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Environment pollution
REVIEW ARTICLE

Environmental and Health Hazard of Herbicides used in Asian Rice Farming: A Review

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A B S T R A C T

Lots of work have been done on herbicide use and its impact on soil, environment and farmers health worldwide especially in Asia. But, very little or no attempt has so far been made to do research on this topic in Bangladesh context. In Bangladesh, herbicide use is not quite an old practice rather a new one. Therefore, the local farmers are not that aware of the impact of herbicides on rice field environment or even on their own health. However, this paper tries to explore the impacts of herbicide on environment, soil and farmers' health in world context, especially in Asian context. This will give some ideas of doing some research on herbicidal impact in Bangladesh context as well.

INTRODUCTION

Rice (*Oryza sativa* L) is one of the most important cereal grains in the world and serves as a staple food source for more than half of the world's population. Roughly three-quarters of a billion of the world's poorest people depend on rice (IRRI 2006) and it influences the livelihoods and economies of several billions people. Rice is the staple food of about 557 million people in Southeast Asia. Approximately 154 million ha were harvested worldwide, of which 31% of the global rice (48 million ha) were harvested in Southeast Asia alone (FAOSTAT 2012). The International Rice Research Institute (IRRI 2000) studied the food problem in relation to world population, and they predicted that 800 million tons of rice will be required in 2025, so that large gains in productivity will be needed in order to meet up the worldwide demand of rice.

Weeds are the cause of serious yield reduction problems in rice production worldwide. Ramzan (2003) reported yield reduction up to 48, 53 and 74% in transplanted, direct seeded flooded and direct seeded aerobic rice, respectively. Herbicide-based weed management is becoming the most popular method of weed control in rice. Weed control in overpopulated areas of Asia has mainly been carried out through a combination of water management and hand-weeding. But hand weeding is becoming less common in areas with an increasing labour shortage problem. On the other hand, many farmers in several areas of Asia have shifted from transplanting to direct seeding rice where less labour is required but herbicides must be used for weed control. In that case, farmers have no other option than the application of herbicides, although they lack knowledge concerning the proper use of herbicides (Labrada 1996). Herbicides should be applied at recommended rates. Besides this, farmers should have knowledge on health and environmental issues related to herbicide application. The application of many herbicides is recommended within precisely-defined stages of the crop's growth. They are specifically plant poisons, and are not very toxic to animals. However, by inducing large changes in vegetation, herbicides can indirectly affect populations of birds, mammals, insects, and other animals through changes in the nature of their habitat (Hossain 2015).

Globally, researchers are focusing on land management, biodiversity, water availability and productivity, and the impact of climate change to develop and promote technologies and options to sustain rice ecosystem (Zeigler 2006). IRRI has given emphasis on strategies to preserve the natural resource-based rice agroecosystems in the face of changing physical and socioeconomic environments. Although herbicide use alleviates the problem of labour for weeding, incorrect use of herbicides may bring about other environmental problems. Conservation

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Agriculture (CA) is rapidly getting acceptance by the people throughout the world. Eliminating the use of herbicides is one of the principles of CA. The reliance of CA on the use of herbicides and the alleged increased input of herbicides and other chemicals for disease and pest control are the main constraints for the full acceptance of CA as a sustainable crop production concept (Kassam et al. 2010). But, significant crop losses due to weeds are simply not acceptable in a world where 2 billion more people will have to be fed in the next 40 years (Gianessi 2013). Therefore, it is almost impossible to boost up the rice production without using herbicides. At this moment what we need is the judicial application of herbicide.

Mamun (1990) reported that weed growth reduced the grain yield by 68-100% for direct seeded aus rice, 14-48% for aman rice and 22.36% for modern boro rice. Therefore, proper weed management is essential for satisfactory rice production in Bangladesh. Potential yield reductions caused by uncontrolled weed growth throughout a crop season have been estimated to be in the range of 45- 95%, depending on the cultural system, cropping season, plant spacing, amount of fertilizer applied, ecological and climatic conditions, and duration, time, type, and amount of weed infestation (Moody 1991). Even using a more conservative estimate of a 10-15% yield reduction in well-managed fields (Baltazar and De Datta 1996), losses caused by weeds in Asian rice systems amount to approximately 50 million tons of rough rice, valued at more than US$ l0 billion in 1995 (World Bank 1996).

Herbicides offer one of the most effective means by which rice farmers can reduce labor costs for two reasons. First, labor inputs for hand weeding are extremely high, accounting for up to half the total pre harvest labor hours in some irrigated rice systems of Asia (Naylor 1996). Second, effective use of herbicides permits direct seeding of rice, which further economizes on labor.

However, use of herbicides is an easy and effective method of controlling weeds in rice field but it should also be kept in mind that herbicides not only affect the environment but also cause harm to health of living organisms especially to the human bodies. Therefore, the present paper will try to focus on some important aspects on herbicides use and its impact on health and environment with special emphasis on Asian rice farming.

GLOBAL SCENARIO OF USING HERBICIDES IN RICE FARMING

Benefits of herbicides over conventional weeding practice forced developed countries to consume 90%, Latin America 70%, Europe 67%, Asia 84% and Africa 94% more herbicides after 15 years of initiation (Figure 1) (WAP, 2014).

Nowadays, herbicides are the key to sustainable crop production throughout the world. Gill et al. (1992) showed that weed control through both traditional and chemical methods influence crop growth and yield attributes of rice. Moreover, the use of herbicides is increasing in worldwide crop production. The value of the world wide herbicide market grew by 39% between 2002 and 2011 (Philips 2013).

During 1950s-1970s, rapid growth of industrialization has occurred in western European countries, the United States of America, Canada and South Korea. This industrialization has created shortages of workers for hand weeding and tillage operations in agriculture which worked as trigger for rapid adoption of herbicide. In Japan, herbicide adoption reduced the amount of time required for weeding operations by 97% (Takeshita and Noritake 2001). In Korea, manual weeding had been the prevalent control for centuries. In Korea, use of herbicide was started by 1970s since the 1980s, 100% of Korea's rice fields have been treated with herbicides (Kim 1981). According to Holm and Johnson (2010), the introduction of glyphosate has facilitated the adoption of minimum tillage and zero tillage farming system in the semi-arid prairies of Canada. Greater moisture conservation has contributed a 70% reduction in fallow in western Canada (Blackshaw 2006).

In the Philippines, 96–98% of rice farmers use herbicides (Marsh 2009). In China, about 1 billion person-days of labor would be required to hand weed China's rice fields adequately (Moody 1991).

In developing countries, herbicides are being rapidly adopted by the farmers due to the shortages of hand weeding labor and the need to raise crop yields. Farmers were more interested to use herbicide in rice fields. The herbicide application areas of crop fields have steadily increased from less than 1 million ha in the early 1970s to more than 70 million ha in 2005 (Zhang 2003).

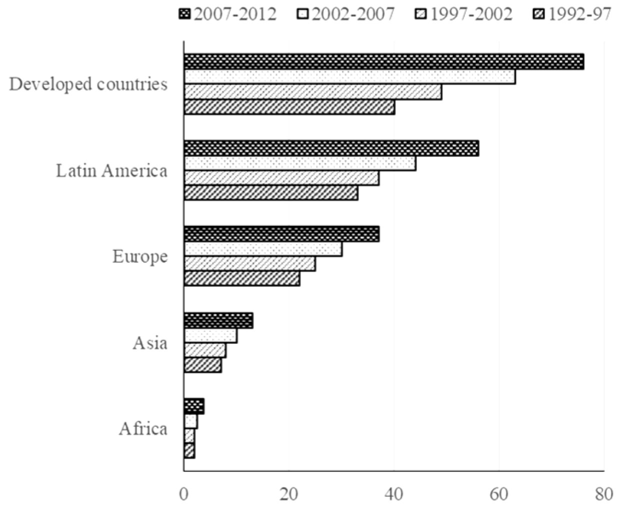

Figure 1. Trend of herbicide adoption in different continent (Million Pound) (adapted from Hossain, 2015)

Wheat production has increased dramatically in India and Pakistan due to the introduction of higher-yielding varieties of wheat responsive to intensive irrigation and fertilizer application. But still there was a potential yield gap due to the weed infestation. Khan et al. (2005) have identified that introduction of very effective grass-specific herbicides is one of the prime reasons for increased wheat yields in Pakistan.

In Bangladesh, according to Bangladesh Crop Protection Association (BCPA, 2016) consumption of herbicides are in a steady state condition for the last several years. In 2007, the consumption was about 3825 metric ton while it was increased a bit in the next year in 2008 but in 2014 the consumption was decreased a bit (Figure 2).

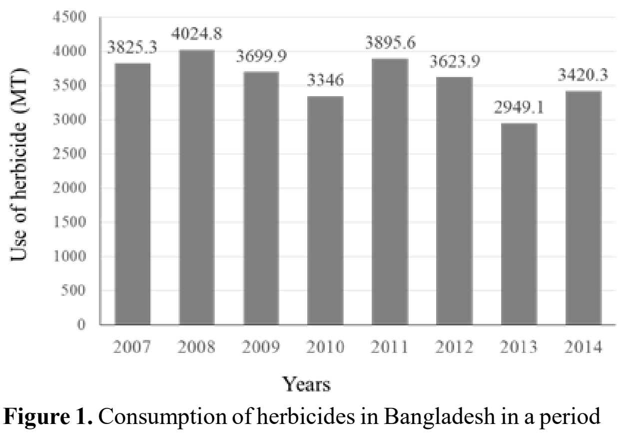

Figure 1. Consumption of herbicides in Bangladesh in a period from 2007 to 2014 (BCPA, 2016)

ENVIRONMENTAL IMPACT OF HERBICIDES

Effects of Herbicide on Soil Microbial Activities

Microbial degradation of herbicides

Herbicides degradation in ricefields is accelerated by the reducing conditions caused by submersion and by the temperature and pH ranges that favor microbial activity (Ponnamperuma 1972). As a result, herbicides often persist longer in non-flooded soils than they do in flooded soils (Sethunathan and Siddaramapa 1978). In a data base on the half-life of herbicides in rice soils, only 8 of 45 tests reported shorter half-lives in non-flooded than in flooded soils (Roger et al. 1994). Herbicides with faster degradation in flooded soils include trifluralin (half-life >4 d in flooded soil and >20 d in nonflooded soil, pyrazoxyfen (half-life <10 d in flooded soil and 3-34 d in non-flooded soil (Arita and Kuwatsuka 1991), and MCPB-ethyl (half-life 2 d in flooded soil and 3 d in non-flooded soil (Asaka and Izawa 1982). Some herbicides degrade faster in non-flooded, upland soils than they do in flooded, lowland soils. These include molinate (half-life 4-160 d in flooded soil, 8-25 d in non-flooded soil (Imai and Kuwatsuka 1982), thiobencarb (half-life 45 d in non-flooded soil, 100 d in flooded soil (Duah-Yentumi and Kuwatsuka 1980), and MCPA (4-chloro-2-methylphenoxyacetic acid (Duah-Yentumi and Kuwatsuka 1980). The persistence of MCPA, 2,4-D, and 2,4,5-T about half as long under moist as under flooded conditions was explained by the need of an aerobic microflora to rapidly degrade phenoxy acid herbicides (Sattar and Paasivirta 1980).

Effect of repeated herbicide application on soil microbial population

Repeated application of the same herbicide on the same field has been reported to increase the growth of related, specific decomposing microorganisms and cause its rapid inactivation. Several bacteria that have the ability to degrade a given herbicide were isolated from the soil and water of ricefields previously treated with the herbicide. This has been reported for a number of insecticides, including gamma-BHC, diazinon, and aldicarb (Roger et al 1994). Watanabe (1977) isolated PCP-decomposing and PCP- tolerant bacteria from soils. He observed a 1000-fold difference in the number of PCP-decomposing microorganisms between treated and untreated soils (Watanabe 1978). Data for thiobencarb are somewhat contradictory. Nakamura et al. (1977) reported that repetitive application of thiobencarb did not lead to an increase in thiobencarb-degrading microflora. However, Moon and Kuwatsuka (1985) reported that when thiobencarb was repeatedly applied to a soil, the lag time for dechlorination decreased from 20 d to 10 d to 2 d due to the multiplication of specific facultative anaerobes that degrade thiobencarb. Those anaerobes rapidly decreased or disappeared when thiobencarb was absent.

Impact on microalgae and cyanobacteria

Photosynthetic organisms like cyanobacteria and algae can be expected to be more sensitive than other microorganisms to herbicides, especially the photosynthetic inhibitors. Several unicellular eukaryotic algae most common in rice fields (Chlorella, Chlamydomonas, Euglena) have been shown to be sensitive to photosynthetic inhibitor herbicides (Arvik et al. 1973). Quantitative data obtained at concentrations corresponding to the recommended level of field application are mostly estimates of the inhibitory effect of herbicides on cyanobacteria cultures; experiments with soil in vitro and in situ make up less than 10% of the data (Table 1). Results confirm, however, that among herbicides not aimed at controlling algae, herbicides are most detrimental to cyanobacteria and algae, causing partial or total inhibition in 67% of the in vitro tests and in 42% of the in situ or soil tests at recommended levels of field application. These values also confirm that herbicide effects are more marked in vitro than in situ.

Table 1. Effects of herbicides on photosynthetic rice field microorganisms (cyanobacteria and microalgae) at concentrations corresponding to recommended field application.

Nature of data	Data	Data (%) corresponding to different levels of inhibition				
		None	<50	50	>50	100
All data	407	39	19	26	2	14
All data in situ or with soil	39	62	8	3	3	26
Algicides (3 tested)	33	3	0	67	0	30
Fungicides (22 tested)	30	40	10	7	0	43
Herbicides (57 tested)	252	33	25	28	2	12
Herbicides in situ or with soil	24	59	8	4	4	25

Modified from Roger et al (1994)

Effects on photodependent biological nitrogen fixation and biofertilizers

Herbicides can inhibit cyanobacteria and photodependent biological nitrogen fixation (BNF). Laboratory experiments showed that PCP, a pesticide used both as an insecticide and a herbicide, was inhibitory to cyanobacteria and diatoms when applied on the surface, but not when incorporated into the soil (Ishizawa and Matsuguchi 1966). In field studies, CNP (2,4,6-trichloropheny1 4-nitrophenyl ether) inhibited photodependent BNF and several formulations used inricefields reduced algal growth (Srinivasan and Ponnuswami 1978). Some herbicides seem to affect the N 2-fixing ability of cyanobacteria specifically; the inhibitory effect of butachlor on N 2 -fixing strains growing in an N-free medium was markedly decreased or reversed by inorganic N sources (Kashyap and Pandey 1982). Whereas many herbicides seem to be most detrimental for photo dependent BNF, several species of cyanobacteria tolerated 100-500 ppm of 2,4-D, a level much higher than that recommended for field application. This suggests that this herbicide might be compatible with cultural practices aimed at promoting cyanobacteria growth as biofertilizer (Venkataraman and Rajyalakshmi1972).

Impacts of herbicides on chemotrophic microorganisms

Chemoautotrophic and chemoheterotrophic microorganisms are the agents of nutrient recycling and maintenance of soil fertility. In contrast to experiments with microalgae and cyanobacteria which were conducted primarily with laboratory cultures, tests of herbicide effects on non-photosyntheticmicroflora and their activities were performed primarily in small-scale experiments with soil or in situ at concentrations corresponding to the recommended level of field application. The data base contains 606 records obtained at those concentrations, although most of the studies deal with insecticides. Studies with herbicides (a mere 102 records) only allow us to identify very general trends (Table 2). Insecticides affected the microflora or its activities less often (no effect in 68% of the studies) than fungicides (Roger et al 1994).

Change in herbicide metabolism

Repeated application of a single herbicide has been reported to cause changes in the pattern of its metabolic decomposition. This has been observed for the insecticide parathion (Sudhakar-Barik et al 1979) and the herbicide thiobencarb (Moon and Kuwatsuka 1984). Such changes in degradation pathways could lead to agricultural problems. Thiobencarb usually is detoxified by hydrolysis, but its repeated application to flooded soil favors the

Table 2. Effects of herbicides on non-photosynthetic rice field microorganisms at concentrations corresponding to recommended field application.

Nature of data	Data (no.)	Data for each effect (%) All negative	Negative trend	No effect	Positive trend	All positive
All data	606	8	12	60	11	9
Fungicides	58	5	0	50	24	21
Herbicides	102	13	23	30	21	14
Insecticides	440	6	11	68	7	8
Biological N_2 fixation	176	2	23	31	26	19
Fungicides	25	0	0	20	52	28
Herbicides	26	0	23	23	35	19
Insecticides	125	2	27	35	18	17

Modified from Roger et al (1994)

multiplication of anaerobic bacteria that decompose thiobencarb by reductive dechlorination. That reaction results in the formation of a phytotoxic compound (S-benzyl N, N-diethylthiocarbamate) that causes dwarfing in rice (Moon and Kuwatsuka 1985).

Impacts on soil microbial biomass

Several long-term experiments evaluating continuous herbicide applications have resulted in declining rice yields over time (Cassman and Pingali 1995). The reasons are not fully understood, but one factor might be intensive hand weeding and herbicide use combined with a dense rice canopy that could restrict the growth of the photosynthetic aquatic biomass. That, in turn, would restrict the replenishment of soil microbial biomass and N fertility. Pesticides, including herbicides, also might be involved in decreasing populations of aquatic oligochaetes (Simpson et al. 1993) and the translocation of the nutrients accumulating at the soil surface to a deeper soil layer. Little data are available to substantiate this hypothesis, but in experiments at IRRI that totally prevented photosynthetic activity in the floodwater of planted fields by covering them with black cloth, soil microbial biomass was reduced 22% after 2 yr (IRRI 1989).

Consequences of Using Herbicides on Environment

The environmental burden of applied herbicides is heaviest in water. Herbicides used in rice fields are carried by irrigation drainage and run-off sequentially from the rice fields to irrigation channels, small riversand large rivers, whereby they are dispersed widely throughout water systems. The run-off rate into watersystems is higher than the rate of about 1% for herbicides applied to upland fields (Ueji and Inao 2001).

In agricultural production, herbicides are used to reduce the undesirable effects of non-crop plants (weeds) growing interspersed with crop plants. The ability of a herbicide to selectively affect unwanted plants while leaving desirable plants undamaged is based primarily on differences in physical and biochemical characteristics that are peculiar to plants, such as photosynthesis (Crosby 1996).

Concentrations of herbicides in rice fields will vary widely, depending on the formulation and rate of application of the chemical, on climate and temperature, and on the time that has elapsed since the chemical was applied. Most herbicides dissipate over time, in response to physical, chemical, and biochemical forces. The effective life of a herbicide is defined as its persistence (Crosby 1996).

Volatilization is the most important route for the dissipation of many herbicides. The chemicals evaporate from field water and, to a lesser extent, from damp soil. The rate of volatilization is governed primarily by Henry's Law: $H = P/S$, where H is the Henry's Law constant, P the vapor pressure of the chemical, and S the aqueous solubility of the chemical (Lyman et al 1990). Water depth, temperature, and wind speed also affect volatilization. Volatilization can be quite rapid (Table 3). The half-life (time required for an initial concentration to decrease by half) of the herbicide molinate is 2 d, close to that predicted by Henry's Law. This short half-life indicates that the dissipation of molinate is due primarily to its volatility. An estimated 75-85% of molinate applied as a granular formulation to a flooded ricefield volatilizes into the atmosphere (Crosby 1983).

Table 3. Environmental properties of rice herbicides

Herbicide	Half-life (h)	Relative volatility	Solubility (ppm)	Soil binding
Fenoxaprop ethyl	3	0.003	1	6800
Bensulfuron methyl	12	<0.001	120	57
Butachlor	20	0.03	23	1075
MCPA	29	<0.001	825	20
Molinate	50	1.2	800	190
Thiobencarb	60	0.11	30	1400

Modified from Crosby and Mabury (1992)

Breakdown of herbicides in the soil is especially important because soils and sediments often are the final repositories of chemical residues (Kuwatsuka 1983). Biodegradation of herbicides by microorganisms in the soil and water is largely independent of sunlight, except in the case of algae. The degradation will take place under either non-flooded (aerobic) or flooded (anaerobic) conditions, or both, depending on the chemical structure of the herbicide. Nitrofen or trifluralin, which contains easily reduced nitro groups, have especially short half-lives under anaerobic conditions, while readily oxidized compounds such as 2,4-D tend to be less persistent under aerobic conditions (Table 4). A herbicide such as propanil, which reacts rapidly with water, may have little persistence under either condition (Matsunaka 1968).

Table 4. Persistence in soil of rice herbicides

Herbicide	Initial concentrate (mg kg^{-1})	Half-life Flooded	Non flooded
Propanil	1	1	1
Trifluralin	10	3-10	150
Nitrofen	10	11	50
2,4-D	20	28	9
PCP	100	30	50
Thiobencarb	20	30-60	10-26

Source: Senthunathan and Siddaramappa (1978)

Effect of Herbicides on Aquatic Environment

Effect on fish

The type and degree of toxicity seen in fish as a result of herbicides depend on the types of chemicals applied. It is not possible to separate herbicide impact from insecticide impact because the same chemicals might be used both as herbicides and as germicides or as insecticides and molluscicides. Insecticides are the most toxic to fish, molluscicides the next most toxic, and herbicides the least toxic (Cagauan and Arce 1992). The persistence of herbicides in soil and water is rather short. In submerged ricefields, nitrofen has a half-life of 206 d (Qian et al. 1982). If the irrigation water is slightly basic, the half-life of molinate is only about 1 d (Feng et al 1988).

Jiang (1986) studied the reactions of sensitive fish species silver carp Hypophthalmichthys molitrix and grass carp Ctenopharyngodonidella and strongly tolerant species crucian carp Carassius auratus and tilapia Oreochromis niloticus to 25 pollutants. The pollutants included heavy metal ions separated from chemical compounds, insecticides, herbicides, germicides, and some drugs used to cure fish diseases.

Effect on water quality

There are indirect effects on water quality, which involves oxygen content, pH, ammonia content, sediment, and taste and odor. During summer and autumn, blue-green algae blooms often currently to control those blooms is the application of 0.7 ppm copper sulfate. Copper sulfate is a herbicide, an algicide, and a bactericide. The decaying of dead algae consumes large amounts of dissolved oxygen in fish pond water, depriving aquatic life. National fishery water quality criteria recommend that dissolved oxygen levels should be greater than 5 mg liter-1 for 16 h out of 24, and not less than 3 mg liter-1 for the remaining 8 h. For salmon habitat, the recommendation is not less than 4 mg liter-1. Tang and Chen (1983) reported that waste water from a Jiangduan agricultural chemical factory had only 0.2 mg liter-1 dissolved oxygen. The fry of grass carp and common carp Cyprinus carpio placed in that water died within half an hour.Urea group herbicides (methylurea, dimethylurea, phenylurea) produce ammonia after hydrolysis (Guenzi 1974). Smith and Isom (1967) treated Myrionphyllum spicatum with 112 kg 2,4-D ha -1. The concentration of 2,4-D in the water decreased to below 1 ppb after 8 h, the concentration of 2,4-D in the sediment reached 950-5,600 ppb 4 d later. This indicates that fish in the bottom layers of a pond could be exposed to higher concentrations of chemicals and for a longer time than fish in the surface layers.

HERBICIDAL EFFECT ON HUMAN HEALTH

The medical literature provides a set of indicators for assessing long-term health effects due to herbicide exposure (Nemery 1987). Of these, the impact of chemicals on the eyes, the respiratory system, the neurological system, the skin, and the gastrointestinal system are most discernible in a cross-section analysis.

Effect on Eye

The eyes are extremely vulnerable to the physical and chemical hazards that confront those involved in agriculture. Some herbicides, such as 2,4-D and the acetamides, are known eye irritants (Morgan 1977). The user group farmers had been using acetamides and 2,4-D for at least 5 years.

Effect on Skins

Herbicides primarily enter the body through the skin, not (contrary to common belief) through the respiratory tract. Mixing and transferring pesticide concentrates pose a greater health hazard to farm workers than doesherbicide application. For spray operators, dermal exposure levels are higher than inhalation levels. The degree of contamination is proportional to the concentration of the chemical and the proximity to the source of emission (Hamilton 1982). Spraying or dusting herbicides leaves residues on exposed skin that is about 20-1700 times the amount that reaches the respiratory tract. The quantity varies with working conditions, application techniques, protective equipment, and duration of exposure (Bainova 1982). Dermal contamination is greater when a knapsack sprayer is used than when a spinning disc applicator or an electrodyne sprayer is used (Durand et al. 1984). The hands and forearms are most exposed and have the highest potential for herbicide contamination (Castañeda et al. 1990). Of the herbicides used in rice, 2,4-D and acetamides, and the organochlorine insecticides are mild to moderate skin irritants and potential sensitizers (Morgan 1977). Eczema, a chronic allergic dermatitis characterized by lichenification and fissuring, is a health indicator of herbicide exposure.

Respiratory Tract Effects

Long-term exposure to chemical irritants can cause such respiratory symptoms ascough, cold, sputum formation, wheezing, rales, tenderness, and decreased chest expansion (Nemery 1987). Incipient lung disorders can be detected by a thorough physical examination and medical history. Bronchial asthma and other abnormal lung findings are two respiratory tract indicators of herbicide exposure.

Gastrointestinal Tract Effects

Herbicides usually enter the gastrointestinal tract accidentally. A farmer who is applying herbicides and who smokes or wipes off sweat near the mouth may unknowingly ingest herbicide particles. Carbamate insecticides formulated in methyl alcohol that are ingested can cause severe gastroenteritis irritation (Morgan 1977). When given in large doses to experimental animals, 2,4-D and organochlorines are moderately irritating to the gastrointestinal lining, causing vomiting, diarrhea, and mouth ulcers (Morgan 1977). Organophosphates and copper salts also irritate the gastrointestinal tract, causing intense nausea, vomiting, and diarrhea.

Neurological Effects

Organophosphorous compounds and 2,4-D are neurotoxicants (Morgan 1977). They have been implicated as causative agents for polyneuropathy, a neurological disorder typically manifested as motor weakness in the distal muscles and sensory deficit with what has been called a “glove-and-stocking” distribution. In the early stages, absence of deep tendon reflexes may be the only sign of a problem. The neuropathy may be purely motor or purely sensory.

DISCUSSION

Herbicides application in rice field contributes greatly to alleviating weeding labor and stabilizing rice production. Many herbicides have been developed to reduce toxicity to humans, domestic animals and organisms in the environment; to reduce persistence; and to improve herbicidal effectiveness. However, it is difficult to overlook the environmental impacts of herbicides at a time when increasing attention is being focused on environmental issues. The environmental burden of applied herbicides is heaviest in water. Herbicides used in rice fields are carried by irrigation drainage and run-off sequentially from the rice fields to irrigation channels, small rivers and large rivers, whereby they are dispersed widely throughout water systems. The run-off rate into water systems is higher than the rate of about 1% for herbicides applied to upland fields. The highest herbicide concentration in rice water, which is on the ppm level, appears between the time immediately following application and the following day, and the greater a herbicide’s water solubility, the higher the concentration in the rice water tends to be. The half-life of herbicides in rice water is 2–5 days for nearly all herbicides. Except for herbicides such as simetryn, which are detected long after their application, herbicides are generally detected in rivers and other water systems in concentrations on the ng/L level for only 2–3 months after use.

Microbial degradation is one of the main factors that affect herbicide persistence in flooded soils. Its importance varies quite broadly, depending upon the herbicide formulation, the mode of application, and the environmental conditions. While herbicides in general persist longer in non-flooded than in flooded soils, there is no obvious trend for herbicides. Trifluralin, pyrazoxyfen, and MCPB-ethyl persisted longer under non flooded conditions; molinate, thiobencarb, and MCPA persisted longer under flooded conditions.

The most obvious toxic impact of herbicides on flooded rice is to change plant, and perhaps animal, ecology etc. However, in many places establishment of a rice monoculture already has erased the native ecosystem. Current evidence, however, indicates that modern organic weed killers do no lasting harm and may even be ecologically beneficial, if the recommended rates and frequency of application are followed and modern herbicides are selected. More and more rice-growing nations are regulating herbicide use, through government policy, education, and research. Governments can regulate and supervise herbicide importation, storage, and use. Herbicide use impacts aquaculture by directly harming fish, by indirectly reducing the quality of the aquatic environment, and by changing linkages in the fish food chain.

Though careful documentation of the consequences to human health of herbicide use is rare in evaluations of developing country agricultural practices but still some evidences are there in Philippines and other countries. Eye, skin, pulmonary, and neurological problems were associated significantly with long-term herbicide exposure. Most of the herbicides which might be linked to these impairments, the highly hazardous category I and II chemicals, are commonly available in the Philippines, although they are banned or severely restricted in industrialized countries. Herbicides in particular were implicated in high incidence of skin diseases, polyneuropathy, and gastrointestinal problems.

However, in Bangladesh, there is not enough data on herbicidal effect on environment or aquaculture or human health. Local farmers are applying herbicides without thinking of this impact focusing on just killing the weeds. The perception or concept of herbicidal impact on environment or farmers' health is also somewhat ignored by the local farmers. Therefore, study should be taken to find out farmers' perception on herbicide use in rice field and their impact on surrounding environment to reconsider the use of herbicide in the rice field of Bangladesh for better environment and human health.

CONCLUSION

Herbicide application in rice field is not a new concept in the world but for Bangladesh farmers, it is rather a new technology for weed management in the rice field. More than 100 companies in Bangladesh are either producing or importing different kinds of herbicides with various degrees of toxicity, having both residual and non-residual effects on the rice field environment. These companies are trying to motivate the local farmers to apply herbicides in their rice field. The farmers only think of an easy removal of weed from the rice fields but they are not concerned about the negative impact of the herbicides to the environment as well as their health. Therefore, all these issues should be properly addressed by the policy makers, researchers and extension workers for the sake of our environment and human health.

CONFLICTS OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this paper.

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