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Trends of Chemical Pesticide Consumption and its Contamination Feature of Natural Waters in Especial Reference to Bangladesh: A Review

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Abstract: Collection of chemicals that can resist pests and diseases, pesticides are now an extensively used tool for pest and disease managing across agrarian countries like Bangladesh. In the country, pesticide use grew at an alarming rate of 10% per annum, while the corresponding response in production growth of main crops has been negligible (<1% y^{-1}). Globally, 750% increase in pesticides production from 1955 to 2000 and that period minimum 30 countries have highly contaminated by these hazardous substances. Bangladesh lies in the second position on the list of fast-growing pesticide-consuming countries in the world. The review paper focused on the present pesticide consumption rate in the country and entire world, their environmental fate and how much contaminate the natural water resources through the application of chemical pesticides. For this purpose, we reviewed over 50 related literatures to extract expressive info about the national wide water contamination by pesticides and presented methodically. Results show that among the Organophosphorus and Carbamate pesticides such as Chlorpyrifos, Diazinon, Malathion, Parathion, Carbaryls, Carbofuran and Cypermethrin was identified in various surfaces and groundwater samples and maximum of those are above the World Health Organization (WHO) guideline value. The serious concern is that in many regions of Bangladesh, organochlorine insecticides such as Dichlorodiphenyldichloroethane (DDD), Dichlorodiphenyldichloroethane (DDE), Dichlorodiphenyltrichloroethane (DDT), Aldrin and Dieldrin was found in the range of 0.01 to 1.20 mg/L which are much higher than recognized level. To control the misapplication of pesticides and to reduce the possible environmental risk, appropriate regulatory systems of pests such as the Integrated Pest Management (IPM) system and the use of bio- or herbal pesticides should be applied immediately in the country.

Key words: Bangladesh · Chemical Pesticides · Global Pesticide Consumption · Integrated Pest Management (IPM) · Water Contamination

INTRODUCTION

Chemical pesticides are working in several agricultural activities to control pests, unwanted plants and diseases in crops. Insecticides, fungicides, herbicides, nematicides, rodenticides, etc., are the major class of pesticides. Those are vital tools for crop protection and better yield in the agricultural process. Almost, 50% of the yearly food production is lost owing to pest attacks in the vast agrarian countries. So, actual pest management by using extensive categories of pesticides is obligatory to encounter pests and to increase the yield [1]. Though, from the mid-nineteen century, about 750% increases in production of chemical pesticides globally but these often persuade calamitous impacts on the natural environment [2, 3]. Improper use of those noxious substances with other organic pollutants in agricultural sectors of vast farming areas may damage the soils and water environment due to their persistent and ubiquitous nature [4].

Bangladesh is a densely peopled (2890/mile^2, which ranks 10th in the world) and a vast agrarian country. Nearly 90% of its lands are cultivatable and 55% of the residents are involved in the farming sector [5]. This sector plays a vital role in the country's economy, which accounts for about 21% of participation in the national gross domestic product (GDP) [5]. There is an estimate of 70, 000 different pest varieties together with plant pathogens, insects and mites and weeds which cause an estimated 13, 14 and 13% farming crop damage, respectively in the world [6]. But 5500 registered varieties of pesticides are used in Bangladesh [7]. In the country

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around 40% of the crop loss is caused by insects and pests attacks which are a significant loss [8]. Peshin and Dhawan [6] stated that crop loss from pests can reduce to 35-42% using pesticides, even though the hazards of using pesticides are serious as well. Owing to insufficient knowledge and guidance about the uses of pesticides, growers spray extreme amounts of pesticides in the farming lands in Bangladesh [9, 10].

The natural water bodies are easily polluted by runoff water or by rain-wash for the undiscerning use of pesticides. The extensive use of pesticides may pollute the environment and freshwater biota [11, 12]. It is compulsory to incoming the portions of applied insecticides and pesticides into the aquatic ecosystems because of the unscientific application techniques for crop protection [13-15]. In this study, we reviewed numerous published literature and briefly described and established the present situation of countrywide water contamination by residual pesticides. In addition, we have discussed the global trend of pesticides consumption and the rate of water contamination by them.

Jepson *et al*. [16] classified a total of 659 chemical pesticides based on their hazard to human well-being and the ecosystem. The pesticide residues from water bodies directly or indirectly pass through the food wave and ultimately harm human and terrestrial or other aquatic lives. Numerous problems can cause in the human physique because of pesticide exposure. Organophosphorus pesticides may affect sperm chromosome segregation and supplement the risk for genomic syndrome [17, 18]. Lee *et al.* [19] described a connotation between chlorpyrifos use and the occurrence of lung cancer in North Carolina and Iowa (USA) and the connotation of soft-tissue sarcoma with definite pesticides such as Diazinon and Aldrin in 6 regions of Canada has been observed [20]. Organochlorine (OC) pesticides such as Dichlorodiphenyldichloroethane (DDD), Dichlorodiphenyldichloroethane (DDE), Dichlorodiphenyltrichloroethane (DDT), Aldrin, Dieldrin, etc. use are related to an increase in cancer risk [21-23]. A very few studies about the health impacted by residual pesticides have been conducted in Bangladesh. Endrin was the first introduced pesticide in Bangladesh of which 3 metric tons (MT) were imported in 1955 for farming pest control [24]. Initially, the Bangladesh government providing 100% financial support for pesticides and provided free of cost to the farmers but the pesticide industry has gone to farmers in 1979 when the 100% price was obligatory [25]. In this country, from 1995 to 2019, the consumption of chemical pesticides is increased by 500% [26]. A portion of this huge amount of applied pesticides remains in the environment and on a long-term basis, this residue can cause serious toxicity in nature. Water is the final receiver of pesticides and it can vastly contaminate these substances. This study is envisioned to deliver a general understanding of pesticide use in developing countries with Bangladesh, including the scale of the consumption, most distinguished trends, including the environmental impacts and the role they play concerning water quality.

Pesticides Consumption in Bangladesh: In Bangladesh, farmers widely use chemical pesticides (Table 1) rather than bio- or natural pesticides for pest control of their reputation for quick effectiveness. Though, the rising use of chemicals has already posed a serious health risk as well as threatening extensive biodiversity and ecological harms. In the country, some illegal traders are engaging themselves in selling some banned items by violating the Government Ordinance (Ordinance No. II of 1971), modified in 1984 which makes foolish to the illiterate farmers [10]. These issues eventually increase the cost of crop production and leading pesticide contamination alarmingly in the country. In addition, some reports have revealed that most of the farmers are not aware of the minimum safety measure of pesticides. Nowadays, the good news is some Government and Non-governmental Organizations (NGO's) are trying to motivate farmers to increase their awareness about pesticide safety measures.

In Bangladesh, just 8000 metric tons (MT) of chemical pesticides were used in 1997, but this amount reaches approximately 40, 000 MT in 2018, i.e., consumption is increasing by 500% (Figure 1). The survey of Pretty and Bharucha [26] indicated that Bangladesh lies in the second position on the list of fast-growing pesticide-consuming countries (Figure 1). The total registered pesticides are 5500 and 90% of the consumed pesticides were imported from China, the rest from India, Germany and other countries. But pesticide use drops 25% in the last 7 years (Global Plant Protection News, November 2016). The use of chemical pesticides is gradually decreasing (Figure 2) due to Integrated Pest Management (IPM) practices and promotion against the use of chemical pesticides. It gives a great scope of use of Bio-pesticides in Bangladesh. The variety of pest control substances that are widely used in Bangladesh are listed in Table 1. The used pesticides in Bangladesh are moderate to highly toxic to every biota and according to WHO, all of them are category I and II hazardous material (Table 1). The common health effects of those pests are dizziness, excessive sweating, fatigue, nausea/vomiting, dizziness, cough; and diarrhea for the human body.

Table 1: Types of chemical pesticides used in Bangladesh and relative health impacts

Pesticides	Chemical type	Hazard characteristics	Health effect	WHO categorized class
Edifenphos	Organophosphate	Highly toxic	excessive sweating; dizziness; fatigue, nausea/vomiting; dizziness; cough; diarrhea	Class Ib
Carbofuran	Carbamate	Highly toxic	cough; diarrhea excessive sweating; dizziness; fatigue, nausea/vomiting; dizziness	Class Ib
Monocrotophos	Organophosphate	Highly toxic	dizziness; excessive sweating; fatigue, diarrhea. nausea; vomiting; dizziness; cough	Class Ib
DDT, DDE, DDD	Organo-chlorine	Highly toxic	excessive sweating; dizziness; fatigue, nausea/vomiting; dizziness; cough; diarrhea	Class Ib
Cyhalothrin	Pyrethroid	Moderately toxic	burning nose; skin redness/white patches on skin/ skin scaling; burning/stinging/itching eyes	Class II
Diazinon	Organophosphate	Moderately toxic	nausea; vomiting; excessive sweating; dizziness; fatigue, dizziness; cough; diarrhea.	Class II
Cypermethrin	Pyrethroid	Moderately toxic	excessive sweating; dizziness; fatigue, nausea/vomiting; dizziness; cough; diarrhea	Class II
Chlorpyrifos	Organophosphate	Moderately toxic	dizziness; excessive sweating; fatigue, nausea/vomiting; dizziness; cough; diarrhea	Class II
Malathion	Organophosphate	Slightly toxic	burning nose; headache	Class III
Dioxathion	Organophosphate	Not classified	----	----

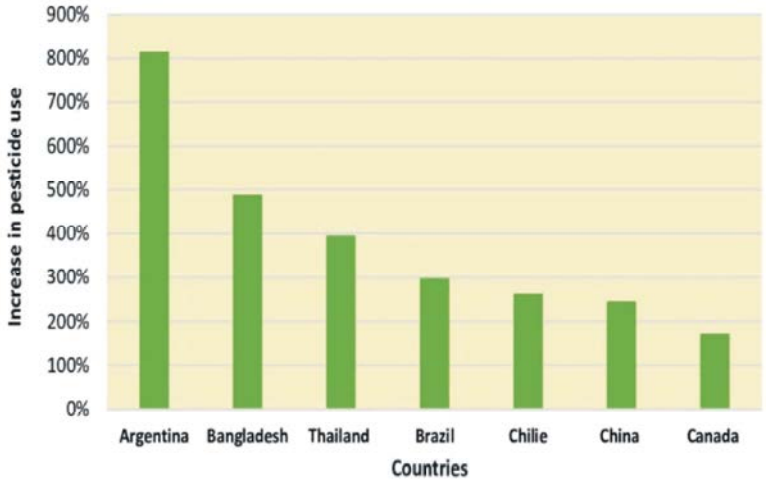

Fig. 1: Pesticide consumption rate from 1990 to 2012 in Bangladesh comparing other countries Only showing countries that use over 20 million kg of pesticides annually (source: Pretty and Bharucha, [26])

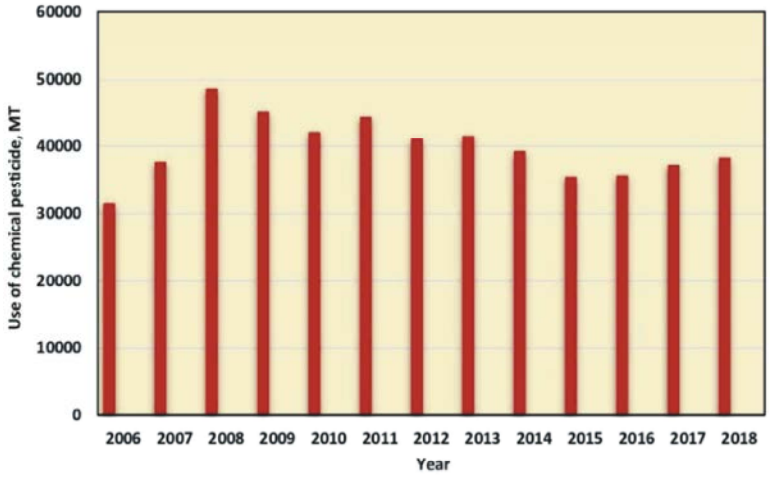

Fig. 2: The rate of chemical pesticide consumption in Bangladesh (2006-2018)

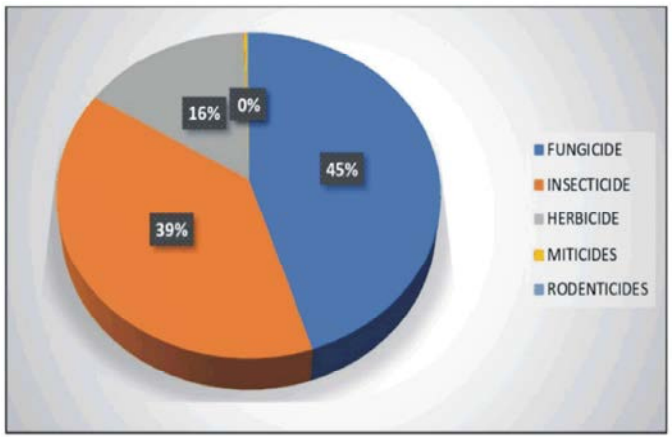

Fig. 3: Category wise chemical pesticide use in the agricultural field of Bangladesh

The arrangement of pesticides over time was conquered by the fungicides and insecticides ranging from 75% to 97% (mean 84%) of total pesticide use (Figure 3). Fungicides got a peak of 29% of total pesticide use only in 1981 and compressed dramatically afterward [27]. Nevertheless, the use of herbicides and fungicides has been increasing gradually in recent past years. At present fungicide and herbicides uses 45% and 16% of total consumption respectively. The main reasons for the increased use of granular insecticides and fungicides are a lengthier protection period, confirmed effectiveness, the lack of effective spray kits and a 'ready to use' design [28]. While statistics do not exist in the configuration of chemical pesticides, data for the year 1987/88 is available and this data showed that Organophosphates are the major types (60.2%) after that Carbamates (28.8%), Organochlorines (7.5%) and others (3.5%) [29]. The farm-level indication also delivers a comparable picture. For instance, Rahman [30] stated that 69.3% of the 410 surveyed agriculture growers used Organophosphates after that Carbamates (19.1%), Organochlorines (6.6%) and Pyrethroids (4.6%).

Pesticide production is decreasing steadily at a rate of -8.6% per annum in Bangladesh [30]. Implementation of Green Revolution Technology (GRT), crops divergence, farmland size and awareness rate is the substantial determinants of pesticide use. Even though the government has shifted focus from pesticide use to integrated pest management (IPM), its coverage remains insufficient as only 7.4% of the total farmers are covered after 30 years of effort [10]. Development of IPM through public and constricted pesticide regulation and its active execution, private and NGO stakeholders are suggested to decrease pesticide consumption.

Pesticide Consumption – Global Scale: At present, the total cultivable land area is around 5 billion hectares or 38% of the global land surface [31]. A meta-study on pesticide uses, a class of chemical products that have seen a 750% increase in production from 1955 to2000, things to see for the first time that natural water (the final receiver of pesticides residue) may be at high risk from pesticides exposure on a universal scale [2]. Stehle & Schulz [32] were analyzed 838 published papers on pesticides consumption and contamination from more than 2500 places in 73 countries. The 28 chemical pesticideswere designated because the majority is permitted for application in the USA and the EU and they cover all major pesticides categories: organochlorines, carbamates, pyrethroids, organophosphorus and neonicotinoids. The study illustrations that 40% of the pesticides concentrations measured in natural waters and 80% of the pesticides levels measured in soils and sediments exceed monitoring threshold limits and result in declining aquatic biodiversity and ecosystems. In addition, they were found there is no scientific investigation or monitoring of pesticide pollution for 90% of the global farmland. The lack of monitoring appears mostly severe in crops-rich countries like China, South American, South Asia and some areas of Africa. Generalizing results from checked to unchecked waters, the scientists estimate that 65% of global cultivated zones are at high risk for exposure to pesticides [2]. A statistical investigation reveals that concentrations are mostly high for a newer group of pesticides like pyrethroids, a class of prevalent domestic insecticides [33, 34].

Now a day, less developed countries are in great vulnerable to pesticide contamination in the local environment. Pesticides are extensively used all over the

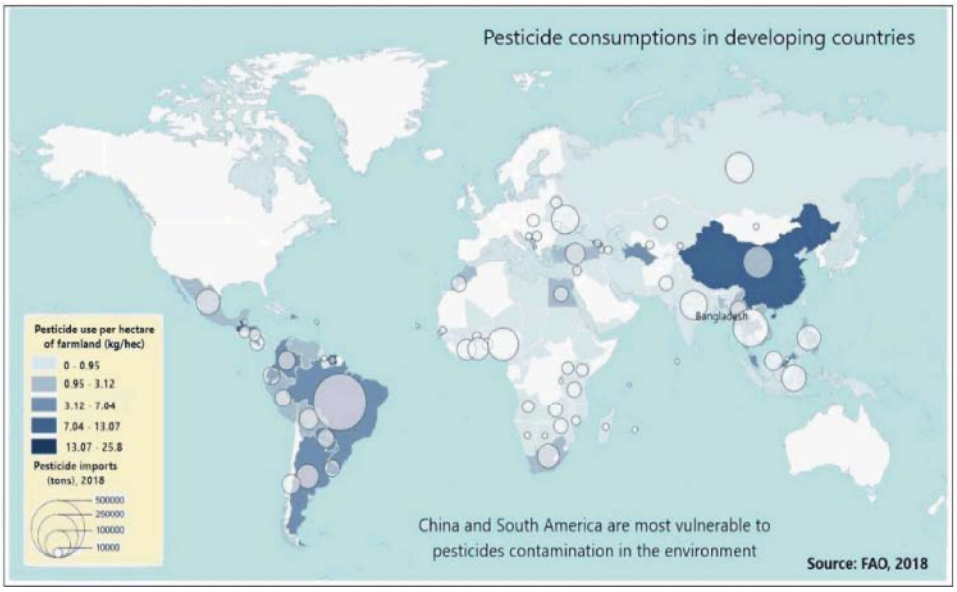

Fig. 4: The scale of pesticide uses in selected developing countries

developing world and their demand is rising due to the recent crop yield system, which prioritizes high agricultural productions. Nonetheless, government grants for pesticides have become less common in maximum developing countries in the later 1990s, because of a combination of structural adjustment policies and emergent sustainability thoughtful. Presently, around 2 million tons of pesticides are consumed in less developed countries per year [27]. This statistic will be increased in the future particularly in the developing agrarian countries. For example, in Brazil, prediction shows that agricultural production will continue increasing and so will the demand for pesticides. In the same country, growth in 2020 relative to 2019 was projected at 6.6% in terms of pesticide amount (9.75 million tons), 5.8% in terms of national income; and 8.0% in terms of application zone (1.6 billion hectares), of which 2% denoted to new agrarian areas [34].On the other hand, 47% increase in pesticide use from 2015 to 2019 in Ukraine and this trend is expected to continue [35]. The complete scenarios of pesticide use in farmland (kg/hectare) and the amounts imports per year of the developing countries in the world are showed by mapping as Figure 4. Globally, entire South American regions, China, South Asia with Indonesia and Thailand, Iran and western-southern countries of Africa are in the top position concerning pesticide consumption and import [36]. Sharma's study [27] and EU report [34] given similar statistics of FAO. These reports are good for more yields but it brings us serious ecological impacts which damage public health and more loss of biodiversity. The ultimate and final receiver of the pesticide's residue after use is the natural surface water as well as groundwater through effective leaching. If the above-mentioned global trends of increasing pesticide consumption continue, thus indicating more and more water-body contamination.

Environmental Fates of Pesticides: All traditional pesticides do have not equal toxic impacts on the environment. Jepson *et al*. [16] classified a total of 659 chemical pesticides based on their hazard to human well-being and the ecosystem. Among them, 243 classes have a lower risk to biota and farmers need to use single-layer personal protection equipment (PPE) in applying time. On the other hand, 95 are lesser hazardous (additional PPE mandatory) and 163 have a high risk to the human body. Besides, 158 types of pesticides are obsolete materials and highly hazardous; those handles with maximum consciously. It is well known that chemical pesticides for agricultural purposes have created more or less human health and environmental impacts. Nevertheless, the statistics remain largely unimaginable. It is projected that 1 to 5 million agricultural employees are affected by pesticide toxicity per year and the WHO reports that a minimum of 20, 000 farmworkers dies from exposure to pesticides every year in the world [37]. The use of lethal chemical pesticides in agriculture activities not only generate different diseases in the human body (over 200 diseases stated by WHO) such as kidney diseases, cancer, skin diseases, affects the

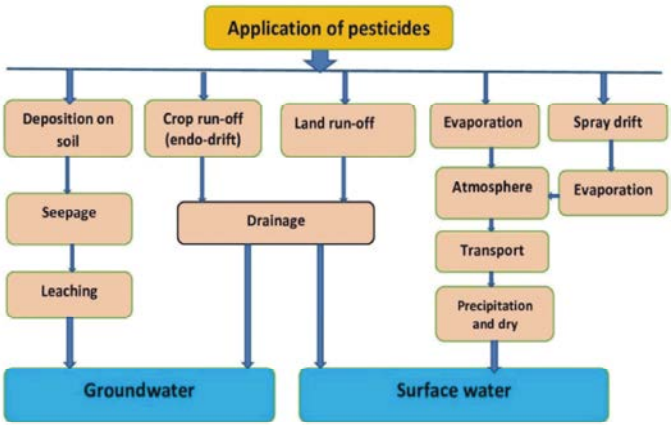

Fig. 5: The pathways of pesticide contamination in the environment

nervous system, hypertension, irritate skin and eye, etc. but also contaminate the water, soil and air, through surface run-off with leaching the residual portion [14]. Also, pesticides can affect others animals, birds, aquatic lives, plants, as well as total ecosystem. The pathway of pesticides contamination in the environment showed in Fig. 5.

The main attention is the impact of chemical pesticides on non-target species. Near about 100% of sprayed herbicides and insecticides reach a terminus other than their target species, because they spread or sprayed across whole croplands [38]. Run-off can transport pesticides into the water body and the wind can transmit them to other fields or the human environment. Additional problems arise from the poor production systems and transport and storage performance [39]. Over time, the regular application intensifies pest resistance, but its effects on other species can enable pest resurrection [40].

Water bodies are the ultimate receiver of residual pesticides. The impacts of pesticides on natural aquatic systems are regularly studied using a hydrological transportation model to study the transport and fate of substances in rivers, streams, or fixed water bodies. There are 4 key routes through which pesticides reach the water: a) it may stream or drift externally the desired area when it is sprayed, b) it may infiltrate, or leach into the topsoil, c) it may be passed to the water body as runoff, or/and d) it may be dropped, e.g., unintentionally or through negligence [41]. Residual pesticides may also be carried in water by soil corroding. Influences that affect a pesticide's capability to pollute water included its water solubility, the distance from an application spot to a water body, soil type, weather, the presence of a growing crop and the technique used to apply the pesticide [42]. The soil of Bangladesh is very coarse and sandy and that is why the residual part of pesticides easily penetrates the groundwater.

Pesticide Pollution in Bangladesh

Groundwater Contamination: Globally, ever collective demand for food and agricultural resources has led to an increase in pesticide toxicity and environmental threat [43]. Agriculture is the determining factor of the Bangladesh economy. Nationally, around 7 kg of 5500 varieties of chemical pesticides are consumed per hectare [36] and annually 37, 258 tons of pesticides are used in total farmland [7]. Runoff of pesticides is a serious hazard of Bangladesh, may leach into groundwater, causing public health problems from polluted water wells [44]. Overall, more pesticide ingredients detected as groundwater quality monitoring programs have become more widespread, but much less monitoring conducted in developing countries, like Bangladesh, because of high investigation costs [44].

Pesticide poisoning of groundwater is an issue of national consideration because groundwater is used for potable purposes by about 95% of the nation's populace, particularly in rural areas [45]. Before the mid-1970s, it was thought that soil acted as a natural protective filter that hindered pesticides from reaching unconfined groundwater aquifers [46]. Nowadays, studies have shown that this is not a fact. In Bangladesh, groundwater tables are high and soil is mostly sandy, coarse and lose types, so there is a big chance that groundwater can have contaminated by the leaching of pesticide residues. Anwar and Bari [47], Anwar and Saing [48] and Anwar and Yunus [49] confirmed that the Leaching Potential Index (LPI) of sediment and soil in the maximum zones of Bangladesh is sufficiently high to leaching pesticides into

Table 2: Pesticide contamination (mg/L) of groundwater samples in Bangladesh

Sampling location	Water type and depth	Pesticide detected	Concentration	WHO [45] Standard	Ref.
Nayerhat, Dhaka District	STW 20-40 m	*p.p'-Dichlorodiphenyldichloroethane, DDE Dieldrin*	0 Traces	- 0.00003	Rahman [53]
Dhamrai upazila, Dhaka District	STW 25-40 m	*Malathion Diazinon*	0.0042 0.0003	0.0019 0.0020	Hasanuzzaman *et al*. [54]
Deferent region of Bangladesh	STW	*p.p'-Dichlorodiphenyldichloroethane, DDD*	0.014-0.365	0.001	Matin *et al*. [55]
		p.p'-Dichlorodiphenyldichloroethane, DDE	0.010-0.084	0.001	
		p.p'-Dichlorodiphenyltrichloroethane, DDT	0.027-1.204	0.001	
		Heptachlor	0.025-0.789	0.00003	
Daudkandi, Comilla District	STW 07	*p.p'- Dichlorodiphenyldichloroethane, DDD*	BDL	0.001	Hasanuzzaman *et al*. [56]
		p.p'- Dichlorodiphenyltrichloroethane, DDT	BDL	0.001	
		p.p'- Dichlorodiphenyldichloroethane, DDE	BDL	0.001	
		Malathion	BDL	-	
		Diazinon	BDL	-	
		Chlorpyrifos	BDL	0.03	
Ghior, Manikganj District	STW 21	*Cypermethrin*	BDL-310	-	Shubhra *et al*. [57]
		Chlorpyrifos	BDL-34.6	0.03	
		Diazinon	BDL-27	-	
Nagarpur, Tangail District	STW 42	*Malathion*	0.0258	-	Hasanuzzaman *et al*. [10]
		Diazinon	0.0002	-	
		Chlorpyrifos	0.0037	0.03	
		p.p'- Dichlorodiphenyldichloroethane, DDD	BDL	0.001	
		p.p'- Dichlorodiphenyldichloroethane, DDE	BDL	0.001	
		p.p'- Dichlorodiphenyltrichloroethane, DDT	BDL	0.001	

BDL-Bellow detection limit

Fig. 5: Water contaminated area by pesticide in Bangladesh

the subsurface environment. Pesticides, like most other chemical contaminants, can easily reach water-bearing layers from cultivation fields, seepage of polluted surface water, inappropriate disposal, unintentional or accidental spills and leaks and even through injection waste substances into wells [50].

Accumulated pesticides can create a serious long-term risk to human body systems. In Bangladesh, the pesticide exposure level (0.018 mg kg^{-1} day^{-1}) is much higher than that of the permissible level (0.005 mg kg^{-1} day^{-1}) [51]. Thus, there is a substantial risk of exposure threats of pesticides to humans and other non-targeted species in Bangladesh. Runoff, spillage, washing of pesticide containers in pond water non-contributor pesticide residues to surface and groundwater in the country. A study showed that 0.0448 mg/L concentration of DDT arrived pond from the adjacent paddy field through water by rain wash [10]. Some pesticides have denominated the maximum contaminant limit in potable water set by the WHO and US-EPA but many have not. Similarly, in drinking water, the consequence of combining more than one pesticide might be different than the things of each specific pesticide alone [51, 52]. This is another situation where has no adequate systematic data to draw dependable conclusions.

Limited information is being available concerning pesticide contamination of groundwater in Bangladesh. Like other less-developed countries, inadequate financial grants and laboratory services are the key hindrances to the obtainability of data in the country. The results of separate studies detailing pesticide accumulation in groundwater of Bangladesh and the relevant WHO standard values are arranged in Table 2. Most of the farmers used mainly chlorinated hydrocarbons, organophosphates, chlorophenoxiacids and carbamate pesticides in Bangladesh and a residual portion of those pesticides can accumulate in living beings through the food chain or drinking water [58]. Organochlorinated pesticides like Heptachlor, Dieldrin, DDT, Lindane were generally used in farmlands and control diseases like malaria in Bangladesh from the early '50s [12]. In 1993, Bangladesh's government banned those pesticides, but there were reports that they used up unlawfully [59, 60]. Organochlorine pesticide having high lipophilicity, lower polarity, less aqueous solubility and a very stable half-life make it a serious threat to public health and the environment as it can bio-accumulate in the food wave [59, 61-64]. On the other hand, organophosphorus pesticides are inexpensive and efficiency is very good, farmers are stimulated to use them. Nonetheless, these pesticides are very injurious to farmer's health and those are also carcinogenic and genotoxic [65]. As chlorpyrifos can cause attention to insufficient hyperactivity disease and development uncertainty, both in embryo and children [65, 66]. On the other hand, carbamate especially carbofuran pesticides cause main problems in the reproductive system and it can cause blurred vision, breathing, vomiting and nausea problems [67].

After applying the pesticides, rain washes the residues to the adjacent water bodies and they become polluted [68]. Matin *et al*. [55] have collected 144 groundwater samples from around the country and found maximum of the samples carried 10 to 1000 times higher concentrations of pesticide residue than WHO recommendation values (Table 2). In this investigation, all DDT values found ranging from 0.27 to 1.204 mg/L were very much higher than guideline values. They also found Heptachlor residues ranging from 0.025 to 0.789 mg/L. Another researcher Islam, [69] collected 48 cultivated field water samples from various zones in the country and found groundwater samples from 10 sites contaminated by DDT, lindane and heptachlor. In this investigation, DDT was found at Bogra and Rajbari Districts; lindane was found in Dhaka, Noakhali, Sylhet and Shariatpur Districts; and heptachlor was found in Dhaka, Chittagong and Magura Districts in which the highest level of DDT residue was estimated in Bogra and it was 0.54 ppm. On the other hand, in Dhamrai and Savar Upazila, among the 27 well water samples, carbofuran and diazinon were found from Savar at 198.7 mg/L and 0.9 mg/L respectively. In Dhamrai Upazila malathion, carbaryl and carbofuran were found at 105.2 mg/L, 14.1-18.1 mg/L and 105.8 mg/L separately [70]. Hossain *et al.* [71] also conducted studies in the same places and find out the level of the same parameters. Chowdhury *et al.* [72] collected water samples from paddy fields, lakes and well in Rangpur city and found carbofuran levels from 0.949 to 1.671 mg/L, chlorpyrifos ranging from 0.554 to 0.895 mg/L and carbaryl was 0.195 mg/L in the lake water. Also, they found carbofuran in 7 samples ranging from 0.934 to 3.395 mg/L, chlorpyrifos in 7 samples ranging from 0.477 to 1.189 mg/L and carbaryl in 2 samples at 0.055 and 0.163 mg/L in the paddy-field water samples. Besides, Chowdhury *et al.* [72] collected irrigated groundwater samples from 22 districts in Bangladesh and they detected DDT residue in Rajshahi, Feni and Chapai Nawabganj Districts. The uppermost DDT level was 8.29 mg/L. Also, they found both heptachlor and DDT residues in water samples from Chhatak at Sunamganj district and observed Heptachlor residues in Madaripur, Sunamganj and Natore districts with a maximum concentration of 5.25 mg/L. Sumon *et al.* [73] measure the residues of 10 most generally used

Table 3: Pesticide contamination (mg/L) of surface water samples in Bangladesh

Sampling location	Water type	Detected pesticide	Concentration	WHO [77] Standard	Ref.
Different regions of Bangladesh	River and pond water	p, p'- *Dichlorodiphenyldichloroethane, DDE*	0.013–0.060	0.001	Matin *et al*. [55]
		p, p'- *Dichlorodiphenyldichloroethane, DDD*	0.014–0.038	0.001	
		p, p'- *Dichlorodiphenyltrichloroethane, DDT*	0.015–0.068	0.001	
Savar and Dhamrai Upazila	Surface and paddy field water	*Malathion*	BDL-105.2	0.0019	Chowdhury [70]
		Diazinon	BDL-0.9	0.0020	
		Carbaryl	BDL-18.1	0.001	
		Carbofuran	BDL-198.7	-	
Rangpur district	Surface and lake water	*Chlorpyrifos*	BDL-1.189	0.03	Chowdhury [72]
		Carbofuran	BDL-3.395	-	
		Carbaryl	BDL-0.163	0.001	
Meherpur district	Surface water	*Diazinon*	BDL-0.0775	0.002	Uddin *et al*. [74]
		Chlorpyriphos	BDL-0.0143	0.03	
		Carbofuran	BDL-0.0387	-	
		Carbaryl	BDL	0.001	
Jessore district	Surface water	*Quinalphos*	BDL-0.241	-	Fatema *et al*. [75]
Savar Upazila	Surface and paddy field water	*Cypermethrin*	BDL-80.5	0.03	Hossain *et al*. [71]
		Chlorpyrifos	BDL-9.31	0.002	
		Diazinon	BDL-7.86	-	
		Ethion	BD -56.3	-	
		Fenitrothion	BDL-33.41	0.0042	
		Malathion	BDL-59.9	-	
		Parathion	BDL-6.23	0.001	
		Carbofuran	BDL-43.2	-	
		Carbaryls	BDL-6.3	-	
Different spots in Bangladesh	River and pond water	*p, p'-Dichlorodiphenyldichloroethane, DDD*	BDL – 8.29	0.001	Chowdhury *et al*. [72]
		p.p'-Dichlorodiphenyldichloroethane, DDE	BDL-4.06	0.001	
		p, p'-Dichlorodiphenyltrichloroethane, DDT	BDL	0.001	
		Endrin	BDL	-	
		Lindane	BDL	-	
		Heptachlor	BDL-5.24	-	
48 different zones in Bangladesh	Surface water	*p, p'-dichlorodiphenyltrichloroethane Heptachlor*	BDL-0.5401	0.001	Islam [69]
		Lindane	BDL-1.479	-	
			BDL-1.826	-	
Comilla	Surface water	*p.p'-Dichlorodiphenyldichloroethane, DDE*	0.0001	0.001	Rahman [53]
		Dieldrin	0	-	
		p, p'-Dichlorodiphenyltrichloroethane, DDT	6×10^{-6}	0.001	
Different regions of Bangladesh	Pond water	*p, p'-Dichlorodiphenyldichloroethane, DDD*	BDL-0.052	0.001	Bagchi *et al*. [8]
		p.p'-Dichlorodiphenyldichloroethane, DDE	BDL-0.014	0.001	
		p, p'-Dichlorodiphenyltrichloroethane, DDT	BDL-0.316	0.001	
		Heptachlor	BDL-0.048	-	
		Carbaryl	BDL-0.609	-	
		Carbofuran	BDL-1.760	-	

BDL-Bellow detection limit

Organophosphorus pesticides, OPPs in water and sediment in northwest Bangladesh and evaluate their ecological hazards for aquatic plants and animals. Results presented the most often detected pesticides that seemed in high levels were, Quinalphos, Diazinon and Chlorpyrifos, in sediment and water. The maximum concentration of chlorpyrifos measured in water was 0.0091 mg/L (average of 0.002 mg/L), while this was 0.0051 mg/L for Diazinon (average of 0.0011 mg/L) for sediment [48]. Moreover, these results showed high chronic risk quotients (RQ>1) in sediment and water samples for Diazinon, Chlorpyrifos, Malathion, Fenitrothion and Quinalphos. That information is not for groundwater entirely but gives also a complete picture of residual pesticide levels and possibilities of poisoning in groundwaters in Bangladesh.

Surface Water Contamination: The surface water body can easily contaminate rather than groundwater. Pesticides reached in nearby surface water sources through run-off or rain-wash. Numerous studies have been performed regarding these types of contaminations in Bangladesh, some of those are included in Table 3. Hossain *et al.* [64] showed that in Dhamrai and Savar Sub-district, out of 27 surface water samples, Carbofuran and Diazinon were found in surface water samples from Savar at 0.9 and 198.7 mg/L, respectively and Malathion was found in Dhamrai at 105.2 mg/L. In another study in the same place, out of 12 surface water samples in the agricultural wetland, Carbofuran residues were founded 43.2 mg/L, Carbaryl residues ranging from 4.6 mg/L to 6.3 mg/L, Cypermethrin in 3 water samples varied from 54.36 mg/L to 80.5 mg/ [64]. Islam *et al*. [62] collected

48 samples from agricultural wet paddy fields from different areas in Bangladesh and found water samples from 10 sites were contaminated by Heptachlor, DDT and Lindane (Table 3). Also Table 3 Showed that Heptachlor was found at Dhaka, Chittagong and Magura Districts; DDT was detected at Bogra and Rajbari; Lindane was found at Dhaka, Noakhali, Sylhet and Shariatpur Districts; also, the maximum level of DDT deposit was observed in Bogura at the level of 0.5401 mg/L. Furthermore, Chowdhury *et al.* [72] collected surface water samples from 22 Districts in the country and they observed that DDT residue exists in the surface water of Nawabganj, Rajshahi and Feni Districts. This study was found the highest DDT load of 8.29 mg/L. Again, they also found that the Heptachlor deposits in Madaripur, Sunamganj and Natore Districts with the highest concentration of 5.24 mg/L. Likewise, Chowdhury *et al*. [70] 16 water samples were collected from lakes and paddy fields in Rangpur city and these water samples carry Chlorpyrifos ranging from 0.554 mg/L to 0.895 mg/L, Carbofuran ranging from 0.949 mg/L to 1.671 mg/L and Carbaryl in 1 sample at 0.195 mg/L. The same study in the river water samples found that Chlorpyrifos in 7 samples (0.477 mg/L to 1.189 mg/L), Carbofuran in 7 samples (0.934 mg/L to 3.395 mg/L) and Carbaryl in two samples at 0.055 mg/L and 0.163 mg/L. They also found both Heptachlor and DDT residues in surface water samples from the Sunamganj District.

Some studies were carried out in Pond water and the results also confirmed that this water source can be contaminated by pesticides. Bagchi *et al.* [8] 20 pond water samples were collected and observed that the presence of Heptachlor and DDE in 1 water sample and DDT, DDD, DDE in other samples but their level was within the WHO standard value. In the same study, it was also found Carbofuran residues in 10 samples but that was also within the WHO-recognized level. Likewise, 25 pond water samples were collected by another study from Brahmanbaria district and found Malathion in 3 samples ranging from 0.0241 mg/L to 0.0463 mg/L [74] and other samples were not carried any pesticide residues. Chowdhury *et al.* [72]; Uddin *et al*. [74]; and Hasanuzzaman *et al*. [76] also performed the study on pond water contamination by pesticides in various regions of the country.

World Scenarios: Roughly 40% of the earth's land area and 64% of the cultivable area of the world are at risk of contamination from chemical pesticides [77]. But, yet now, the maximum affected areas are not properly investigated. Several studies e.g., FAO [31], Sharma *et al.* [27], UN [78] were shown that the water body of the Mediterranean region, USA, South-central America, China, middle and southeast Asia, Australia and some countries of Africa are mostly contaminated through pesticides (Fig. 6). Considering climate data, topography, land use patterns, crop diversity and rates of pesticide application, the map displays that the risk of pesticide contamination is comparatively low in Canada, northern Europe and Russia but increases near the tropical and equator. The warmer and humid climate intensifies the crop pest and that type of weather is good for agricultural activity also. The highly water-contaminated countries through pesticides on the map are crop-rich areas and used 15-20 kg/hectare chemical pesticides [36]. The residual portion of it ultimately reaches into a near waterbody and some are leached to groundwater aquifers and those countries face serious water pollution [14].

Controlling Chemical Pesticides -Uses of IPM and Bio-Pesticides: Uses of Integrated Pest Management (IPM) and bio-/herbal/botanical pesticides in agriculture are environment-friendly and have confirmed indications to decrease pest infestation and control the eruption of diseases in crops. The IPM is a farming technique that comprises manifold cropping, planting disgusting crops in the margin of the bed, intercropping, applying biological pest controller agents (e.g., pheromone trap), etc. Botanical or herbal pesticides resulting from animals, plants, bacteria, etc., have like qualities and potentialities compared to chemical pesticides. Another technique, pheromone traps, is a kind of system from where insect sex pheromone releases and attractions the opposite sex to mate. Ultimately the harmful insects are trapped in the device where no reproduction of the pest happens. The use of Vermicompost is another part of IPM and this material gradually gathered popularity in the former community in Bangladesh. IPM in the agriculture sector had been introduced by the government of Bangladesh 3 decades ago but the Pesticide Act, 1985 did not remark the wording 'bio or botanical' and for this reason, agro-based companies did not make IPM related tools or bio-pesticides. Throughout the recent years, IPM and botanical pesticides got a drive. For this reason, the application of chemical pesticides has decreased, which means the use of IPM and botanical pesticides increased. The use of chemical pesticides increased vastly from 1990 to 2007 and then drops steadily which is discussed in Section 2 of this paper.

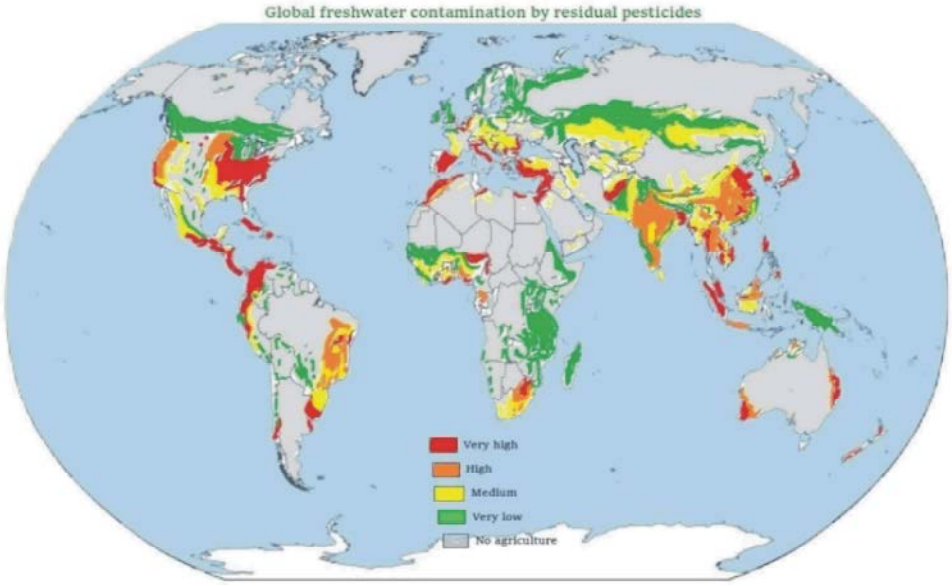

Fig. 6: Countries (red-marked) of high water contaminated through pesticides residue

The idea of IPM contained most of the use of pesticides in a way that was compatible with organic control of pests and insects but the attention of IPM started to shift to non-pesticidal tactics in the 1980s [79]. Application of IPM policies saved USA agriculture from 500 million dollars per annum owing to decreases in pesticide usage [80]. (On the other hand, Norway started a pesticide reduction strategy in the year 1988 which imposed a levied banded tax system based on toxicity at the rate of 3.8 dollars per hectare that bring about a 54% decrease in pesticide usage [81]. In Indonesia, government to control the use of pesticide, decrease pesticide subsidies and directive IPM as the national strategy for crop protection and steadily reduced chemical pesticide subsidies [82, 83]. From a preliminary censored in 1986, subsidies had been removed by 1989. Thus, it is a big opportunity for an agrarian nation as Bangladesh to decrease the probable health hazards along with costs due to pesticide use with the applying of IPM activities. In Bangladesh, the IPM strategy was first in progress from 1981 in rice crop, but it was beginning to increase and became a popular technique among formers from 1987 through the FAO's Inter-Country Program (IPC) [84]. The IPC-FAO affords IPM training through farmers with the help of Farmer Field Schools. Over 1 lakh farmers have now received a season-long practical, in-depth training on IPM. But these figures only 0.28 % of the total 0.37 crore cultivators of the country [85]. The IPM-skilled farmers of Bangladesh can decrease their pesticide application by as much as 80 % together with an increased harvest of about 10 %. Though to ensure a positive and significant result of IPM at the national level, still, many farmers must be skilled in IPM and besides, they should exercise IPM in their crop fields frequently. In this case, in Bangladesh, essential mechanisms will be recognized to ensure the expansion and coordination for a sustainable IPM program.

The Bangladesh government has permitted the *Balai Nashak* (pesticide) Act, 2017 signifying tougher disciplinary actions against the sale, marketing, packaging, advertisement and storage of banded and highly harmful pesticides. According to the existing Pesticide Amendment - 2010, if a company is found adulteration of pesticides, there will be 2-year custody and termination of the company's license. Moreover, Bangladesh had previously passed National Food Safety Act 2013. If all these Rules and Acts applying appropriately, there will be a change in basic assumptions towards pesticide uses and vending.

Other Types of Chemical Pesticides Controls: Traditional chemical pesticides are very toxic to the environment, for that they should use the following least toxic or safe processes to pest control.

Baits - uses sticky or gels materials in a pest's path when pests meet baits, they are joint with it.

Cleaning Solutions - using household cleansers (Lysol and bleach) keep areas disinfected and deter pests.

Insect growth regulators (IGR) - IGRs stop the maturity procedure in insects.

Repellents - these are used to deter animals from specific zones or from feeding on certain plants.

Desiccating dust - desiccating dust attack the outer layer of an insect's body and causes the loss of water and dry out.

Pesticidal soaps/oils - these materials are toxic to insects and decay quickly in the environment, not leaving residues.

Botanical pesticides – these substances are derived from plants and have powerful effects on pests.

Concentrated liquid /powders/ solutions – natural alkaloids, pyrroles and some synthetic less toxic chemicals.

Rodenticide baits – anticoagulants (Coumarins and Indandiones), Non-anticoagulants (Benzenamines) and Zn_3P_2.

CONCLUSION

Bangladesh, devastatingly an agro-economy, has followed the path of quick dispersion of a rice-based Green Revolution Technology (GRT) over the previous 4 decades to achieve the goal of independence in food crops. As well, the government has highlighted crop divergence since the early 2000s to endorse agricultural growth and export incomes. Both these strategies-driven factors have given rise to a significant increase in the use of pesticides and other agrochemicals. There was a 500-750% increase in the production and application of the pesticide from mid nineteen in Bangladesh as well as the whole world. The environmental impacts of these hazardous substances are now reaching a serious position in the country. Not only Bangladesh, other agricultural countries like China, the USA, South American, South and Middle Asia and some areas of Africa are now facing serious environmental impacts by pesticides. From various studies, we have explored the rate of worldwide pesticide consumptions and highly water contaminated countries through different two maps. Water is the primary source of these hazardous materials and is accumulation in the human body through a food chain. This study found that all kinds of chemical pesticides which are massively used in the country's agricultural land exist in the surface and groundwater of several regions in Bangladesh. Especially, the concentrations of very toxic Organochlorine insecticides were identified as a higher level (0.01-1.20 mg/L) than the WHO guideline value. We have explored the 15 studies performed around the country and conducted by a separate researcher. Among these studies, all those wares identified the pesticides in their water samples with more or less concentration. So, this is the greatest threat to the environment as well as humans and other living species. To decrease the thriving trends of pesticide application and thus, the increasing environmental hazard, Integrated Pest Management (IPM) strategy can be a good solution. It is the technique in which the pest population is repressed under the level that causes economic injury using all appropriate policies and methods. Another solution to pesticide hazard is the massively uses of herb- or bio-pesticide in crop fields to protect the pest as well as overuse of chemical pesticides. In addition, the finding of this study advises the essential for worldwide developments to current pesticide guidelines and pesticide application practices and strengthened research efforts on the impacts of pesticides under real-world conditions.

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