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Pesticide exposures towards health and environmental hazard in Bangladesh: A case study on farmers' perception

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A B S T R A C T

The levels perception and behavior of farmers on pesticide uses and its relevant risks to the environment and human health were surveyed among the farmers of Bangladesh in two areas: Savar Upazila (SU) and Mehendiganj Upazila (MU). Significant differences were observed between the farmers' regarding information of pesticides ($\chi2 = 19.679$ at $p < 0.05$). 35% farmers of SU reported different mass communication devices as a primary source of information while 36% farmers from MU reported other farmers as their sources of information followed by pesticide dealers (28%). Proper storage and uses of personal protective equipment (PPE) were absent. However, significant differences were also observed to cover face with cloth ($\chi2 = 22.019$ at $p < 0.05$). Farmers of SU used partial cover 69% while in MU 48% farmers reported no covering. Only 14% and 5% of farmers reported the full use of PPE in both areas. 39% farmers and 42% farmers of the SU and MU, respectively, reported throwing empty pots into the nearby water body followed by taking home for reuse by 31% and 24%, respectively. 88% farmers of SU vs. 82% farmers of MU consumed betel leaf, tobacco or smoking during spraying. 87% in SU and 66% in MU believed that pesticide application decreased soil fertility ($\chi2 = 12.265$ at $p < 0.05$). About 83% farmers in SU and 24% farmers in MU reported that surface water pollution occurred due to pesticide $\chi2 = 69.963$ at $p < 0.05$); excessive uses of pesticides destroyed beneficial insects ($\chi2 = 73.509$ at $p < 0.05$). 67% farmers of SU and 26% farmers of MU responded that environmental quality was deteriorating. Canonical correspondence analysis (CCA) revealed all the background variables (education, age, farming experience, and farm ownership) had a similar contribution towards understanding the danger of pesticides impact of health and environment irrespective of rural or urban location. A DPSIR framework (drivers, pressures, state, impact, response model) for the health and environmental hazard and a conceptual model of training tools for farmers are proposed.

1. Introduction

Pesticides are an essential part for agricultural practices all over the world. Unlike most other chemical products, pesticides are deliberately released into the environment for controlling undesired organisms such as weeds, fungi, and insects. Pesticides are biologically active compounds with a component-specific inherent toxicity (Claeys et al., 2011). The use of pesticides in agriculture is directly related to an increase in farm productivity (Latif et al., 2011). Due to adaptation and resistance developed by pests to chemicals, every year higher amounts and new chemical compounds are used to protect crops, causing undesired side effects and raising the costs of food production (Carvalho, 2006).

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Nevertheless, the common use of pesticide is a major challenge in trying to accomplish sustainable agriculture (Kabir and Rainis, 2014) resulted in the contamination of all necessities of life, i.e. air, water and food (Sharma et al., 2010; Yang and Lee, 2010) and could pose potential risks to food and the environmental safety as well as to human health (Zhang et al., 2015). They are regarded as significant sources of diffuse pollution that might cause long-term health implications in humans (Claeys et al., 2011). Many of the pesticides are proven or suspected to be endocrine disrupting (ED) chemicals which are compounds that alter the normal functioning of the endocrine system, potentially causing disease or deformity in organisms and the offsprings (McKinlay et al., 2008). Women living in areas of recent high agricultural pesticide use experience higher rates of breast cancer (Reynolds et al., 2005).

Agriculture in Bangladesh is in the process of diversifying from subsistence rice production into higher value crops such as vegetables and fruits (Schreinemachers et al., 2016). As an agricultural country with small lands, an enormous population to feed, a developing country like Bangladesh rely heavily on the uses of pesticides to increase crop yields. Nevertheless, during the past decades, the Peoples' Republic of Bangladesh has experienced 26.46% decrease in total pesticide consumption. However, the presence of unregistered pesticides in the environmental samples and agricultural products has pointed out the weakness in the existing legal regime of the pesticide governance (Shammi et al., 2017). Since 1990, organophosphorus pesticides have been widely used in Bangladesh because organochlorine insecticides were banned due to their persistence as well as acute toxicity in the environment (Chowdhury et al., 2012). It was also reported from Bangladesh that residues of organophosphate and carbamate pesticides were in very high concentration in soil and water (Bhattacharjee et al., 2012; Chowdhury et al., 2012; Chowdhury et al., 2013a; Chowdhury et al., 2013b; Shammi et al., 2014). It is also evidenced from the previous report that about 77% of Bangladeshi farmers used pesticides at least once (37% applied once and 31% applied twice, and the rest applied for 3–5 times) in a crop season (Rahman, 2003).

Working conditions in agriculture are hazardous (Stave et al., 2007). Exposure to pesticides is a major occupational hazard of farmers and farmworkers, it is of major importance for farmers' health, and has been extensively studied, although para-occupational (indirect) exposure and residential exposure to pesticides also deserve attention (Bondori et al., 2018). Farming is acknowledged to be a dangerous occupation that poses risks for farmers, farm employees and family members (Thurston and Blundell-Gosselin, 2005). Information on the health impacts of pesticides is quite limited in many developing countries, with many surveys relying solely on farmer self-assessments of their health status (Dasgupta et al., 2007). Exposure to pesticides in agriculture occurs during loading, mixing, application of pesticides and manual activities in treated crops (Tahir and Anwar, 2012). Dasgupta et al. (2007) found that among Boro (winter rice), potato, bean, eggplant, cabbage, sugarcane and mango farmers in Bangladesh, over 47% of the farmers were overusing pesticides. With only 4% of farmers formally trained in pesticide use or handling and over 87% of farmers openly admitted to using little or no protective measures while applying pesticides, overuse is a potentially threatening problem to farmer health as well as to the environment. As end users and distributors, farmers and retailers of pesticides are directly exposed to pesticides, and their behaviors for the safe use of pesticides play an important role in reducing point and non-point sources of pollution, hazards, and acute or chronic intoxication to pesticides in agricultural regions. The levels of knowledge and risk awareness and the practices of farmers and retailers are essential elements for increasing the efficiency of devising to protect these stakeholders (Yang et al., 2014). Rezaei et al. (2017) reported almost half of the farmers (49.5%) from the study area of Zanjan, Iran had shown unsafe behavior in the use of PPE and significant proportions of the farmers showed potentially unsafe behavior in the use of pesticides (42.2%).

In public policy initiatives, agriculture and health have often been pursued in an unconnected manner; evidence across the world, however, shows that there are multiple links between the practice and products of agriculture and environmental health risks (Sarkar et al., 2012). In recent years, the interest in health and safety in the workplace has increased. Agriculture is one of the human work activities with the highest risk indexes. Studies on risk perception of agricultural workers are often referred to as specific risk factors (especially pesticides), but the risk perception plays an important role in preventing every kind of accident and occupational disease (Cecchini et al., 2018). Given the potential risk of pesticides for public health, the use of pesticides in agriculture is subjected to constant monitoring (Claeys et al., 2011). Given the limited or poor literacy skills of farmers of Bangladesh and widespread use of pesticides, it is predictable that occupational exposure to pesticides is likely to be high, cumulating the vulnerability to acute and chronic poisoning to human health and environment. Thus, the objectives of this study were to determine the levels of perception and behavior of farmers regarding usage of pesticide and to evaluate the driving factors related to environmental and human health hazard.

2. Materials and methods

2.1. Study site

This study was conducted in two agriculturally productive regions in Bangladesh. One is situated in the peri-urban region and the other in a rural region (Fig. 1). Savar Upazila (SU) of Dhaka District was chosen in a view of being in the peri-urban farming regions, only 24 km away to the northwest of Dhaka city at 23°51′30″N 90°16′00″E. It is bounded by Kaliakair and Gazipur Sadar Upazilas on the north, Keraniganj Upazila on the south, Mirpur, Mohammadpur, Pallabi and Uttara thanas of Dhaka City on the east, and Dhamrai and Singair Upazilas on the west. It has 66,956 units of household and a total area of 280.13 km^2 (Banglapedia, 2006). The Upazila had several unions. Four unions were selected for the data collection purpose based on intense agricultural activities. The Ashulia, Shimulia, Birulia, and Pathalia union were selected for the data collection. In the Savar area, farmers were more benefited from the cropping pattern, Cabbage (100%) + Tomato (25%) – Aus - T. Aman (Dey and Haq, 2009).

Mehendiganj Upazila (MU) located at 22°49′55″N 90°32′00″E, is in Barisal District, Bangladesh with a total area of 435.79 km^2. It is bounded by Hizla and Muladi Upazilas on the north, Barisal Sadar and Bhola Sadar Upazilas on the south, Bhola Sadar, Lakshmipur Sadar and Raipur Upazilas on the east, Muladi and Barisal Sadar Upazilas on the west. Paddy, jute, wheat, pulse, sweet potato, onion, betel leaf, sugarcane, vegetables (Banglapedia, 2006). The Ulania and Gobindapur union were selected for the data.

2.2. Questionnaire survey

The farmers directly related to the agriculture were the main source of the data. Besides, the experienced people, agriculture officers, school teachers, and some local people also considered as data sources. Data were collected from all the respondents using a pre-designed questionnaire prepared inconsistency with the objectives of the study that comprised both open and close-ended questions. Data collection time was February-March 2012. The questionnaire was composed of three sections (Table 1). The first section included questions related to (1) basic social informa-

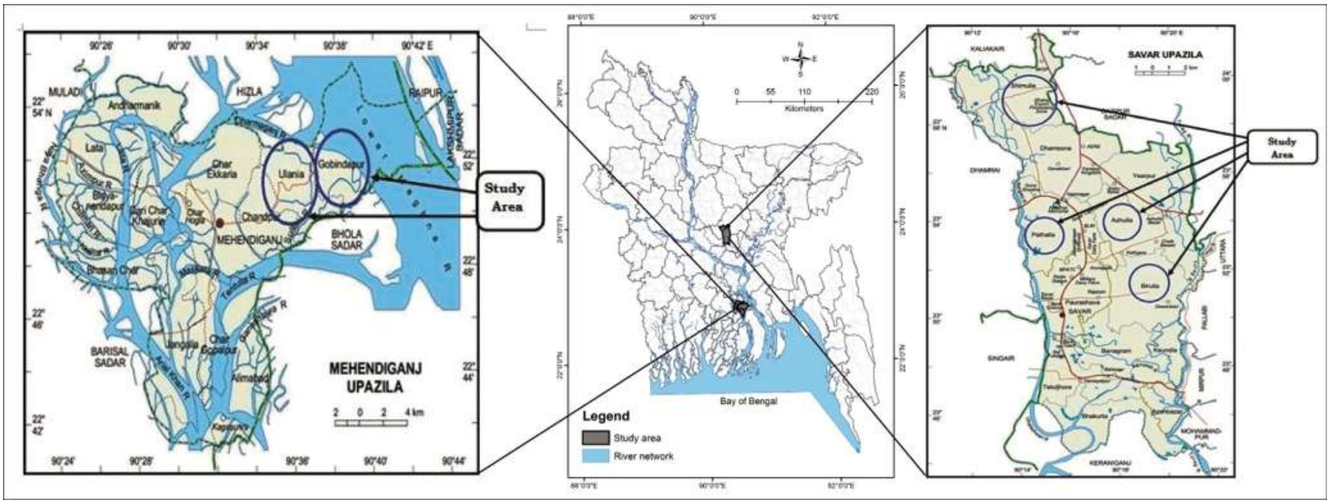

Fig. 1. Geographical location of selected study areas Savar Upazila (SU) and Mehendiganj Upazila (MU).

Table 1
A questionnaire regarding Farmers' knowledge, behavior and experience towards pesticide application, health problems and environment.

Questions
Part 1: Basic information
1. Gender, age, educational level 2. Family members, farm ownership, experience in farming and income from farms 3. Name of pesticide used by farmers during interviews
Part 2: Farmers' knowledge and behavior towards pesticide application
1. Prevailing types of pesticides application practices 2. Farmers' knowledge source on pesticide 3. Farmers' method of pesticide application 4. Application by self 5. Kind of protective covering 6. Precautions just after spraying 7. Methods of storing, preparing and discarding empty pesticide pots
Part 3: Farmer's experience with health problems during or after pesticide application and how they deal with it
1. Farmers experience with health problem perception during pesticide application 2. Farmers' addiction and addiction effect during spraying 3. Visit health centers or doctors
Part 4: Farmers' perceptions about the effect of pesticide application on agriculture and environment
1. Increasing crop output yes/no 2. Decreasing soil fertility yes/no 3. Water pollution yes/no 4. Decline insect predators yes/no 5. Increase in incidence of pest /insects attack over time yes/no 6. More weeds infestation yes/no 7. Environmental quality changes and demand for improvement yes/no

tion about the interviewee, for instance, gender, age, and education followed by (2) number of family members, farm ownership, experience in farming and financial status of Farmers' income from farm and (3) pesticide information during the interview. Regarding this information commercial product name, registered name and active ingredients were taken.

The second part included question regarding farmers' knowledge and behavior towards pesticide application practice, such as (1) prevailing types of pesticides application practices, (2) farmers' knowledge source on pesticide, (3) farmers' method of pesticide application, (4) application by self or others, (5) kind of protective covering (6) other precautions during spraying, (7) precautions just after spraying and (8) methods of discarding pesticides pots. The third section included questions regarding farmers' experiences with health problems during or after pesticide application and how they deal with it. The fourth section included some yes/no answered question regarding Farmers' perceptions about the effect of pesticide application on agriculture and environment.

2.3. Sampling procedure

To ensure the efficient data collection of the questionnaires, it was translated in Bengali and further translated into local dialects during interview processes where necessary. Villages' heads and local educational institute's headmaster were contacted to get prior information of the local area. The head of the selected farmer families who procures and applies agrochemical products was chosen for the interview and the selection process was stratified random sampling (Fig. 2). 150 questionnaires were surveyed from these two areas which resulted in 97 from SU and 52 for MU. For the convenience, we took 100 from SU and 50 from MU. The aim of the questionnaire survey was clearly clarified to reduce the

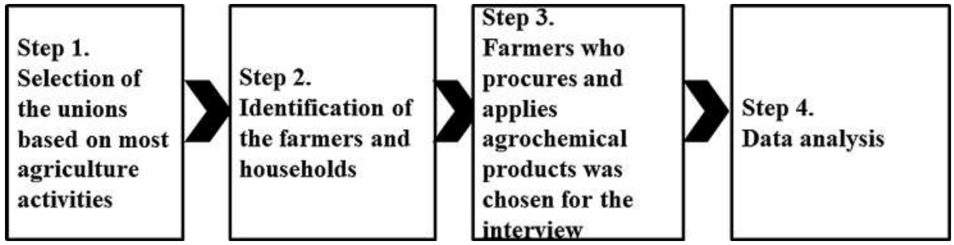

Fig. 2. Sampling Scheme of the farmers for interview.

hesitation of the participants or possibilities of being bias. All the interviewees remained anonymous.

2.4. Data analysis

The raw data from the questionnaire survey were reviewed after the interviews and the answers to each question were coded and entered in Excel. The differences between the two regions were analyzed by Chi-square (χ^2) tests ($p < 0.05$). A canonical correspondence analysis (CCA) proposed by Ter Braak (1986) which is an eigenvector technique based on multivariate analysis originally developed to relate community composition to known variation in environment. In this study, CCA was applied to determine the association between the contextual information of the interviewees (farmers) and their level of responsiveness towards pesticide uses and their dangers towards health and environment, to the same data set obtained from questionnaire survey using Past 3.0 (Hammer et al., 2001).

3. Results and discussion

3.1. Social and demographic characteristics

In this study, a total of 150 farmers from both Upazilas were interviewed. Majority of the individuals were male and belonging to the age group of 46–55 followed by 36–45 age groups in both study areas (Table 2). Significant differences were observed in the educational status in the two study areas ($\chi^2 = 34.383$ at $p < 0.05$). Although 23% farmers of SU and 42% farmers of MU informed to have the primary education of fewer than four years, yet they had very poor reading skills and can be classified as "semi-illiterate". In addition, 2% farmers and 16% farmers from SU and MU respectively were found to be illiterate. Illiteracy rate was higher in MU being a completely rural setting. Nevertheless, 24% of farmers reported completing primary education compared to the 49% of SU.

Socioeconomic variables, including several people per farmers' family, farm ownership, experience in farming and total farm income varied (Table 3). A significant variation was observed in family structure in both study areas ($\chi^2 = 27.71$ at $p < 0.05$) with 1–5 members family comprising 63% and 26% in SU and MU, respectively. On the other hand, a family comprising 6–10 members were found to be 37% and 74%, respectively, in SU and MU. Farm ownership comprised 47% and 34%, respectively, among the farmers of SU and MU. Agricultural laborers comprised 24% in MU compared to the 12% of SU. Experiences in farming years also varied with most reported years from both study areas were 10 to 15 years. Farm income significantly varied in both areas ($\chi^2 = 18.05$ at $p < 0.05$). 43% of the farmers of SU reported income within 5–15000 BDT$^+$ from the farm, while 58% of the farmers from MU reported farm income < 5000 BDT. The agricultural products produced in both the area have an almost the same principal market. 48% of farmers in both study area sell their products to intermediaries and others while 39% in SU 34% in MU sold their products directly to the local market. Self-consumption of the products was also reported from both area with 13% and 18% respectively.

3.2. Farmers' knowledge and behaviour towards pesticide application

Although the behavior is influenced by a highly complex set of factors which are by no means well understood or consistent for different situations, the behavior is partly shaped by attitudes toward the environment, which in turn are influenced by knowledge and information (Lichtenberg and Zimmerman, 1999). We analyzed the farmers' behavior of pesticide application methods with a set of questions which included prevailing types of pesticides application practices, farmers' knowledge source on pesticide, method of pesticide application, application by self or

Table 2
Background information of interviewee in two study areas.

Category	Variables	SU, Dhaka		MU, Barisal	
Respondent		N = 100	%	N = 50	%
Gender	Male	92	92	39	78
	Female	08	08	11	22
Age	≤25	12	12	5	10
	26–35	19	19	8	16
	36–45	25	25	13	26
	46–55	35	35	17	34
	55+	9	9	7	14
Educational level $\chi^2 = 34.383^{**}$	Illiterate	2	2	8	16
	≤Primary	23	23	21	42
	Class 5 to 10	49	49	12	24
	S.S.C. passed	22	22	3	6
	≥H.S.C. passed	4	4	1	2

** Significant at $p < 0.05$.

Table 3
Financial information of interviewees in two study areas.

Category	Variables	SU, Dhaka		MU, Barisal	
Respondent		N = 100	%	Respondent	%
Family member $\chi^2 = 27.71^{**}$	1–5 members	63	63	13	26
	6–10 members	37	37	37	74
Farm ownership $\chi^2 = 9.06$	own farm	47	47	17	34
	Rental arrangement	16	16	8	16
	Sharecropper	11	11	7	14
	Agricultural labour	12	12	12	24
	lease from government	9	9	2	4
	others	5	5	4	8
Experience in farming $\chi^2 = 4.90$	<5 years	20	20	5	10
	5–10 years	27	27	14	28
	10–15 years	35	35	20	40
	15–20 years	12	12	7	14
	>20 years	6	6	4	8
Farmers monthly income in (BDT[+]) from farm $\chi^2 = 18.052^{**}$	>30,000	7	7	2	4
	15–30000	21	21	7	14
	5–15000	43	43	12	24
	<5000	29	29	29	58
	>30,000	7	7	2	4
Principal market of the product	Self-consumption	13	13	9	18
	Local market	39	39	17	34
	Intermediaries and others	48	48	24	48

[+] 1 US$=78.46 BDT.
[**] Significant at $p < 0.05$.

Table 4
Farmers' knowledge and behavior towards pesticide application.

Questions	Variables	SU, Dhaka		MU, Barisal	
		N = 100	%	N = 50	%
1. Prevailing types of pesticides application practices					
$\chi^2 = 3.2287$	Chemical	60	60	24	48
	Organic	19	19	13	26
	IPM/Cultural	13	13	9	18
	Others	8	8	4	8
2. Farmers' knowledge source on pesticide					
$\chi^2 = 19.679^{**}$	Pesticide dealer	10	10	14	28
	Label	14	14	3	6
	Extension officer	16	16	11	22
	Other farmers	25	25	18	36
	Radio/television/leaflet/ advertise newspaper	35	35	9	18
3. Farmers' method of pesticide application					
$\chi^2 = 4.1157$	spray	60	60	24	48
	granular	19	19	13	26
	liquid	30	30	9	18
	other	8	8	4	8
4. Application by					
$\chi^2 = 28.405^{**}$	Self	41	41	39	78
	Applicator	59	59	11	22
5. Kind of protective covering					
$\chi^2 = 22.019^{**}$	No cover	17	17	24	48
	Partially	69	69	21	42
	Fully	14	14	5	10
6. Precautions just after spraying					
$\chi^2 = 23.711^{**}$	Change dress	49	49	13	26
	Washed hand with soap	41	41	18	36
	Took bathe	10	10	19	38
7. Methods of discarding empty pesticides pots					
$\chi^2 = 3.33$	Discarded into the nearby area	7	7	2	4
	Throw into the nearby water body	39	39	21	42
	Buried into the earth	18	18	13	26
	Burned	5	5	2	4
	Taking home for further use	31	31	12	24

[**]and [*] significant difference at $p < 0.05$ and $p < 0.01$.

others, kind of protective covering farmers used for precautions, and the methods of discarding empty pesticides pots (Table 4). In both, the study areas the prevailing type of pest management practice were chemical methods by utilizing pesticides 60% and 48%, respectively. The previous report suggests that most farmers in Bangladesh rely on their own experiences and on pesticide sellers to help select the appropriate pesticide (Chowdhury et al., 2013a).

Significant differences were observed between the farmers of both Upazilas regarding information source of pesticides ($\chi^2 = 19.679$ at $p < 0.05$). Most farmers, 35% of SU reported radio/ television/leaflet/advertise/newspaper/internet as a primary source of information and awareness compared to the 18% of MU. Nevertheless, 36% of farmers from MU reported other farmers as their primary sources of information followed by pesticide dealers (28%). The pesticide label is one of the most important sources of pesticide information. From the question of the farmers' knowledge source of pesticide, it is observed that only 14% and 3% farmers from SU and MU, respectively could get information from reading labels. In many cases, the inability to understand the information displayed led to the adoption of practices which increased exposure, risks to human health and environmental contamination (Waichman et al., 2007). There were no significant differences between the two study areas regarding pesticide application methods. Both the regions reported spraying was the major method of application 60% and 48%, respectively. In the question of the application by self or others significant differences were observed between the two study areas ($\chi^2 = 28.405$ at $p < 0.05$). 59% of the farmers in SU utilized applicators for pesticide application while 78% in MU self -applied pesticides. The reason behind this was to reduce the cost of farming.

Protective measures during and after pesticide application are considered effective means of reducing the risks to farmers (Yang et al., 2014). During the interview, the farmers reported the use of "gamcha" a piece of cloth as personal protective equipment (PPE) which they don't understand from both areas. Uses of personal PPE which include, face mask, shoes, gloves and body covering were absent. In most cases, farmers were found to be barefooted. However, significant differences were also observed protective covering by farmers also ($\chi^2 = 22.019$ at $p < 0.05$). The dominant practice of farmers in SU was using partial cover 69% while in MU 48% of farmers reported no use of covering at all. Only 14% and 5% of farmers reported the full use of covers in SU and MU, respectively. A similar situation is found from the previous report. Even when a farmer is aware of the risks associated with pesticide uses and wants to wear protective gear, he does not have access to it: protective clothing is often very expensive and not appropriate to the climatic conditions (Viviana Waichman et al., 2007). Bondori et al., (2018) reported that a low use of personal protective equipment was reported by almost half of the farmers in the study of Moghan Plain region, Iran. Long-sleeved shirt was the most common protective item used by the farmers surveyed and Personal protective equipment use increased with farmers' negative attitudes toward pesticides.

Immediately after finished spraying pesticides, there were also significant differences seen in the behavior of farmers of both Upazila ($\chi^2 = 23.711$ at $p < 0.05$). Dominant practice method reported by the farmers of SU was change dress 49%, wash hand with soap 41% and take bath 10%, whereas farmers of MU reported to take bath 38%, wash hands with soap 36% and change dresses 26%. A previous study from Oman also reported occupational and phytosanitary practices among the pesticide workers were poor, as most of the workers (59.5%) did not wash their hands after pesticide application, many (43.2%) did not shower and some (20.3%) did not change their clothes (Esechie and Ibitayo, 2011)

There were no significant differences observed between the farmers of both Upazilas regarding the methods of storing, preparing and discarding empty pesticides pots. Pesticides were kept mostly in the farmer's own house in storage areas together with agricultural tools under cot or on the shelf with another household stuff. This dangerous practice of storing inside the house with other household stuff may increase the vulnerability of unintentional pesticide poisoning among children and other household members of the family. Similar results were also found from the previous study in Oman where, methods of handling of partly used pesticides by the applicators (workers from south Asia including Bangladesh) were questionable, with 81.1% storing them in other rooms in the house and 14.9% storing them in their bedrooms. Personal protective equipment (PPE) such as nose mask, overall and eye goggles were hardly used during pesticide application (Esechie and Ibitayo, 2011).

Regarding the preparation of pesticides area, most of the farmers replied in the agricultural fields in both areas. In most cases, the rice fields were near rivers and connected to rivers by canals. The pesticide was applied manually with hydraulic sprayers. 39% farmers and 42% farmers of the SU and MU, respectively, reported throwing empty pots into the nearby water body followed by taking home for father uses by 31% and 24% of the farmers, respectively. Other discarding methods reported by farmers were buried into the earth practiced by 18% and 26% farmers of the SU and MU. Moreover, few farmers also reported discarding pots into nearby area and burning of the containers. Since there is a lack of policy guidelines regarding preparation, storing and disposal of pesticide containers for the end-user like farmers in the legislation, of "The Pesticides (Amendment) Act, 2009" and also in "Environmental Conservation Amendment Act 2010" the indiscriminate disposal of pesticide and its containers are posing a serious threat to the health of farmers, their family, and the environment.

3.3. Farmers' awareness towards the danger of pesticides to human health

Farmers use a wide range of pesticides to prevent crop loss from pest attack (Rahman, 2003). 13 insecticides with 25 different trade names were found to be used by the farmers during the study period (Table 5). Among the insecticides two belonged to the Class Ib, 8 belonged to the Class II, 2 belonged to Class III and 1 belonged to class U. Most of the insecticides were used for rice insects and few for egg-plants and other crops like potato, onion, and cucumbers. No significant differences were observed between the farmers regarding health problems felt after spraying in two study areas. Organophosphorus (OP) and pyrethroid (PYR) compounds are the most widely used insecticides. OPs and PYRs are developmental neurotoxicants (Babina et al., 2012). Chlorpyrifos [O,O-diethyl O-(3,5,6-trichloro-2-pyridinyl)phosphorothioate] (CP) is one of the most commonly used agricultural organophosphorus (OP) insecticides, which controls a broad spectrum of insects. Despite the regulatory decision of the United States to eliminate its residential use, CP continues to be widely used in agriculture (Harishankar et al., 2012) of Bangladesh and its registration was not canceled by the controlling organization Department of Agricultural Extension (DAE) of GOB.

A substantial portion of the farmers (35% in SU and 32% in MU) suffered from headache problem (Table 6). Pesticide-related health symptoms that were associated with pesticides use included skin problems and neurological system disturbances (Ngowi et al., 2007). A previous report from Ghana explained weakness and headache as a frequent symptom of pesticide exposure and that 97% of exposed participants had experienced symptoms attributable to it (Ntow et al., 2009). In addition, a report from Oman mentioned health symptoms due to pesticide exposure were skin irritation (70.3%), burning sensation (39.2%), headache (33.8%), vomiting (29.7%) and salivation (21.6%) (Esechie and Ibitayo,

Table 5
List of pesticide used in the study areas during interviews with the farmers.

Active Ingredients name	Commercial name	WHO hazard Category 2009*	Type**	Application
Carbofuran	Agrifuran 5G	Class Ib	C	Stem borer
	Biesterin 5G			Leaf hopper
	Sunfuran 5G			Stem borer, Defoliator
	Furacarb 3G			Stem borer, Grass hopper
	Carabofuran 3G			Rice bug
Lambada Cyhalothrin	Karate 2.5 EC	Class II	PY	Plant hopper, Green leaf hopper
	Fighter 2.5 EC			
Cypermethrin	Caught 10 EC	Class II	PY	Fruit and shoot borer Green leaf hopper, Rice hispa
Diazinon	Diazinon 60EC	Class II	OP	Green leafhopper, stem borer
	Diazon 60EC			
	Sudin 10G			
Fenitrothion	Sumithion 98 ULV	Class II	OP	Leafroller, rice hispa
	Sumithion 50 EC			
Cartap	Mono Padan 50 SP	Class II	C	Planthopper, Green leafhopper
	Suntap 50 SP			
Edifenphos	Edifen 50 EC	Class Ib	OP	Rice blast, blight
Carbendazim	Knowin 50 WP	Class U	C	Sheath blight
Propiconazole	Tilt 250 EC	Class II	OP	Sheath blight of rice
Mancozeb	Indofil M 45	Class II	OP	Potato late blight, purple blotch of onion
Chlorpyrifos	Dursban 20 EC	Class II	OC	Rice bug, hispa, mosquitoes
	Classic 20 EC			
Carbaryl	Sevin 85 SP	Class III	C	Leafroller, Caseworm, GLH
	Vitabryl 85 WP			Thrips, Hispa & Rice bug, hairy caterpillar
Malathion	Razthion 57 EC	Class III	OP	Leafroller, GLH, Thrips, Hispa
	Semtox 57 EC			Casewarm, Rice bug, aphids

* Ia = Extremely hazardous, Ib = Highly Hazardous, II = moderately hazardous; III = Slightly hazardous; U = Unlikely to present acute hazard in normal use; O = Obsolete pesticide.
** OP = Organophosphorus compound, C = Carbamate; PY = Pyrethroid, OC = Organochlorine.

Table 6
Farmer's experience health hazards and how they deal with it.

Questions	Variables	SU, Dhaka		MU, Barisal	
		N = 100	%	N = 50	%
Farmers experience with Health problem perception during pesticide application					
$\chi^2 = 5.6128$	A headache	35	35	12	24
	Vomiting	9	9	3	6
	Unconsciousness	5	5	2	4
	Stomach ache	4	4	3	6
	Weakness	17	17	13	26
	Skin problem	23	23	14	28
	Eye effect	7	7	3	6
Farmers' addiction					
$\chi^2 = 9.293^{**}$	Smoker	42	42	31	62
	Alcoholic	2	2	0	0
	Betel leaf and other	56	56	19	38
Effects of addiction during spraying					
$\chi^2 = 1.4118$	Avoid consuming	12	12	9	18
	Continue consuming	88	88	41	82
Visit health centers or doctors					
$\chi^2 = 16.862^{**}$	Yes	67	67	19	38
	No	33	33	31	62

**and * significant difference at $p < 0.05$ and $p < 0.01$.

2011). Among other problems, general weakness was mentioned by 17% farmers in SU and 16% farmers in MU. Some farmers also reported vomiting, feelings of unconsciousness, stomach ache, weakness, skin problem and effects on eyes (Table 6).

However, the true extent of the problem is hard to determine for a variety of reasons. First, farmers with mild pesticide poisoning often do not report because treatment services are costly, inaccessible, or fear that drawing attention to themselves may result in the loss of employment opportunities. Second, health-care professionals in rural areas often fail to correctly diagnose poisoning, as many of the related symptoms are quite general in nature or mimic other common health problems (e.g., headaches, dizziness, vomiting) (FAO, 2001). Most of the farmers reported two kinds of addiction in both areas smoking 42% and 62% for SU and MU, respectively, followed by betel leaf and others 56% and 38%, respectively. In addition to that, when we asked what they do during spraying if they feel the urge to smoke or chew betel leaf no significant differences were observed between the responses. 88% of farmers and 82% farmers of SU and MU, respectively, were found to consume something (Betel leaf, tobacco or smoke) during pesticide application. Significant differences were observed in the response to the question of whether they visit health centers or doctors ($\chi^2 = 16.862^{**}$ at $p < 0.05$). 67% farmers of SU compared to the 38% farmers of MU visits a doctor in case they felt problems from spraying pesticides. In a previous study from south-east Asia most farmers were aware of the adverse health effects associated with pesticide use and covered body parts while spraying, but also considered pesticides to be highly effective and indispensable farm inputs (Schreinemachers et al., 2017).

3.4. Farmers' awareness towards environmental risks from pesticide

The investigation of the perception of pesticide uses danger to the environment provided remarkable responses from the farmers of these selected regions (Table 7). Farmers in the study area reported pesticide application is used to increase crop production ($\chi^2 = 6.4379$ at $p < 0.01$) in an unfavorable condition like the insect, disease, and weed. Most of the farmers in the study area (87% in SU and 66% in MU) believed that pesticide application had decreased soil fertility ($\chi^2 = 12.265$ at $p < 0.05$). About 83% farmers of SU and 24% farmers of MU reported that surface water pollution occurred due to pesticide application ($\chi^2 = 69.963$ at $p < 0.05$). Here, biases may occur in the perception of water pollution in SU. As SU has many textile industries, effluents containing colored dyes contaminating water resources including rivers, canals and nearby crop fields which is harmful to aquatic life and decreasing productivity of the lands. Nevertheless, the pesticide is one of the most important sources of water contamination in agricultural countries like Bangladesh. Farmers also perceived that the excessive use of pesticides had destroyed many beneficial pest or predator insects ($\chi^2 = 73.509$ at $p < 0.05$) and decreased pest attack and weeds overtimes (Table 7).

A significant difference of responses was observed regarding the last question whether the farmers' felt environmental quality was changing due to pesticide uses and whether they demand improvement ($\chi^2 = 38.32$ at $p < 0.05$). 67% farmers of SU and 26% farmers of MU responded that Environmental quality was deteriorating due to pesticide uses and they expect and improvement of the environment. In addition, 14% farmers and 22% farmers of SU and MU, the environment seemed unchanged from pesticide uses. Approximately 17% farmers of SU and 34% farmers of MU further responded that environment change was not a concern to the farmers. However, small percentages of farmers (2% of the farmers in SU and 18% of MU) reported environment had no relationship with agriculture pesticide uses. Farmers were relatively aware of some pesticide hazards on humans and non-target organisms, but knowledge of other pesticide hazards (e.g. water contamination) was low (Bondori et al., 2018).

Canonical correspondence analysis (CCA) was performed (see Table 8) on the basis of backgrounds of the interviewee (Table 2 and 3) such as education, age, farming experiences, farm ownership and farm income and revealed perception of pesticide risks towards the environment and the health of farmers (Fig. 3). CCA ordinating the first two canonical axes direction and the green projecting lines representing the different background variables. The direction of the green line represents the correlation between each variable and the canonical axes and each other, whereas the length of the line indicates the status of variable and shows positive or negative correlations with axes and the perception–background relationship (Yang et al., 2014).

The first two canonical axes represent 94.4% (First canonical axes represent 72.77% and second canonical axes represent 21.63%) variation among the background information of the farmers to their perception of knowledge towards pesticide risk of their health and environment. The location of the five variables being far from the center indicates that all have a similar contribution towards understanding the danger of pesticides towards health and environment. The opposite directions of the two variables education and farm ownership indicated that these two variables had opposite influences on the perception of the danger of pesticides to human health and the environment (Fig. 3). In addition, farming experience, farm income, and age were significant factors in understanding the danger of pesticides towards human health and the environment.

Previously a case study reported from China using CCA indicated educational level and age differed between two regions and contributed greatly to the risks from pesticide uses (Yang et al., 2014). Wang et al., (2017) reported about gender differences

Table 7
Farmers' perceptions about the effect of pesticide application on agriculture and environment.

Questions	Variables	SU, Dhaka		MU, Barisal	
		N = 100	%	N = 50	%
Increasing crop output					
$\chi^2 = 6.4379^{*}$	Yes	95	95	42	84
	No	5	5	8	16
Decreasing soil fertility					
$\chi^2 = 12.265^{**}$	Yes	87	87	33	66
	No	13	13	17	34
Water pollution					
$\chi^2 = 69.963^{**}$	Yes	83	83	12	24
	No	17	17	38	76
Decline insect predators					
$\chi^2 = 73.509^{**}$	Yes	91	8	16	32
	No	9	17	34	68
Increase in incidence of pest /insect attack over time					
$\chi^2 = 1.87$	Yes	19	19	6	12
	No	81	81	44	88
More weeds infestation					
$\chi^2 = 0.029$	Yes	21	21	11	22
	No	79	79	39	78
Do you feel the environmental quality is changing due to pesticide uses and do you demand for improvement?					
$\chi^2 = 38.32^{**}$	Environmental quality deteriorating and expect improvement	67	67	13	26
	The environment seems unchanged from pesticide uses	14	14	11	22
	Environment change is not a concern to a farmer from pesticide uses	17	17	17	34
	The environment has no relation to agriculture pesticide uses	2	2	9	18

** and * significant difference at $p < 0.05$ and $p < 0.01$.

Table 8
CCA biplot scores of pesticide risk perception and backgrounds of interviewee farmers.

	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5
Q1	−1.42755	1.95304	−1.45946	−1.97744	−1.25044
Q2	−0.22101	−0.92899	1.1243	0.413471	−1.17468
Q3	−0.0693	−0.50072	−1.78194	1.98188	−1.16504
Q4	1.29363	−0.52154	0.309338	−0.34936	0.27317
Q5	−0.32403	−0.47333	0.963507	−1.98332	−0.72983
Q6	1.73511	1.90515	0.327238	0.396128	−1.59565
Q7	1.40142	1.98505	−0.36085	0.733099	−0.09109
Q8	−1.21389	2.00265	2.2705	1.35163	1.45049
Q9	−1.16324	−0.57081	0.052588	0.390359	−0.05258
Q10	−0.71968	−0.44311	−0.2077	0.160149	0.399133
Q11	−0.17759	−0.0527	−1.13064	−0.31187	1.72617
Q12	1.29189	−0.40351	0.004422	−0.4449	0.663399
SU	−0.58035	0.176264	0.027482	−0.10277	0.198034
SU	0.522717	0.042914	0.001253	0.083333	−0.31642
SU	0.072445	−0.07261	0.029036	0.047188	0.118368
SU	0.013653	−0.35439	0.005769	−0.1269	0.086575
SU	0.0696	0.085881	−0.00013	0.024648	−0.03862
SU	−0.04379	−0.06203	0.011276	−0.02291	0.002846
SU	0.053476	0.075747	−0.01377	0.027974	−0.00348
MU	−0.51263	−0.09089	−0.05335	0.094866	−0.23663
MU	0.409773	0.180115	−0.11957	−0.0589	0.073839
MU	0.037115	0.078236	0.169164	−0.05074	0.078099
MU	−0.04731	−0.28559	−0.04031	0.084124	0.050177
MU	0.024426	0.02984	0.000376	0.008372	−0.01436
MU	−0.05363	−0.07597	0.01381	−0.02806	0.003486
MU	0.061928	0.087718	−0.01595	0.032395	−0.00403
V1 Education	0.405096	0.003818	−0.14017	−0.47093	0.20214
V2 Age	0.230685	−0.7147	0.230455	−0.15314	0.316789
V3 Farming experience	0.34667	0.301843	0.451104	−0.12139	0.220308
V4 Farm ownership	−0.64268	0.156649	−0.12856	−0.01885	0.077275
V5 Farm income	0.28819	−0.57175	0.091175	0.278365	0.253843

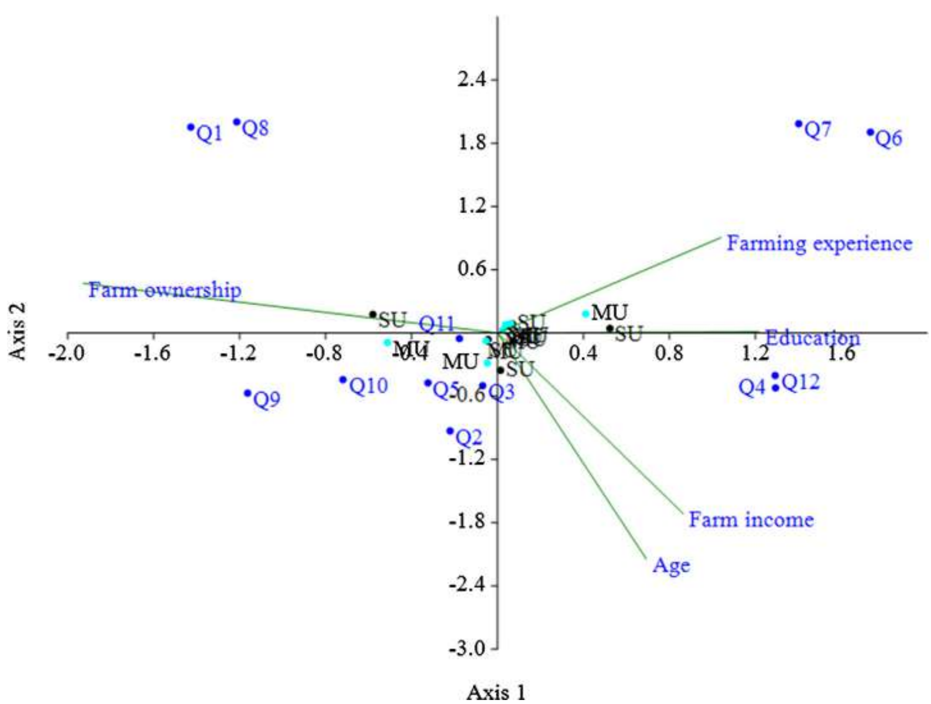

Fig. 3. Biplot of pesticide risk perception and backgrounds of interviewee farmers under CCA as constructed according to data collected. Q1 represents application practices, Q2 self-application, Q3 Kind of protection practiced, Q4 Precaution during spraying, Q4 method of pot discarding, Q5 Precaution after spraying, Q6 Method of discarding pesticide, Q7 Experience with illness, Q8 Changes in environmental quality, Q9 Increase crop output, Q10 Decrease soil fertility, Q11 decline of predator insect, Q12increase of harmful insects. Green line represents the distance of variables from the center.

in pesticide use knowledge, risk awareness, and practices among Chinese farmers by using CCA. Male farmers had a better knowledge of pesticide use and greater awareness of associated health risks. More men than women used pesticides and disposed of the pesticide containers correctly, but fewer men applied protective measures or behaviors when using pesticides. Canonical correspondence analysis indicated that participation in farmer professional cooperatives differed by gender and contributed greatly to the protective behaviors of farmers ($p < 0.05$). Among the socio-economic variables, land ownership and agricultural credit are positively related to pesticide usage. Pesticide use is higher in underdeveloped regions. Sharp regional variations also exist in pesticide usage (Rahman, 2003) in Bangladesh. There was no significant relationship either between age and total importance of the safety measures or between age and total competence on the safety measures due to the impacts of other mediating variables (Hashemi et al., 2012).

3.5. Recommendation for farmers' Health, Safety, and environmental improvement

Since farmers often must develop, plan and solve their safety problems on their own, the support of fellow farmers and arenas for safety development could be beneficial (Stave et al., 2007). The level of perceived the danger of pesticides to the health and environment is vital for farmers as an important stakeholder to reduce environmental pollution and health risks of the farmers and their family. Monitoring the educational level of farmers and retailers on pesticide use would be useful to assess the appropriateness of the information for reducing or/and avoiding the risks from pesticides in rural regions (Yang et al., 2014). The most important predictors for farmers' perceived importance and competence were the experience of pesticide-related adverse health effects in the past and the formal education, respectively (Hashemi et al., 2012). Even though the present study reported that all activities related to pesticide handling were performed exclusively by men, women and children of the farmers' family are at an equal risks due to storing pesticide inside houses, preparation of pesticides in the yards in front of children and washing of clothes and equipment of the farmers (Fig. 4).

Ensuring the safe use of pesticides is a real challenge for regulating authorities and Pesticide policy is criticized to compromise environmental and human health effects even for developed regions like European Union (Storck et al., 2017). Control programs for pesticide residues in the developing countries are often limited due to lack of resources and rigorous legislation is not in place (Chen et al., 2011). Usage of pesticides in Bangladesh agriculture is regulated by "The Pesticides (Amendment) Act, 2009". However, the law failed to address many overlooked issues and enforcement is almost absent. Besides, that of gaps in the current act was found towards empty pesticide containers and expired pesticide waste disposal. Other than this, there is a problem of understanding labels by the farmers. It is clearly stated in "The pesticide amendment act 2009" that the manufacturer, formulator or distributor shall provide wholesale and retail dealers with leaflet of every pesticide which shall be affixed or attached to the package or repacking containing the following details on (a) the plant pests for which the pesticide is to be applied, the adequate direction including the manner in which the pesticide is to be used at the time of application; (b) particulars regarding chemicals harmful to human beings, animals and wildlife; (c) warning and cautionary statements including the symptoms of poisoning, suitable and adequate safety measure and emergency first aid treatment, where necessary; (d) caution regarding storage; (e) instructions concerning the decontamination or safe disposal of used containers; (f) statement showing the antidote for the poison shall be included in the leaflet and the label; (g) if the pesticide is irritating to the skin, nose, throat or eyes, a statement shall be included to that effect. Moreover, it also stated about labeling manners that "The label shall contain in a prominent place and occupying not less than the one-sixteenth of the total area of the face of the label, and square set at an angle of 45° (diamond shape)". The dimension of the said square shall

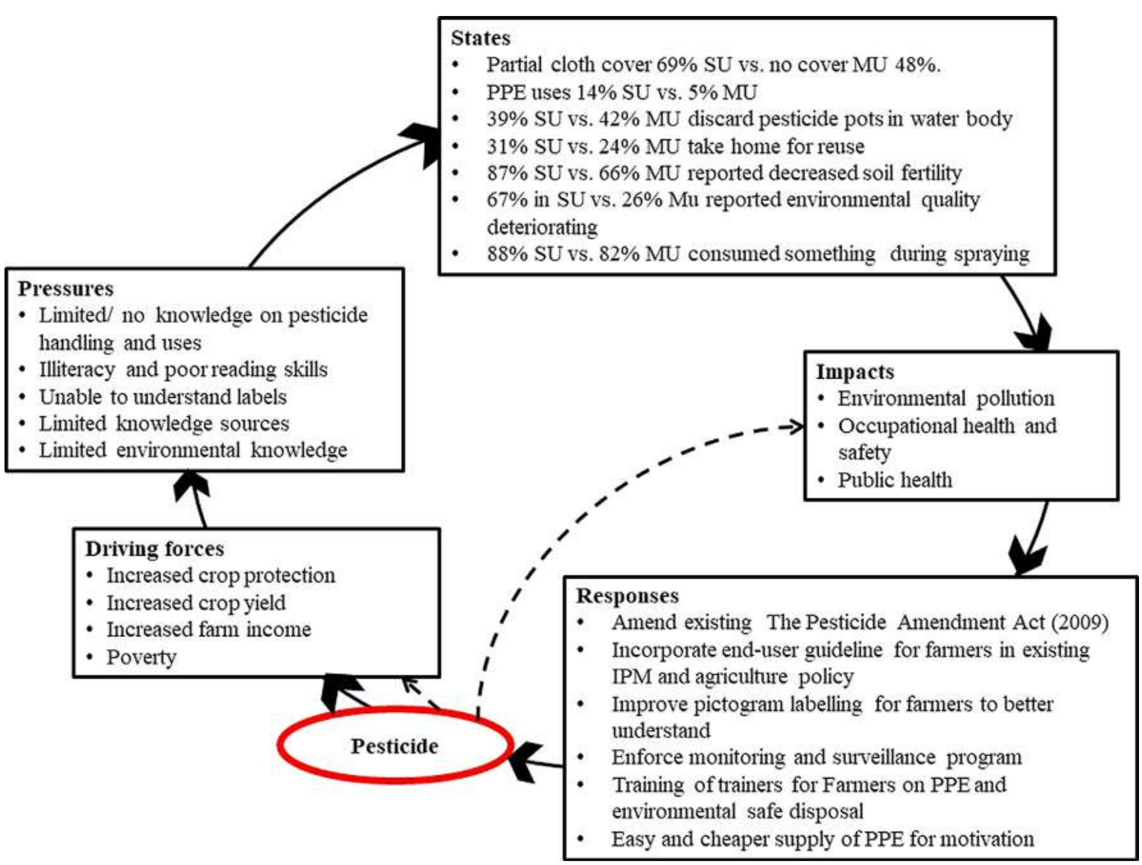

Fig. 4. Drivers, Pressures, State, Impact, Response (DPSIR) model for pesticide exposures towards health and environmental hazard in Bangladesh.

depend on the size of the package on which the label is to be fixed. The said square shall be divided by horizontal lines into two equal parts. The upper part of the square shall contain the symbol and warning statement (i) pesticide belonging to category 1 (highly toxic) contain a symbol of a skull and crossbones and the word "POISON" printed in red and the words "KEEP OUT OF THE REACH OF CHILDREN" shall appear on the label at suitable place outside the square; (ii) pesticides in category II (moderately toxic) shall bear the word "Poison" "DANGER" and the statement "KEEP OUT OF THE REACH OF CHILDREN"; (ii) pesticides in category III (slightly toxic) shall bear the word "Poison" "CAUTION" and the statement "KEEP OUT OF THE REACH OF CHILDREN" shall appear on the label at suitable place outside the square. The label, leaflets affixed or attached to the package or repacking containing pesticides shall be printed in Bengali and must not bear any unwarranted claims for the safety, the efficacy of the pesticide or its ingredients like "safe", "non-injurious", "non-poisonous", etc.

Dugger-Webster and Le Prevost (2018) mentioned pesticide label format loosely fall within four categories aligning with:

1. Food and Agriculture Organization (FAO) / World Health Organization (WHO) (FAO/WHO) International Code of Conduct on Pesticide Management – Guidelines on Good Labeling Practice for Pesticides
2. Globally Harmonized System of Classification and Labelling of Chemicals (GHS);
3. Country-specific regulations (e.g., United States [US]) independent of FAO, WHO, or GHS criteria and
4. Alternatively, some countries use a hybrid of FAO/WHO, GHS, and country-specific criteria and regulation.

However, information displayed on product labels was not effective in promoting protective and safety measures. Farmers do not read the labels, reporting that the fonts are too small and that the instructions are too long and in overly technical language (Waichman et al., 2007) and pictograms; complex and not consistent (Dugger-Webster and Le Prevost, 2018). Pesticide users, therefore, need to be empowered and must be partners in the development of new label and pictogram formats, regulations, and training. Training and education programs need to be dynamic such that they can be understood by the various user types (e.g., professional pesticide applicators, pesticide users with little education, pesticide users who cannot read) and their needs based on the pesticides and use practices (Dugger-Webster and Le Prevost, 2018).

Higher average pesticide use does not necessarily imply higher pesticide risk because pesticide risk is a function of toxicity and exposure as well as dose. Pesticide exposure depends on how farmers handle pesticides such as wearing protective gear during spraying and following proper sanitation methods after spraying. If the training program can be shown to have improved handling practices, then the pesticide risk might be lower even if application rates are higher (Schreinemachers et al., 2016). The common use of pesticide is a major challenge in trying to accomplish sustainable agriculture. Farming systems based on IPM technologies can reduce the use of pesticides without causing harm to the yield (Kabir and Rainis, 2014). Pesticide risk assessment for farmers is based on the knowledge of the mutual relationships between different variables which influence the levels of exposure ("exposure determinants") in the four typical working phases of pesticide application in agriculture, which are (a) mixing and loading of products, (b) application on the crops, (c) re-entry in the treated field and (d) maintenance and cleaning of PPE (Rubino et al., 2012). Applying toxic granules in standing water – the typical practice for applying pesticides to rice crops in Bangladesh is not recommended. Moreover, when using sprays, farmers tend to walk back through areas that have already received insecticide. Both practices are harmful to farmers' health (Robinson et al., 2007).

Moreover, as a response an end-user guideline for farmers should be provided mandatorily on the pesticide usage, safety instruction, preparation, application and disposal, washing of equipment provided in pictograms, fonts easily readable and language easily perceived by farmers. Donor funding programs like Farmers' Field schools (FFS) of integrated pest management (IPM) can have an important intervention in this regard if the guidelines could be incorporated with training program specifically designed on pesticide usage. Since farmers were not well informed about correct application practices and safe handling of pesticides, it is an urgent need to introduce training programs on pesticide uses for farmers and applicators in the study areas with the aim of conveying more specific information on health hazards from pesticides. This will ultimately prevent farmers from further harming their health and environment. For farmers' and applicators' training in pesticide handling, it is important to emphasize the requirement to involve stakeholder groups and other apposite entities in the policy-making process. A framework to implement Farmers' and applicators' training on handling pesticides and evaluation of indicators of efficacy proposed in Fig. 5.

4. Conclusions

Pesticides pollution and occupational health problem of farmers is a serious problem not only for Bangladesh but also for the other developing countries. The study indicated that the farmers of Bangladesh irrespective of a rural setting and peri-urban setting were exposed to the hazards of pesticides and other agrochemicals and at the same time causing serious environmental hazards. The problems associated with pesticide pollution of environment and their own health and safety aspects were: (a) economically underdeveloped, (b) illiteracy to semi-illiteracy with lack of reading skills of labels and preparation procedure, (c) Lack of extension officers to communicate (d) lack of knowledge of pesticide hazards and how to use about personal protection equipment (PPE), (e) often older age and not interested to adopt new methods on personal safety and (f) not interested to use PPE in hot humid weather. Promotion of using PPE through education and dissemination can intervene in this problem. Farmers should be educated and trained through farmers' field school (FFS) or community school regarding the use of PPE and safe ways of pesticide storage, application methods, preparation, and disposal. Since most of the farmers are illiterate or semi-illiterate with no reading skills, pictograms should be developed about the environmental hazard from pesticides and human health safety through the uses of pictograms. Financial support should be provided for research on alternative techniques such as organic farming, integrated pest management (IPM) strategies and good agricultural practice (GAP) to promote sustainable agriculture. Governmental support should be strengthened in restructuring the production system with respect to environmental health risks, enforcing better training for public health workers, agricultural extension workers regarding the safe use of pesticides and its management and amend current legislation. One of the main obstacles to effective pesticide regulation in Bangladesh is the lack of a uniform system designed specifically for pesticide management at the end-user level, i.e., farmers' and retailers' level. This discrepancy has debilitated the enforcement of existing regulations, resulting in misuse/overuse of pesticides, and consequently, increased environmental contamination and human exposure. The government of Bangladesh should amend "The Pesticides (Amendment) Act, 2009" in association with "Environmental Conservation Act Amendment 2010" and incorporate a special section for the end-user of pesticides like farmers mentioning proper methods

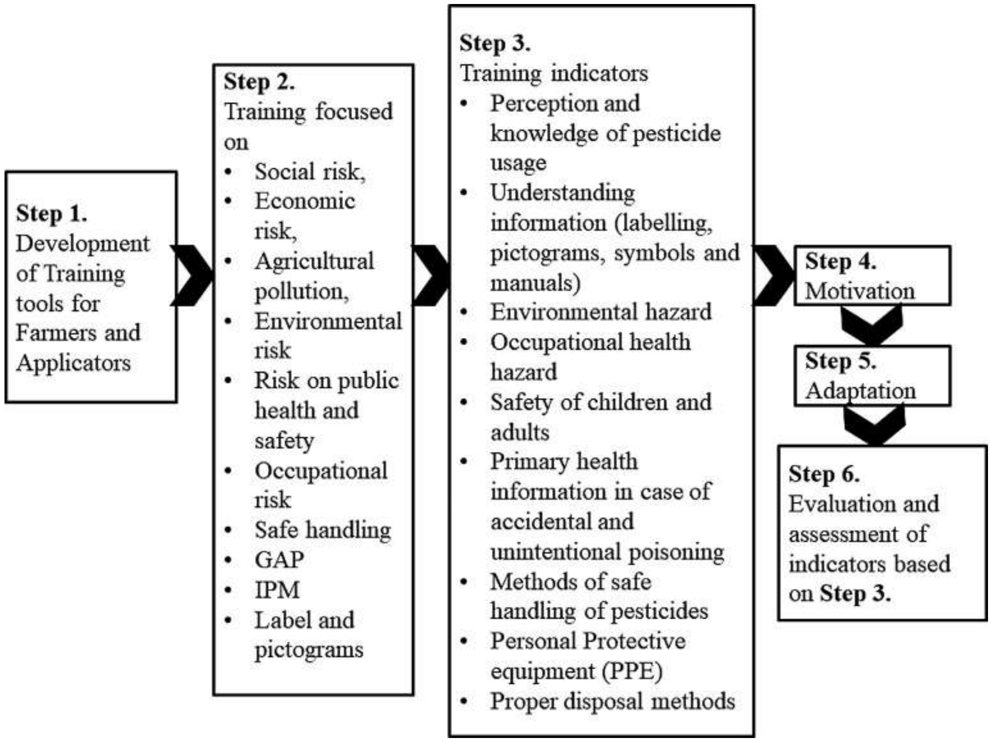

Fig. 5. Conceptual model of the major steps of "Development of Training tools for Farmers and Applicators"

of pesticide storing, preparation, application, and container disposal to protect public health and environment.

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Conflicts of Interest

All authors have read the manuscript and agreed for submission with no conflict of interests.

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