thailand nowadays (Menasveta 2001, Cheevaporn and Menasveta 2003). The runoff from Thailand's four principal rivers ends into the Gulf causing eutrophication: the Chao Phraya is the most polluted of the four rivers, particularly in the river estuary area due to the urban and industrial expansion. The Ta Chin is becoming increasingly polluted due to accelerated agricultural and industrial development as well as urban expansion from the Bangkok area. Eutrophication can cause explosive bloom of algae, frequently in the form of red tides. In occasions, paralytic shellfish poisoning (PSP) after consuming contaminated mussels in the red tide area of Pranburi river estuary have occurred, causing even human deaths (Menasveta 2001). Anoxic conditions due to algal blooms could cause massive fish killed, in August 1991 there was a mass fish killed in the coastal area of Cholburi due to a vast red tide blooming of *Noctiluca* covering the area from Bangsan district to Pattaya (Menasveta 2001).

Rate of occurrences of plankton bloom has been increasing in the last decades in the Gulf of Thailand (Singhasaneh 1995). Two species of blue-green algae (*Trichodesmium erythraeum* and *Trichodesmium thiebautii*) and *Noctiluca miliaris* were found to be the cause of sea water algal blooms. Blooms are also frequently seen in the vicinity of estuarine area as red, green, yellow, and brown tides (Singhasaneh 1995).

Thailand has several strategies to manage and mitigate water pollution from agricultural activities. One of them is to build understanding among farmers in the appropriate uses of agrichemicals to prevent excessive and untimely uses, thus minimizing their residues in soil and water. However, these measures are clearly insufficient and much more needs to be done to avoid water contamination and health risks associated with agrochemicals.

Pesticide pollution

From 1993 to 1999 the main rivers in Thailand were monitored for the presence of pesticide residues; most water samples contained insecticide and herbicide residues in levels above advisable limits, whereas less contamination was observed in sediment samples. In river water, organochlorine pesticides were detected in 40.62% of the samples (in concentration ranging from 0.01 to 1.21 µg/l), organophosphate pesticides were detected in 20.62% of samples (in concentration ranging from 0.01 to 5.74 µg/l). The safety limit established by the European Union is 0.1 µg/l for any single pesticide and 0.5 µg/l for the sum of all pesticides detected. Both organochlorine and organophosphate pesticide residues were found above those safety limits. Additional compounds, like carbamate pesticides were detected in 12.39% of samples (in concentration ranging from 0.01 to 13.67 µg/l), triazines were detected in 20.0% of samples (in concentration ranging from 0.01 to 6.63 µg/l), and paraquat was detected in 21.36% of samples (in concentration ranging from 0.14 to 87.0 µg/l) (Chulintorn, et al., 2002). An earlier study has also found residues of the pesticides DDT and dieldrin in five Thai rivers (Upper Ping, Lower Ping, Wang, Yom, Nan, Chee), in concentrations above acceptable standard levels (Sombatsiri, 1997).

The Division of Agricultural Toxic Substances in the Department of Agriculture (Ministry of Agriculture and Cooperatives) has also monitored the presence of pesticide residues in rivers and canals around agricultural areas in the country. The contamination of pesticides in water and sediments was generally low in water resources used for domestic consumption like ponds and reservoirs that have no connection to agricultural plantations. However, the water resources in certain agricultural areas, like orchid and ornamental plantations, were contaminated with organophosphate and carbamate insecticides.

From 1999 to 2001, a survey of three major rivers along paddy field areas (Thachin river in Suphanburi and Nakornpathom, the Chao Phraya river in Pathumthani and Nonthaburi, and the Bangpakong river in Chachengsao), found the highest residues of the insecticide endosulfan in the Thachin River, followed by the Chao Phraya and Bangpakong Rivers. In all cases, the levels of pesticide residues were above the safety limit set by the European Union (0.1 µg/l) (Chatsantiprapha, et.al., 2002).

In 2001, groundwater in the lower Central and the lower Northeastern region of Thailand was contaminated with pesticides residues, in many cases in concentration above the safety limit set by the EU (0.1 µg/l). In the lower Central region during the rainy season in 2001, 68% of the total groundwater samples were contaminated with endosulfan and other insecticides, in concentration ranging from 0.02 to 3.2 µg/l, and paraquat, 2,4-D, butachlor, atrazine and metribuzin herbicide residues ranging from 0.02 to 18.9 µg/l. In lower Northeastern region during the dry season in 2001, 71.2% of the total groundwater samples were contaminated with endosulfan and other insecticides, in concentrations from 0.01 to 0.33 µg/l, and atrazine and paraquat herbicide residues at the level of 0.5-4.0 µg/l (Sakultiangtrong, et.al., 2002).

In 1993, the Department of Agriculture investigated shallow groundwater wells from Rayong Province. From 160 samples collected from wells, 67% were contaminated with organochlorine and organophosphate pesticides, but in concentration below the safety limits (Pollution Control Department, 2004).

4. Health risks associated with nitrates and pesticides

Nitrates

Babies and infants living around agricultural areas and who drink water from wells are the most vulnerable to health risks from nitrates. Additionally, anyone drinking from a contaminated well or eating vegetables with high nitrate levels could be vulnerable to the long-term effects of nitrates, such as various types of cancer (Greer et al. 2005). The greatest risk of nitrate poisoning is considered to be the *blue baby syndrome* or *methemoglobinemia*, which occurs in infants given nitrate-laden water, and affects particularly babies under 4 months of age (Greer et al. 2005). Blue-baby syndrome occurs when the hemoglobin in the blood losses its capacity to carry oxygen and this can ultimately cause asphyxia and death.

Eutrophication of coastal and marine ecosystems, caused in part by intensive fertilizer use, can also impact human health through ecological changes like the worldwide increase in harmful algal blooms (Robertson and Swinton 2005). Algal blooms can lead to the proliferation of algal species that produce toxins. When the algae are ingested by shellfish this can result in neurological, amnesic, paralytic, and/or diarrheic shellfish poisoning in human consumers.

Pesticides

In 1972 the government put in place the primary legislation for the control of pesticide use in Thailand, the Hazardous Substance Act (1972). While this legislation has reduced pesticide impacts, cases of pesticide poisoning of Thai farmers continue to be reported. In 2003, 131 thousand tonnes of pesticides were used and 2,406 cases of pesticide poisoning were reported.

Over the past decade, pressures to sustain high crop yields have led to heavy usage of pesticides. Residues, especially organochlorine and organophosphate compounds, have been found in soil, water, and agricultural products throughout the country. Occupational exposure and suicide are the main causes of pesticide poisoning to Thailand's residents. Recognizing the growing problem, Thailand's government has enacted environmental laws and education programs aimed at minimizing adverse effects of pesticides (Poapongsakorn, et.al., 1998).

All of the organochlorine insecticides that were classified under the Stockholm Convention as persistent organic pollutants (POPs) were prohibited or banned from use, import, export and production in the country on different occasions: Endrin in 1981, DDT and Toxaphene in 1983, Aldrin, Dieldrin and Heptachlor in 1988, Mirex in 1995 and Chlordane in 2000.

Like in the other Asian countries, several factors contribute to the direct health risks associated with pesticides, including the mixing high potency pesticides to make toxic cocktails, increasing pesticide dosages over recommended limits, preference for strong and fast acting pesticides, improper disposal of empty containers, using inappropriate pesticides, and lack of education on handling the pesticides.

The application of pesticides adversely affects consumers indirectly through the chemical residues left in food after application. A study conducted between 1982 and 1984 by the Food and Drug Administration and the Department of Medical Sciences detected chemical residues in 52 % of the 663 food samples analyzed; including DDT in 39 %, and Dieldrin in 15 % of the samples (Jungbluth 1997). Another study published in 1995 by the Division of Toxic Substances found that 37 % of the sampled vegetables were contaminated with insecticide residues.

In 1995, the Occupational Health Department (Ministry of Public Health) found that 18 % of the farmers tested (85.140 farmers out of 463.142) had unsafe levels of pesticides in their blood, an increase over the 16 % found from similar blood testing of farmers done in 1994.

One earlier study examined the problem of pesticide poisoning in Rayong Province in 1985. Researchers assessed an agricultural community for pesticide poisoning. Of the total community, 46.2% of people had agriculture-related employment, and 42.3% handled pesticides as part of their daily work. Of those, 19.5% had experiences some type of pesticide poisoning. Data showed that pesticide poisoning was a major problem, and researchers concluded that implementation of pesticide control legislation was inadequate (Wongphanich, 1985).

The amount of the chemical residue left in the crop is higher when higher is the concentration of the pesticide applied and when spraying rounds are more frequent in time (Sombatsiri, 1997). As Thai farmers generally spray highly concentrated pesticides with little intervals between spraying rounds, chemical residues in food are generally high.

A study by the Division of Toxic Substances on pesticides residues in fruit and vegetables found that around 37 % of vegetables were contaminated with organophosphate insecticide residues. About 20 % of kale and 10 % of cowpea showed residues exceeding the Maximum Residue Limits (MRL). 73 % of tangerine samples were contaminated with pesticide residues (around 10 % exceeding the MRL). Pesticide residues consisted mainly of malathion, monocrotophos and methyl parathion (Palakool, 1995).

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