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Article *in* Environment Systems and Decisions · September 2017

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Environ Syst Decis
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REVIEW

Sustainable pesticide governance in Bangladesh: socio-economic and legal status interlinking environment, occupational health and food safety

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Abstract Pesticides, regardless of their known toxic impacts to human health and environment, are widely used in the rapid growing agricultural sectors of developing countries. As an agricultural country with small lands and 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, 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. This, in turn, is threatening the livelihood and health of the farmers, food safety and consumer health. This paper reviews the antiquity of the status of pesticide consumption, evolution and drawbacks of pesticide in the context of existing socio-economic position of Bangladesh. A consolidated uniform system is lacking to project pesticide management in the country. Existing legal policy, rules and regulations in the context of international agreements regarding pesticide management have been reviewed and suggested for further amendment. Moreover, role of green microfinance in sustainable management of pesticides and food safety were recommended. A framework is proposed for pesticide governance with a stronger pesticide surveillance program and coordination of ministries interlinking environmental, occupational health and food safety.

Keywords Environmental contamination · Pesticide governance · Agricultural policy · Green microfinance · Integrated pest management (IPM)

Abbreviations

BAEC	Bangladesh Atomic Energy Commission
AI	Active ingredients
BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BCPA	Bangladesh Crop Protection Association
BCSIR	Bangladesh Council of Scientific and Industrial Research
BECA	Bangladesh Environmental Conservation Act
BECR	Bangladesh Environmental Conservation Rules
BFSA	Bangladesh Food Safety Authority
BSTI	Bangladesh Standards and Testing Institution
CLA	Crop Life Asia
DAE	Department of Agriculture Extension

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Published online: 02 February 2017

DGHS	Directorate General of Health Services
DoE	Department of Environment
ECA	Environmental Court Act
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FBCCI	Federation of Bangladesh Chambers of Commerce and Industry
GDP	Gross domestic product
GOB	Government of Bangladesh
GAP	Good agricultural Practice
HYV	High-yielding variety
IVM	Integrated vector management
IPM	Integrated pest management
IFRB	Institute of Food and Radiation Biology
MRLs	Maximum residue limits
MSD	Medical Sub-Depots
MFIs	Microfinance Institutes
MoA	Ministry of Agriculture
MoEF	Ministry of Environment and Forest
MinLaw	Ministry of Law
MoHFW	Ministry of Health and Family Welfare
MoI	Ministry of Industries
MoLE	Ministry of Labour and Employment
MoHFW	Ministry of Health and Family Welfare
MoLGRD	Ministry of Local Government, Rural Development and Cooperatives
MoSICT	Ministry of Science and Information Communication Technology
NAP	National Agricultural Policy
NIP	National Implementation Plan
PKSF	Palli Karma-Sahayak Foundation
POPs	Persistent organic pollutants
PTAC	Pesticide Technical Advisory Committee
WHO	World Health Organization

1 Introduction

Crop protection from pest attack is an essential component in modern day agricultural practices. Pest management has played a critical role in achieving the current level of the global food supply, and its importance will only increase in future (Waterfield and Zilberman 2012). Situated in the tropical South Asia, Bangladesh has a population of 160.48 million (Bangladesh Bureau of Statistics (BBS) 2016) and an average population density of about 1113.98 km^2, the highest in the world (WB 2015). In 2061, the population of Peoples' Republic of Bangladesh is estimated to be 251.45 million under high-variant fertility assumption (scenario I), 223.39 million under medium-variant fertility assumption (scenario II) and 209.42 million under low-variant fertility assumption (scenario III) (BBS 2015). With a total land area of only 143,998 km^2 and an ever-increasing population to feed, it is dire necessity to increase crop production. Bangladesh relies heavily on the uses of pesticides to protect crops and increase yields (Rahman et al. 2012a). With limited land area, horizontal expansion is rarely possible, but increase in crop production is still possible with vertical expansion through increasing crop yield per unit area (Ahmed et al. 2009). A total GDP of Bangladesh is 7.05% (BBS 2015) with a declining agriculture contribution to GDP from 17.7% (1996–2000) to 16.1% (2011–2015) (WB 2015). Agriculture sector still remains the largest employer in the country by far; 47.5% of the population is directly employed in agriculture, and around 70% depends on agriculture in one form or another for their livelihood (Planning Commission of GOB 2015).

Use of pesticides in crop is dependent upon pest infestations and the types of crops grown. Nevertheless, consumption of pesticides grew by a staggering 1340% from only 3135 metric tons of active ingredients (AI) in 1977 to 45,172 metric tons in 2009 (Rahman 2013a). Levels and trends in agricultural pesticide use for a large cross section of countries using FAO data for the period 1990–2009 analysis had shown that a 1% increase in crop output per hectare was associated with a 1.8% increase in pesticide use per hectare. On the contrary, the growth in intensity of pesticide use levels off as countries reach a higher level of economic development (Schreinemachers and Tipraqsa 2012). It is clear from previous literature that the consumption of pesticides in Bangladesh closely followed growth in the area under HYV rice and wheat (Rahman 2013a). Moreover, usage of pesticide has also become an essential component for other non-cereal crops as well (Rahman 2013a). Other cash crops that include jute, sugarcane, tea (grown in some specialized areas only) and cotton and major fruit crops that include banana, mango, pineapple, jackfruit, guava and jujube are seriously damaged by insect pests and diseases (Rahman et al. 2012a, b). However, the consumption of total pesticide has been decreasing over the years since 2008 (BCPA 2016). In 2014, the rate of total pesticide consumption fell down to 26.46% in comparison with the total pesticide consumption of 2008 (Fig. 1a). On the other hand, Fig. 1b represents the value (in US$) of the imported pesticides from 1960 to 2012 in Bangladesh (FAOSTAT 2016).

After evaluation of the benefits of using pesticides in crop production by simple economic analysis, studies show that there is an increased pesticide use in agriculture which consequently produced pesticide-induced ''public ills'' (Atreya et al. 2010). Although popular news media very often reports indiscriminate pesticide usage, consumption pattern of pesticide in Bangladesh is relatively limited.

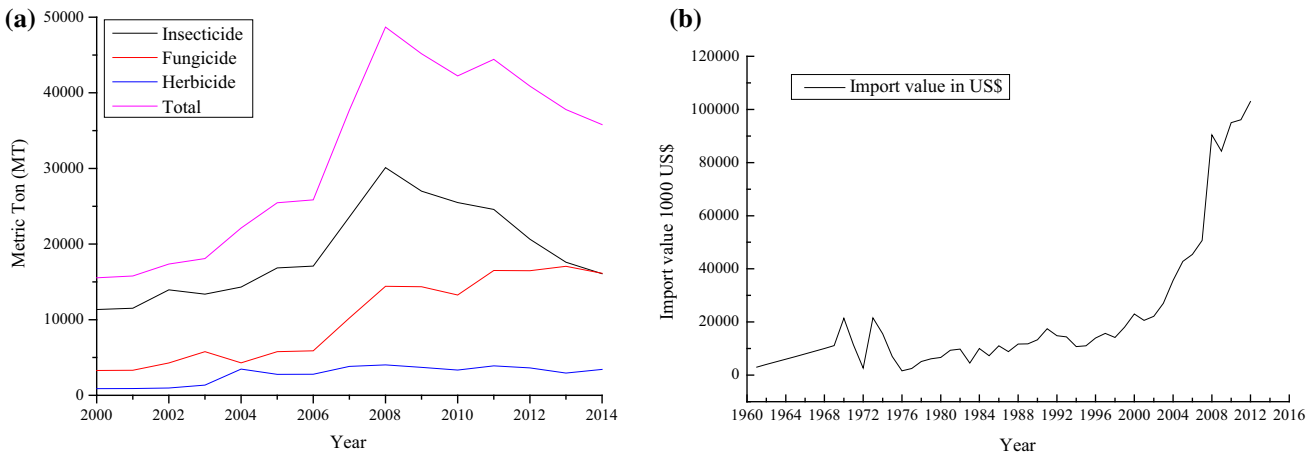

Fig. 1 **a** Summary of pesticide consumption in Bangladesh from 2000 to 2014 (*Source*: BCPA 2016) and **b** pesticide import value from 1961 to 2012 (*Source*: FAOSTAT 2016)

Furthermore, the systematic study on the level of pesticide residue analysis in environmental media such as soil, water, sediment, food residue examining MRLs, occupational health and safety management of farmers, family, women and children utilizing and handling pesticide and pesticide management practices is largely non-existent. While Bangladesh is on course for "Middle Income Country status" by 2021, rural Bangladeshi people are still heavily dependent on agriculture as their chief source of income generation (Planning Commission of GOB 2015). The interest and growth in microfinance have proliferated with the involvement of both private and public sector agencies (Lal and Israel 2006) in the country. Microcredit for agricultural development often goes to purchase pesticides, fertilisers, cattle and land; activities which have serious ramifications from deforestation to hazardous chemical pollution; and occupational safety concerns (Lal and Israel 2006). As a result of the interest in this sector, MFIs are often involved in serious environmental hazards. Given these backdrops, it is important to promote pesticide governance that protects the environment and human health sustainably. It is essential that we look for approaches that can deliver multiple goals. This study attempts to provide a comprehensive review on the following:

1. A review on the evolution and drawbacks of pesticide governance regime of Bangladesh to the unique socio-economic and environmental conditions prevailing in the country
2. A discussion on sustainable pesticide management practices (i.e. government policies, regulations, ban status) interlinking occupational health, environment and food safety;
3. An examination of the scope to sustainably manage pesticide in terms of present socio-economic positions in collaborating different ministries within the existing legal frame work and weak points that need to be amended.

2 Pesticide management regime in Bangladesh

The GOB has enacted several laws and rules regarding the manufacture, import and uses of pesticides (Table 1). Conferring to the Pesticide Ordinance 1971, as soon as the commencement of the mentioned ordinance, the government shall constitute a committee, known as Pesticide Technical Advisory Committee (PTAC) to advise the government on technical matters arising out of the administration of this ordinance and to perform any other functions assigned to it by or under this ordinance (GOB 1971). Following the legal ordinance, "The Pesticides Rules (1985)" were made in consultation with PTAC. In accordance with the rules, the "Licensing Authority" of any pesticide involves the Director, Plant Protection Wing of the Department of Agricultural Extension (DAE), and any person authorized by the Director for the registration (Ministry of Agriculture (MoA)/GOB 1985). The Pesticides Rules (1985) was later amended as The Pesticides (Amendment) Act 2009. However, the Pesticides (Amendment) Act 2009 and the policies relevant to it failed to provide a uniform pesticide management guideline which is further discussed in Sect. 4.

2.1 Registration process of pesticide

Registration of pesticide is mandatory in Bangladesh. The registration of pesticides in the country started in 1986 in exercise of clause 4 and clause 5 of "The Pesticide Ordinance 1971". The Pesticide Rules, 1985, provided the registration of manufacturing or importing of pesticides

Table 1 National laws and regulation regarding pesticide management and control

Laws and acts	Main content
Pesticide Ordinance, 1971 (GOB 1971)	An ordinance to regulate the import, manufacture, formulation, sale, distribution and use of pesticides
Amendment to Pesticide Ordinance, 1980	Power to fix maximum price of pesticides, storage, uses and development of PTAC
Pesticide Rules, 1985 (MoA/GOB 1985)	The GOB defined the process of pesticide registration and re-registration and certification in consultation with the PTAC
The Pesticides (Amendment) Act, 2009 (National Parliament of GOB 2009)	Environmental certificate is required from DoE for pesticide re-packer, formulation factory or manufacturer following BECA 1995 and BECR 1997. Ensuring of periodic monthly blood cholinesterase test for workers and removal from plant of workers, whose blood cholinesterase level is below WHO (2009) limits

valid for 3 years (Rahman et al. 1995). In the Pesticide Rules 1985, many general issues were overlooked including the persons who could handle pesticides. In The Pesticides (Amendment) Act, 2009, it was clarified that the definition of "persons" means importer, manufacturer, formulator, re-packer, vendor or stock holder, wholesaler and retailer of pesticides but does not include farmer or end user. The Pesticides (Amendment) Act gave a timeframe for application of renewal and registration of certificates of pesticides and provisions of monetary punishment in case of failure to do so. It also included a directive for biopesticide companies for application and renewal. According to the 2009 Amendment Act, for registration of a pesticide, an application with relevant data and specific sample is submitted which is then reviewed by PTAC (National Parliament of GOB 2009). Chemical tests are done by a chemist of sub-PTAC followed by field trial of two seasons in two locations by various researchers. According to Pesticide Ordinance, no one is entitled to import, manufacture, formulate (repack), hold in stock for sale, sell, offer for sale, or in any manner advertise any brand of pesticide without obtaining a certificate of registration from registration authority. Only few companies manufacture granular pesticides using imported AI. Pesticide registration committee consists of 22 members which includes all of the heads of Department of Agriculture and is headed by Executive Chairman Bangladesh Agricultural Research Council (BARC); while PTAC consists of 26 members, headed by National Plant Protection Organization (NPPO)/Director Plant Protection wing of DAE.

2.2 Pesticide marketing system in Bangladesh

The Pesticide industry in Bangladesh is comprised of private companies and foreign companies. Only the registration-holding company can import registered pesticides from the principal manufacturer. Local companies just pack or bottle them for marketing. The marketing of pesticides in Bangladesh had been privatized since 1979. The government only maintained some reserve stock for emergency purposes (Shidhu and Mudahar 1999). Figure 2 represents the schematic diagram of marketing channels of pesticides in Bangladesh. BCPA is the association of pesticide traders and is the representative organization of the business enterprises who are involved in importing, formulation and marketing of plant protection chemicals. BCPA acts as a representative of pesticide industry which negotiates with different ministries of Bangladesh. BCPA was also awarded compulsory membership by the GOB for any pesticide company to better monitor their performance. Moreover, BCPA is a dignitary of PTAC of DAE and is enrolled as "A" class association of Federation of Bangladesh Chambers of Commerce and Industry (FBCCI) and a member of Crop Life Asia (CLA) which implements the responsible use of pesticide program and anti-counterfeiting of pesticides program throughout the country (BCPA 2015). It was reported that about 63% of traders return unsold pesticides to the company, whereas only 22% take back unsold pesticides from their buyers. The traders receive other pesticides in lieu of unsold pesticides. Since the company supplies officially only to the distributor, majority (81%) of distributors can return expired pesticides to the company compared to other traders (Sabur 1999). However, there is no report on the management of the expired pesticides by the companies upon reception in Bangladesh.

2.3 Status of obsolete and banned pesticides in Bangladesh

Pesticides become obsolete when they can no longer be used for their intended purpose. Bangladesh started discontinuing, banning, deregistering extremely hazardous pesticides in the 70s and lastly banned heptachlor in 1998 (Rahman et al. 2012b). So far, Bangladesh banned 13 pesticides AI with respect to the 316 pesticides (PAN international 2016). The Persistent Organic Pollutants (POPs) pesticides, which have been discontinued, banned

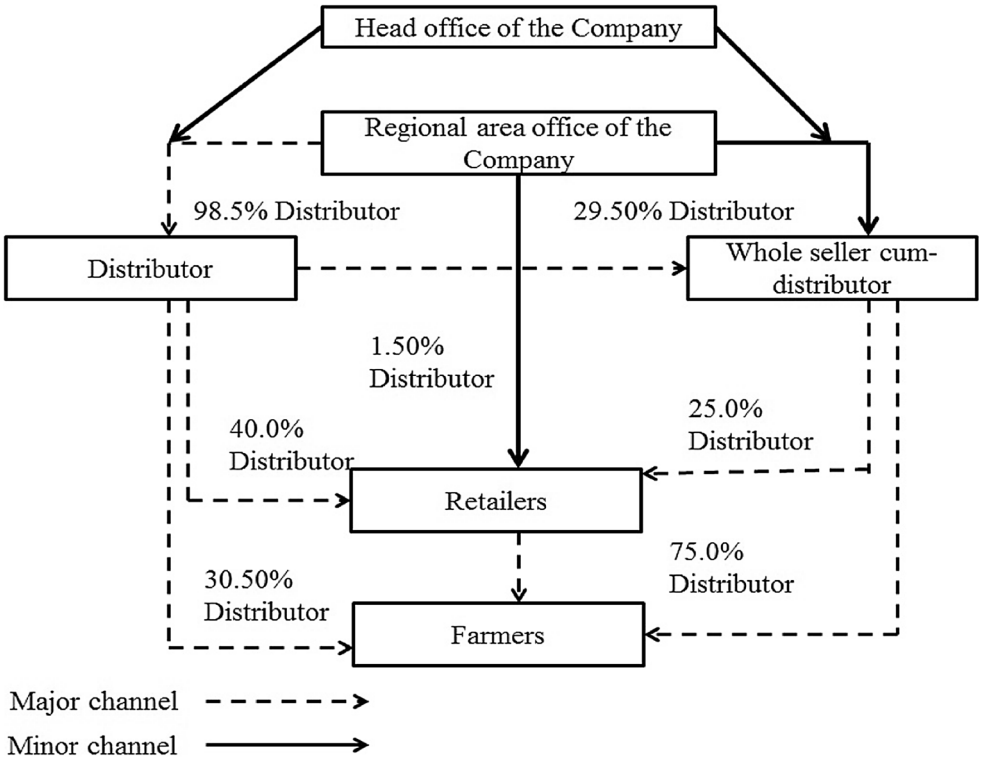

Fig. 2 Schematic diagram of marketing channel of pesticides in Bangladesh (Sabur 1999)

or deregistered, include endrin and HCH/lindane (1970), aldrin (1975), chlordane (1985), dieldrin (1997) and heptachlor (1998). The government imposed only restricted use permission for DDT(Dichlorodiphenyltrichloroethane) in 2005. Other POPs pesticides such as toxaphene and mirex were never imported and used in Bangladesh (Rahman et al. 2012b). Additional banned pesticides include alachlor, aldicarb, captafol, endosulfan, hexachlorobenzene (HCB), ethylene dichloride/1,2 ethylene dichloride, fluoroacetamide, monocrotophos and parathion ethyl (PAN International 2016).

DDT has been officially replaced by number organophosphates and/or synthetic pyrethroids and their combinations in addition to the integrated vector management (IVM) package (Rahman et al. 2012b). Although the use of DDT is banned in Bangladesh, there are reports of its illegal use in different forms. As per one report, about 500 MTs of DDT stockpiles are lying in the Medical Sub-Depots (MSD) at Chittagong for over a period of 26 years (Rahman et al. 2012b). The discontinuation of DDT as well as import of substandard DDT caused obsolete DDT stockpiles in different locations of Bangladesh. The DDT stockpiles of 602.389 MTs comprise 482.904 MTs of substandard DDT at a single location in four MSDs in Chittagong, 101.69 MTs of DDT technical at Bangladesh Chemical Industries Corporation (BCIC), Chittagong, 12.795 MTs of DDT 75 WP (75% formulation of weighable powder) at district godowns of Directorate of Health and 0.005 MTs of DDT 75 WP at district godowns of DAE (Rahman 2007). The very poor storage conditions of the MSDs are resulting in seepage, pilferage, weathering and misuse of DDT, which are contaminating the environment (Rahman et al. 2012b). DDTs might have been also dumped randomly around the warehouse after the closing of the factory (Table 2). The concentrations of *p*,*p*-DDT were found to be greater than those of *o*,*p*-DDT in soil, sediment and water clearly indicating contamination was carried out by technical-grade DDT (Al Mahmud et al. 2015).

3 The evolution and drawbacks of pesticide management regime in Bangladesh

3.1 Difficulty in chemical inventory

A single-ingredient pesticide in Bangladesh may have as many as hundreds of different trade names, making the control of usage and management of chemical inventory particularly difficult (Table 3). Trade names are loosely controlled by current legal instruments; one chemical can have multiple trade names making control of the active ingredient (AI) difficult (Panuwet et al. 2012). Misleading advertisements also confuse farmers who are largely illiterate (Rahman 2013b). From the database, it was found that at least five AI belong to WHO (2009) hazard

classification of Class Ib compound (carbaryl carbofuran, carbosulfan, chlorpyrifos, cypermethrin, etc.), several AI belonging to Class II (diazinon, dimethoate, 2,4-D, 3Paraquat, etc.) and Class III (3 Glyphosate and malathion etc.) Moreover, there is no inventory on the management of the expired and out-dated pesticides by the companies and how they manage the chemicals.

3.2 Lack of testing facilities before port clearance

"The Pesticides Rules (1985)" clearly stated in Section 11 that no pesticide shall be imported into Bangladesh unless: (1) it has been registered and it complies strictly with the application for registration, (2) it is packed and labelled in compliance with these rules, and (3) only recognized custom stations of Bangladesh will be used for import. However, due to lack of testing facilities before port clearance, the authority could not know whether or not the imported chemicals are registered pesticides or unregistered pesticides. This issue was not addressed in the Pesticide (Amendment) Act 2009 and the relevant policies. Therefore, it is recommended to amend the law incorporating the provisions to test imported pesticides substances on arrival in ports before clearance in the laboratories of DAE. As the evaluation of pesticide quality is the responsibility of the DAE, the percentage of AI must match the substances and conform to the percentage proposed for registration. Nevertheless, it is also not monitored properly.

Table 2 Concentration of DDT and its metabolites found in the vicinity of closed-down DDT factory in Chittagong (Al Mahmud et al. 2015)

Substances	Concentration reported in environmental media
DDT and its metabolites	Water body 0.59–3.01 μg/L Soil 1.0–48.6 × 10^2 to 2904 × 10^2 mg/kg

3.3 Difficulty in identification of the responsible person

Another weakness of the above said regulation is in Chapter VII Section 33 Subsection I (a) which provides the provision to state the manufacturer name, formulator name or re-packer name in the label even in a case when the certain pesticide is not registered on his/her name. This could make the identification of a respective person very difficult (Parveen and Nakagoshi 2001). This issue was also not addressed in the Pesticide (Amendment) Act 2009.

3.4 Smuggling from neighbouring countries

In theory, the regulatory scheme is systematic. But in practice, however, there are gaps between the policies and implementation. For example, while the intent of the Ordinance and Rules to monitor formulations and residues is commendable, the lack of facilities and trained analysts makes proper monitoring difficult. Thus, specification of pesticides on the market may differ from those registered (FAO 2005). Smuggling of unregistered and illegal pesticide in the country is another significant problem existing in the country. It was further revealed that some unknown brand pesticides are readily available in border areas of Bangladesh, where they are known to farmers for their effectiveness, high toxicity and relatively low price (Anwar and Yunus 2013). The absence of a strong legal framework in the Pesticide (Amendment) Act 2009 facilitated a significant increase in the entrance and uses of low-quality environment-deteriorating pesticides in the country. Farmers ignore the risks, safety instructions and protection directives when using these pesticides. They are only

Table 3 List of registered agricultural, biopesticides and public health pesticide in Bangladesh approved up to 65th technical advisory committee meeting (DAE 2016)

Type of pesticides	Common AI found	Number of trade name available in the market	List of companies in the market
Miticide	6	164	139
Fungicide	51	663	271
Insecticide	78	1715	428
Herbicide	31	319	154
Biopesticide	3	4	3
Storage grain products	4	66	62
Rodenticide	2	13	13
Public health pesticides	73	1512	95
Banned pesticides	13	–	–
Registration cancelled	–	195	66

concerned about the effectiveness of the pesticides for killing pests, without paying attention to the effects on their health and the environment (Thuy et al. 2012).

3.5 Unique socio-economic and environmental conditions prevailing in the country

Poverty, scarcity of the working capital as well as the land scarcity are high in Bangladesh. With the seasonal climatic conditions like cyclone, rain, drought, floods and soil situations like salinity problem in the south of the country, the agricultural production risks are extreme. Farmers are more vulnerable to external and internal shocks. With the greater penetration of microfinance to alleviate poverty by engaging communities in microloans and microbusinesses, there could also be certain unique positive developments (Rouf 2012). However, MFIs are not aware of the environmental impacts of rural microfinance and the potential for improving the environmental performance of smallholder agriculture in the developing world (Lal and Israel 2006).

4 Pesticide management implications in Bangladesh with respect to international conventions and agreements

The International Code of Conduct on the distribution and use of pesticides of the FAO are the most acknowledged international initiative for reducing negative impact from pesticide uses in developing countries (Wesseling et al. 2005; Jansen 2008). There are five major international agreements and international policy instruments with direct operational implications for pesticide management (WHO/FAO 2014) in which GOB is trying to implement within the scope of its national policies, laws and regulations.

First is The Codex Alimentarius, and the more specific Codex Committee on Pesticide Residues that is operational since 1966. Bangladesh is implementing Codex standards through BSTI (discussed further in Sect. 6.1 with the relevant laws). Second is The Montreal Protocol on Substances that Deplete the Ozone Layer, adopted in 1987 and entered into force in 1989, and its subsequent amendments. Bangladesh ratified the Montreal Protocol on 2 August 1990. With regard to this, GOB is implementing different plan of actions to phase out consumption of different chloroform-containing substances (UNEP 2016). Third is The Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal, adopted in 1989 and entered into force in 1992. Bangladesh ratified the convention on 1 April 1993 and entry into force on 30 June 1993. It first banned import of all sorts of waste in the "Import Policy Order". In 1996, Bangladesh prepared a regulatory framework, but at the commencement of the regional technical assistance (Grama et al. 2013), there was no significant direct legislative support focused on management of hazardous waste or the issues surrounding the GOB obligations under Basel Convention (ADB 2010). The fourth important convention is The Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, adopted in 1998 and entered into force in 2004. Although Bangladesh is not a part of this convention and the Protocol, it has limited PIC correspondence with EU. The fifth important international convention is the Stockholm Convention on Persistent Organic Pollutants (POPs), adopted in 2001 and entered into force in 2004. The GOB signed the Stockholm Convention on 23 May 2001. As a signatory party, the government was committed to prepare their NIP for POPs and to take action for creating awareness regarding consequences of POPs releases and ultimately their elimination. For NIP, the concerned authorities were DoE of MoEF. The sound management of chemicals was addressed by 17 different multilateral agreements including the 1998 Rotterdam Convention on the PIC Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and the 2001 Stockholm Convention on POPs (both effective since 2004) (DoE 2007). In compliance with the WHO specifications as well as other relevant multilateral environmental agreements, Bangladesh banned and/or discontinued the use of the most hazardous pesticides including POPs by 1998 (Rahman et al. 2012b). There are some established policy and legislation that can provide support for hazardous obsolete pesticide waste to meet the requirements of the Basel Convention. Table 4 provides the relevant legislation in Bangladesh to manage obsolete and unregistered pesticides in concordance with the international agreements.

5 Effects of pesticide mismanagement in Bangladesh

Improper pesticide usage (e.g. increased concentration and spraying frequency, not using protective clothes, etc.) and improper disposal of the empty pesticide containers result not just in a direct cropping yield loss but also in indirect health and environmental damages, such as killing useful animals (Thuy et al. 2012) or the pollution of the air and water resources (Thuy et al. 2012; Sharma et al. 2010). Due to the increased use of agro-chemicals in agricultural fields, contamination of soil and groundwater by pesticide leaching has become one of the major threats to the subsurface environment (Anwar and Yunus 2013). Pesticides with low persistence are generally non-threatening to

Table 4 Relevant legislation in Bangladesh to manage obsolete and unregistered pesticide waste

Relevant policies, management plans, rules and acts	Content	Compliance with international conventions	Implications regarding pesticide management
1. Bangladesh Environmental Conservation Act (BECA) 1995 Amendment 2010 (National Parliament of GOB 2010a, b)	Main legislative document relating to environmental protection in Bangladesh	This act is in compliance with the Montreal Protocol, Basel Convention and the Stockholm Convention including ban of all sorts of obsolete pesticides and wastes in the Import Policy Order	Power given to DoE for the formulation and declaration of environmental guidelines, declaration of ecologically critical area (ECA), restriction on manufacture, sale, etc., of articles injurious to environment, conduction of remedial measures to the injury of environment, etc
2. Bangladesh Environmental Conservation Rules (BECR) 1997	Rules under ECA 1995 provide additional guidance for specific components of the Act that is to be enforced by the DoE	Essential powers for hazardous waste management like pesticide in line with international requirements are in place Penalties for failure to comply with ECA rules and regulations	Standards set for liquid effluents and gaseous emissions with some legal authority and powers given to DoE Initial Environmental Examination (IEE)/Environmental Impact Assessment (EIA) studies for pesticide formulation industry and waste management
3. The Environmental Court Act 2000 Amendment 2002 Amendment 2010 (National Parliament of GOB 2010a, b)	Supports BECA and BECR by establishment of environmental courts for offences relating to environmental pollution	Confirms powers for hazardous waste management like obsolete pesticides and enforcement in line with international requirements	Application of BECA and BECR

health, while pesticides with low sorptivity should be taken as a serious concern as they pose a significant impact on groundwater. Top soils are found to be particularly vulnerable to the accumulation of organochlorine pesticides (Anwar and Yunus 2013).

It has been observed from the literature review that in most of the report, organophosphate and carbamate reported to have very high concentration in soil and water (Table 5). Water samples from five locations (Feni, Nawabganj, Putia, Burichang and Chatak) were contaminated with DDT; the highest DDT concentration detected was 8.29 μg/L, and its metabolite, DDE, was detected at 4.06 μg/L. Water samples from four other locations (Natore, Sikderpara, Chatak and Rajoir) were contaminated with heptachlor residues, and the highest level detected was 5.24 μg/L (Chowdhury et al. 2013a, b). A number of samples of surface water from paddy fields were found to contain chlorpyriphos, carbofuran and carbaryl at concentrations ranging from 0 to 1.189, 0 to 3.395 and 0 to 0.163 μg/L, respectively. Surface water from the lakes had chlorpyriphos, carbofuran and carbaryl at concentrations ranging from 0.544 to 0.895, 0.949 to 1.671 and 0 to 0.195 μg/L, respectively (Chowdhury et al. 2012).

5.1 Strengthening environmental surveillance program

As the continuous use of pesticides has caused the deleterious effects to ecosystem (Sharma et al. 2010), it is significant to strengthen environmental surveillance program on pesticide monitoring in Bangladesh by DoE. Unfortunately, BECR 1997 allows standards set for liquid effluents and gaseous emissions with some legal authority and powers given to DoE, but did not provide any standard information on agriculture farm contaminant like different types of pesticides. In this respect, DoE must update BECR 1997 with standards for pesticide contamination or adopt MRLs in conjunction with EU Water FrameWork Directive (Directive 2000/60/EC of the European Parliament) which is also a complex process to set a regulatory limit.

5.2 Addressing the issues of occupational health problem for farmers, children and other stakeholders

Chronic health effects associated with prolonged exposure to pesticides have been well documented for applicators in

Table 5 Type of pesticides and concentration reported in soil and water from Bangladesh

Type of pesticides	Districts	Substance concentration	Concentration reported in environmental media	References
Organochlorine	Feni, Nawabganj, Comilla, Sunamganj	DDT 0.133–8.29 µg/L	Irrigated surface water samples	Chowdhury et al. (2013a, b)
	Comilla	DDE 4.06 µg/L		
	Bandarban, Sunamganj, Madaripur	Heptachlor 5.04–5.24 µg/L		
Organophosphate	Rangpur	Chlorpyriphos 0–1.189 µg/L	Surface water samples from paddy field	Chowdhury et al. (2012)
		Carbofuran 0–3.395 µg/L		
Carbamate		Carbaryl 0–0.163 µg/L		
Organophosphate	Rangpur	Chlorpyriphos 0.544–0.895 µg/L	Surface water from ponds and lakes	Chowdhury et al. (2012)
		Carbofuran 0.949–1.671 µg/L		
Carbamate		Carbaryl 0–0.195 µg/L		
Organophosphate	Gazipur	Fenitrothion 0.04–1.47 mg/L	Surface water sample from paddy field	Shammi et al. (2014)
		Diazinon 0.3–1.26 mg/L		
		Chlorpyrifos 23.5 mg/L		
Carbamate		Carbaryl 1.8 mg/L		
Organophosphate	Gazipur	Diazinon 0.73 mg/L	Sediment sample	Shammi et al. (2014)
		Carbofuran 0.42–0.89 mg/L		
Carbamate		Carbaryl 0.15–1.00 mg/L		
Organochlorine		Endrin 0.153 mg/L		
Organophosphate	Manikganj	Chlorpyrifos (0.06 ± 0.001 µg/L)	Paddy field water sample	Bhattacharjee et al. (2012)
		Cypermethrin (0.605 ± 0.011 µg/L)		
		Diazinon (0.039 ± 0.002 µg/L		
Organophosphate	Manikganj	Chlorpyrifos 0.012 ± 0.0006 µg/L	River water sample	Bhattacharjee et al. (2012)
		Cypermethrin 0.11 ± 0.003 µg/L		
Organophosphate	Savar Upazila, Dhaka	Chlorpyrifos 3.27–9.31 µg/L	Lake water samples	Hossain et al. (2014)
		Fenitrothion 0.1–to 33.41 µg/L		
		Parathion 0.73–6.23 µg/L		

rice crops (Robinson et al. 2007). Effective and low-risk methods of pest and disease control are needed to protect farmers' health and the environment and to avoid a trade-off between income and health (Schreinemachers et al. 2016). It is significant to have proper training when handling pesticides. Schreinemachers et al. (2016) found out that trained farmers protected themselves better during spraying. With regard to this, training on handling methods of pesticides and its equipment can be an important intervention for the protection of occupational health and safety of farmers and their family. However, most farmers in Bangladesh rely on their own experiences and on pesticide sellers to help select the appropriate pesticide (Chowdhury et al. 2013a, b).

Due to physiological and behavioural differences, pesticide-related exposures and health effects among children are different and often worse than exposures among adults (Panuwet et al. 2012). Additionally, children of farmers have unique para-occupational exposures resulting from using their parents' workplace as their playground (Panuwet et al. 2012). Two reported incidents have been found from Bangladesh, and in both cases, cholinesterase-

inhibiting pesticide was suspected from the symptoms of acute illness (Table 6). The onset of this outbreak corresponded with the lychee harvesting period which was also reported from Vietnam (Paireau et al. 2012). The clinical appearances of the cases and the rapid advancement from onset to death suggested the outbreak was caused by pesticide poisoning due to close proximity of lychee orchards to case-households (Royster et al. 2002). Lychee grower heavily used multiple pesticides in the lychee orchards during the short lychee-growing season (ICDDR, B 2012). Therefore, frequent and sustained exposures to lychee orchards and fruit among children increased their exposure to pesticides (Royster et al. 2002).

5.3 Suggestion for pesticide-related chronic/acute poisoning surveillance program

The use of different pesticides in fruit orchards should be evaluated by DAE and DoE officers. The toxicity and likelihood of particular pesticides to cause acute risk of morbidity, mortality to the farmers and his families should be defined. Introduction of IPM and GAP among fruit growers and monitoring of pesticide levels in the fruits and garden environment can reduce the impact of pesticides. Other than this, there should be a strong prohibition of children to play, visit and work in fruit plantations that have been sprayed with pesticides. Regulations should be developed locally and possibly nationwide, to inform growers, farmers, sprayers and garden owners and workers to protect children who live near orchards and crop fields from unintentional pesticide poisonings.

It was clear from previous report that there were certain differences of pesticide poisoning data of DGHS and other discrete institutions (Dewan 2014). Introduction of a single pesticide-related chronic/acute poisoning surveillance program can investigate in case of any exposure circumstances. Physicians of respective health centres, clinics, hospitals and medical colleges have to report to DGHS any recognized or suspected symptoms caused by a pesticide exposure. This will be aimed in collecting and evaluating health report prior to assigning DAE/DoE officials to investigate exposure circumstances of the respective areas. Scientists then review the collected information and enter it in a database which will reflect the regulatory program imposed by DAE/DoE. This will further assist into monitoring exposure and health of the people affected by pesticide poisoning.

6 Sustainable pesticide governance in Bangladesh in terms of present socio-economic policies

Burgeoning demand on safe agricultural food production, escalating concern on food safety, occupational and public health in the present societal context needs to be addressed. However, until now Bangladesh does not have any sustainable pesticide management plan for agriculture, environment, food safety and occupational health in the present socio-economic context of Bangladesh. Microcredit is assumed to be likely to contribute both directly and indirectly to agricultural farm performance, farm output, poverty reduction and food security in Bangladesh (Wadud 2013). Effective pesticide governance capacity is the foundation of efficient management of pesticide in the country. Pesticide governance processes must work towards capacity building in a unified and pronounced attitude that links national policies, laws and institutions, within an enabling environment that allows for their implementation.

6.1 National Agriculture Policy (NAP) to manage pesticide contamination in raw agricultural products and processed foods

Agriculture in Bangladesh is in the process of diversifying from subsistence rice production into higher-value crops such as vegetables and fruits. In view of this, the GOB introduced NAP in 2013 with the emphasis on increasing agriculture production, alleviating poverty through generating jobs and highlighting food security and safety issues. NAP focused on agro-processing, marketing, agricultural equipment, irrigation, seeds, fertilizer and mechanization which are an integral part of promoting IPM policy of 2002 (Table 7).

Food safety has become one of the most important topics due to public health concern as well as serious adulteration in food stuffs. Article 15 and Article 18 of the Bangladesh Constitution suggest food safety necessities for

Table 6 Unintentional pesticide poisonings of children reported from Bangladesh

Reported year	Reported incident	Death reported	References
2009	Farming villages	3 deaths of children aged 1–10 years	Martin et al. (2011)
2012	Lychee gardens during harvest season	13 deaths of children out of 14 reported	ICDDR, B (2012)

consumers, and the State must ensure it through enactment of appropriate laws (MinLaw/GOB 2010). The responsible ministries, departments, agencies for enforcement of food laws, rules and regulations in Bangladesh are listed in Table 8. Although the GOB is concerned about pesticide residues in the food and the environment, facilities (infrastructure and man power) to conduct the necessary monitoring programs are not sufficient. In addition, the country has not yet established legal limits for residues and depends upon Codex allowable limit which are not always proposed for all crops and major pesticides used within the country (FAO 2005). BSTI is adopting Codex standards for many packaged food. For pesticide residue in processed food products, Codex MRLs and Codex Extraneous Maximum Residue Limits (EMRLs) for pesticide/commodity combinations can be adopted.

6.2 Green microfinance and safer agricultural productions

The microfinance sector provides a valuable interface within the informal sector in developing countries and can help address the serious lack of environmental management institutions (Lal and Israel 2006). It was clear from previous study that timely and fair distribution of microcredit to marginal and small farmers could lead to improvement in farm performance and farm output (Wadud 2013). GOB, Palli Karma-Sahayak Foundation (PKSF) and other institutions have started funding in agricultural activities. Use of microcredit in agriculture has been on the increase and now it constitutes about 40 per cent of all credits that the farmers receive (Wadud 2013). Allet and Hudon (2013) reported that MFIs registered as banks tend to perform better in environmental policy and environmental risk assessment. Furthermore, more mature MFIs tend to have better environmental performances, in particular in providing green microcredit and environmental non-financial services. In essence of this green microfinance follows the environmental mantra of: recycle, refine and reuse of resources. Green microfinance further accelerates green social development that is people-centred, fosters human health, promotes social justice, generates income, addresses the issue of poverty and reduces environmental waste. Moreover, it not only seeks profit, but also looks at ecological balance within businesses, resources, the environment and the society. Green microbusiness can increase marginalized people's income in order to survive, improve quality of life as well preserve environmental integrity (Rouf 2012).

6.2.1 Green microfinance to promote integrated pest management (IPM) and safer foods

The common use of pesticide is a major challenge to accomplish sustainable agriculture. Farming systems based on integrated pest management (IPM) technologies can reduce the use of pesticides to a great extent without causing harm to the yield. Therefore, Bangladesh, like many other developing countries, launched IPM technologies to reduce the adverse effects of pesticides in social, economic and environmental aspects (Kabir and Rainis 2014). To reduce the frequent use of pesticides in Bangladesh agriculture, the government has made an effort to disseminate IPM technologies among vegetable growers since 1996. Despite continuous disseminating programs for various organizations to promote IPM, majority of the farmers are still non-adopters which demands extra efforts (Kabir and Rainis 2014).

An understanding of the farmers' acceptance in choice may help to expand the efficiency of IPM diffusion in the developing country like Bangladesh with the promotion of "Green microfinance". Without collective adoption, neighbours' continued reliance on chemicals to eliminate pests will also kill helpful parasites and predators, as well as expose IPM farmers and local ecosystems to chemical spillovers from adjoining fields. Successful IPM adoption may therefore depend on institutional support for collective action (Dasgupta et al. 2007). Alternative ways of controlling pests include community IPM along with education and training activities. Such measures are likely to reduce

Table 7 National policies regarding implementation of IPM,, food safety and occupational safety

Policy	Main content
1. National Agriculture Policy (NAP) 2013	To increase agriculture production and alleviate poverty through generating jobs and highlighting food security
	Agro-processing, marketing, agricultural equipment, irrigation, seeds, fertilizer and mechanization, the role of women in agriculture and financing were also prioritized
	However, the issues of food safety were ignored which is the weakness of the policy
2. National IPM policy 2002 (MoA/GOB 2002)	To train 1.7 million farmers in IPM by 2016. This is interlinked with food safety, occupational safety of farmer, farmers' family and children

Table 8 Existing national legislations and regulations for food safety regarding pesticide contamination in Bangladesh

Legal regulations	Main content
1. The pure food ordinance 1959 (MinLaw/GOB 2010)	To provide better control of the production and sale of food for consumption
2. The Bangladesh Standards and Testing Institution (BSTI) Ordinance, 1985 (Amendment) Act, 2003 (MinLaw/GOB 2010)	BSTI is the standardization body in the country entrusted with the responsibility of formulation of national standards of industrial, food and chemical products as per regional and international standards. Also responsible for the quality control of the products ensured by the technical committees formed by BSTI
3. Fish and Fish product (Inspection and Quality Control) Rules, 1997	To promote quality improvement in export of fish and fish products in the importing countries
4. Bangladesh Pure Food (Amendment) Act, 2005 (MinLaw/GOB 2010)	Under this Act, The National Food Safety Advisory Council (NFSAC) had been constituted
	NFSAC is comprised of the representatives from all the key ministries and their agencies, chaired by Honourable Minister, Ministry of Local Government, Rural Development and Cooperatives (MoLGRD) including business communities, academics
5. The Food Safety Act 2013 (National Parliament of GOB 2013)	Development of Bangladesh Food Safety Authority (BFSA), Central Food Safety Management Coordination Committee and Technical committees in February 2015. BFSA acts to fight food adulteration and take care of other food-related concerns of consumers (BFSA 2015)
	However, the organizational structure and formation of the code of conduct for the regulatory body, which is in progress with the technical assistance of FAO, is yet to be finalized

the health and environmental costs of pesticide pollution, and also enhance the capabilities of third world agricultural communities in terms of knowledge, decision making, innovation and policy change (Atreya et al. 2010).

Other than IPM, a four-pronged strategy can be used, which includes: (1) creating awareness among consumers and producers regarding the risks of pesticide use; (2) investing into integrated crop management focused on pest prevention, (3) rationalizing pesticide use through economic regulation and incentives and (4) certifying safe farm products to assure consumers and reward producers (Schreinemachers and Tipraqsa 2012).

6.2.2 Green microfinance to promote GAP and organic agriculture

Pesticides in foodstuff are becoming a major issue due to their intensive use in agriculture (Lesueur et al. 2008). Continuing overuse and misuse of pesticides in the agricultural practices characterizes crop production in Bangladesh. Since pesticides are potentially harmful to the environment and consequently to human beings through the consumption of pesticide contaminated food and water, the European Community established MRLs, based on the assumption that GAP is applied at the use of pesticides in farming, for pesticide residues in water (Commission of the European Communities, 2000) and foodstuff (Commission of the European Communities, 1990). As Bangladesh does not have its own standard to manage pesticide contamination of food commodities for raw and processed agricultural products, the quality of the raw foods and food products must have to be controlled by following international standards. With regard to this, production and processing of agricultural and food products must be established following Codex MRLs. In addition, at the primary production, packaging, transport and distribution of food, DAE under MoA can play an important role by introducing GAP. GAP is aimed at increasing the supply of safe and high-quality food by promoting a more sustainable crop production that uses fewer pesticides (Schreinemachers et al. 2012). As an alternative to conventional farming, organic farming is considered a promising type of production to meet the challenges of modern agriculture. In particular, organic farming is assumed to favour the biological control of pests by their natural enemies and, therefore, is considered a possible way to reduce the use of pesticides (Puech et al. 2014). Microfinance institutions (MFIs) can promote soft loan services in line with this. However, it was also identified that GAP program pays too much attention to the consequences rather than the root cause of the pesticide problem (Schreinemachers et al. 2012). Other than GAP, there is a costly but rapidly growing market of organic agriculture for urban consumers in Dhaka city, Bangladesh. Other than this, if certain MFIs can obtain the complicated and costly certification on behalf of the farmers, they can export the products as well (Lal and Israel 2006).

Table 9 Inter-ministerial agency collaboration interlinking environmental, occupational, health and food safety regarding pesticide usage

Ministries	Roles	Proposed task
Ministry of Agriculture (MoA), DAE	Approval of pesticides is a responsibility of this ministry. DAE of this ministry is working together with the BAEC to perform a survey to monitor residues of pesticides in agricultural products all over the country. Furthermore, the ministry is also implementing IPM in 201 Upazilas	Can monitor on farm pesticide contamination program in collaboration with DoE and other research organization like BAEC–IFRB/BCSIR and other educational institutes
		Introduction of policies to reduce pesticides through GAP
Ministry of Environment and Forest (MoEF)/DoE	Presently, the DoE along with DAE and Bangladesh Power Development Board is implementing a project on POPs under Stockholm Convention aimed to protect human health and environment	Can update and amend BECR 1997 to implement MRLs for water following EU directives and strengthening monitoring program in collaboration with BAEC–IFRB/BCSIR and other educational institutes
Ministry of Health and Family Welfare (MoHFW)/DGHS City corporation	MoHFW has the major accountability for the implementation of food control legislation to ensure safe food. The ministry is also responsible for monitoring of food quality and safety situation including collection of food samples. Inspection of food manufacturing/processing and selling premises as well as collection of food samples, public health pesticides and acute and chronic pesticide poisoning records	DGHS can implement a single nationwide database for the record of acute and chronic pesticide poisoning in collaboration with ICDDR, B and other institutes
Ministry of Science, Information and Communication Technology (MoSICT)/BAEC/IFRB/BCSIR	Test pesticides residues in food items; research and development	Strengthening of monitoring program and further research and development
Ministry of Labour and Employment (MoLE)	Enacted "Bangladesh Labor Act of 2006" and established occupational health and safety regulations	To strengthen enforcement of occupational health and safety in pesticide formulation plants, pesticide applicators, farmers and farm workers in their respective workplaces
		Provide education, training and awareness on health and safety of pesticide handling
Ministry of Local Government, Rural Development and Co-operatives (MoLGRD)	Responsible for the food safety and quality of food in city corporations and municipalities	Strengthen monitoring program on food contamination in domestic agricultural products
Ministry of Food and Disaster Management	Directorate General of Food having food inspectors at the Upazila and District level and usually deal with the food security aspects. They are also responsible for checking the quality, as well as storage, of imported and locally procured food grains and other food items including sugar, edible oil, etc	Strengthen monitoring program on food contamination
Ministry of Industry (MoI)	MoI is responsible for standardization, certification marks and monitoring quality control of processed food items through its BSTI	BSTI has right to adopt International Standards (ISO, Codex, etc.) as Bangladesh Standards. For food and drinking water BSTI, it can establish Codex MRLs of pesticide residues
BSTI	BSTI follows Codex MRLs	
Ministry of Law, Justice and Parliamentary Affairs	The ministry is responsible for revision of existing rules/ordinance or to formulate new rules/ ordinance (for vetting, parliamentary approval) and for amendment, as per request of or recommendation from the concerned sectors	Can update and amend stricter laws regarding pesticide MRLs, environmental, occupational health and food safety
Ministry of Fisheries and Livestock	Through this Ministry, the Department of Fisheries is responsible for prevention and control of diseases in fishes and aquatic animals, checking of safety and quality of fish and aquaculture products	Can monitor on farm pesticide contamination program in collaboration with DAE/DoE and other research organizations like BAEC–IFRB/ BCSIR and implement MRLs for fishery products following EU directives

6.2.3 *Green microfinance to promote market of biopesticides*

Biopesticides are considered to have lower risks than synthetic pesticides. Consequently, there is strong interest for their use in integrated pest management. Biopesticides could be alternatives for traditional plant protection products, either as a base for the synthesis of new products or integrated with traditional plant protection products (Villaverde et al. 2014). In accordance with "The Pesticides (Amendment) Act, 2009", NAP (2013) allows the registration of commercial production and marketing of biochemical pesticides including its distribution and use, research and development to farther diffusion of IPM in the country (Katalyst 2010). In this respect, promotion of green microfinance can further push the market for biopesticides to be more competitive leading to production of better quality, affordable and readily available products for the farmers. Furthermore, the small entrepreneurship can be grown out of this green microcredit programs to develop biopesticide companies engaging in promotional activities and dialogues with their rural customers, i.e. farmers. This will increase awareness of safer agricultural production of such products among farmers.

6.3 Coordination of respective ministries to develop national master plan

Three most important dimensions should be considered for pesticide governance in Bangladesh—ethics, health and

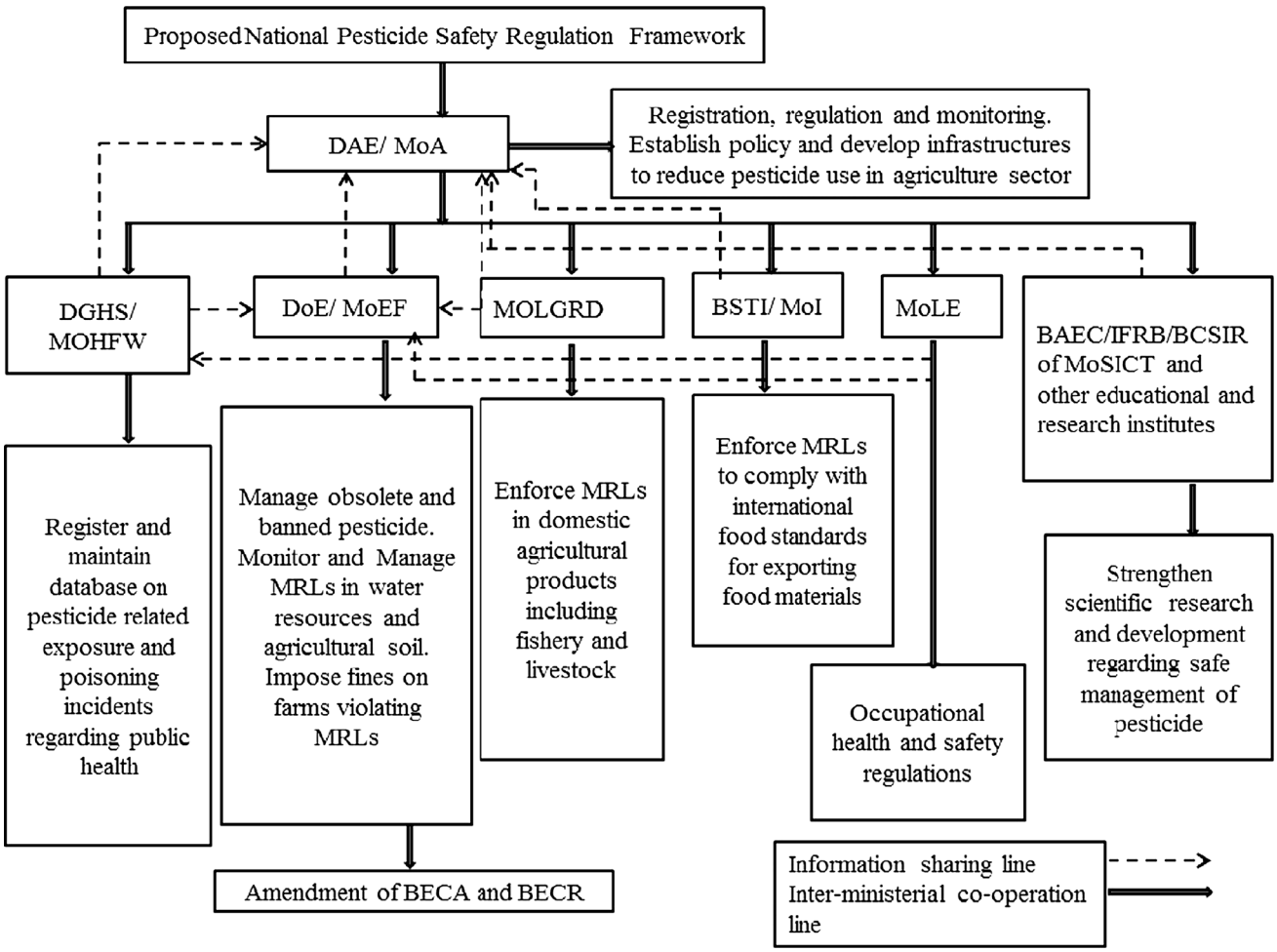

Fig. 3 Proposed pesticide governance framework scheme for environmental, occupational and food safety. The key acronyms used in the figures are: *DAE* Department of Agriculture Extension, *MoA* Ministry of Agriculture, *DGHS* Directorate General of Health Services, *MoHFW* Ministry of Health and Family Welfare, *MRLs* Maximum Residue Limits, *DoE* Department of Environment, *MoEF* Ministry of Environment and Forest, *MoLGRD* Ministry of Local Government, Rural Development and Co-operatives, *BSTI* Bangladesh Standards and Testing Institution, *MoI* Ministry of Industries, *MoLE* Ministry of Labour and Employment, *BECA* Bangladesh Environmental Conservation Act, *BECR* Bangladesh Environmental Conservation Rules, *BAEC* Bangladesh Atomic Energy Commission, *IFRB* Institute of Food and Radiation Biology, *BCSIR* Bangladesh Council of Scientific and Industrial Research, *MoSICT* Ministry of Science and Information Communication Technology (Source: author)

food values. The aim of pesticide governance should be to persuade farmers to undertake levels of pest control that are closer to social optimum. This goal can be achieved through adaptation of a number of different policies, of which the most intuitive could be imposing a tax on pest control treatment that exactly captures its social cost (Waterfield and Zilberman 2012). There is no coordinating mechanism that exists within respect of sound hazardous chemical like pesticide management which have been discussed in the policy and legal structures mentioned in previous sections. Although the existing laws and regulations mentioned in Table 9 can be applied in development of national master plan on sound chemical management of pesticide substances, an inter-governmental agency networking can take an inclusive approach to involve in pesticide regulation to use their respective information.

6.4 Development of pesticide information database

A nationwide pesticide information database can be developed with skilled human resources including organizational structure for better pesticide management. This inter-agency cooperation can be headed with the expertise from DAE of MoA, along with other governmental and education institutions (Fig. 3). Inter-agency information sharing is proposed in the framework for decision-making processes. As an example, DGHS of MoHFW will maintain database on any pesticide poisoning incidents whether intentional or unintentional. In case of unintentional poisoning incidents, relevant agency like DoE can monitor soil, water and other samples including agricultural products. DoE can also propose fine for the violating farms. MoLGRD can monitor MRLs in the agricultural food products in the domestic market, while BSTI of Ministry of Industries (MoI) can check MRLs for international food standards aiming for exports. DAE can further develop emergency response and preparedness to prevent and handle chemical accidents in the pesticide formulation plants. DAE can also train pesticide applicators and farmers on occupational health and safety protocols of handling pesticides and prepare policy. In collaboration with research institutes and educational institutes, DAE can promote and strengthen national capacities and capabilities in pesticide management with respect to environmental, occupational health and food safety.

Moreover, other regulatory mechanisms and policies also need to be in place for controlling pesticide use at farm levels. Information and guideline on the proper application techniques and its handling method should be made available by suppliers association such as BCPA, DAE of MoA and academic institutions. DoE of the MoEF, BSTI of MoI and DGHS of MoHFW can provide information on contamination of environmental components, processed and unprocessed food and acute and chronic poisoning events, respectively, and maintain a country database. All the respective ministries and their associated research wings should attempt to expand their laboratory capacity such that more selective and sensitive monitoring of pesticide and its AI, factory formulation, environmental sample analysis particularly in water and soil, and residues in fresh food can be tested upon arrival. Respective ministries responsible for above-mentioned monitoring program must work in a synchronized manner with academic institutions to research and train farmers to be precise in selecting pesticide relevant to the crops and pest attacked rather than providing irrelevant information. Unfortunately, the limited financial allocation for research and development, lack of human resource with expertise and laboratory resources unavailability means that the system will remain unmanaged in the coming years unless proper policies for system improvements are taken.

7 Conclusion

Sustainable pesticide governance is a burning issue in the present socio-economic and environmental condition of Bangladesh. Here, we reviewed several key mechanisms recognized to manage agricultural pesticides in Bangladesh in the context of its current policies and existing legal infrastructure for better pesticide governance. The list of issues is inevitably extensive, yet others would have different propositions. Nevertheless, the main complication to effective pesticide regulation in Bangladesh is the non-existence of an amalgamated, uniform system designed specifically for pesticide management. Under the existing socio-economic conditions, MFIs providing credits for agricultural activities should encourage to provide green microcredits to farmers for sustainable agricultural activities. Moreover, it is clear that weak law and enforcement for pesticide management under the existing regulations is resulting in environmental contamination and human exposures. Existing policies and laws should be amended—particularly: analysis of pesticide before port clearances, regular update and monitoring of un-registered pesticides in the country, and control in border smuggling of pesticides. Moreover, other regulatory mechanisms and policies also need to be in place for guiding pesticide use at farm levels. Information and guideline on the proper application techniques and its handling method should be made available from suppliers association such as BCPA. DoE of the MoEF, BSTI of MoI and DGHS of MoHFW can provide information on contamination of environmental components, processed and unprocessed food and acute and chronic poisoning events, respectively, and maintain a country database. All the respective ministries

and their associated research wings should attempt to expand their laboratory capacity such that there is more selective and sensitive monitoring of pesticide and its AI. Respective ministries responsible for above-mentioned monitoring program must work in a synchronized manner with academic institutions to research and train farmers to be precise in selecting sustainable pest management methods. Nevertheless, it is a matter of disastrous fact that the fatalities in the system will remain alike unless the policies and regulations are amended and reinforced by the government according to the above-discussed challenges.

Acknowledgements This project was supported by Jahangirnagar University Science Research Grant on "Occupational Health and Safety Assessment of Farmers using pesticides" and provided to Ms. Mashura Shammi.

Compliance with ethical standards

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

References

ADB (2010) Technical Assistance Consultant's Report: Managing Hazardous Wastes. http://www.adb.org/sites/default/files/project-document/62157/38401-01-reg-tacr-02.pdf. Accessed 18 April 2016

Ahmed A, Doe D, Sharma OP, Kumar KCG, Talpur S, Piyasena K (2009) Status of integrated pest management (IPM) in SAARC countries. SAARC Agriculture Centre, Dhaka

Al Mahmud MN, Khalil F, Rahman MM, Mamun MI, Shoeb M, Abd El-Aty AM, Park JH, Shin HC, Nahar N, Shim JH (2015) Analysis of DDT and its metabolites in soil and water samples obtained in the vicinity of a closed-down factory in Bangladesh using various extraction methods. Environ Monit Assess 187:743

Allet M, Hudon M (2013) Green Microfinance: characteristics of microfinance institutions involved in environmental management. J Bus Ethics 126:395–414

Anwar AHMF, Yunus A (2013) Groundwater vulnerability to pesticides in Northwest Bangladesh. Environ Earth Sci 70:1971–1981

Atreya K, Sitaula BK, Johnsen FH, Bajracharya RM (2010) Continuing issues in the limitations of pesticide use in developing countries. J Agric Environ Ethic 24:49–62

BBS (2015) Population projection of Bangladesh dynamics and trends 2011–2061. Bangladesh Bureau of Statistics (BBS) and Statistics and Informatics Division (SID), Ministry of Planning of the People's Republic of Bangladesh. http://www.bbs.gov.bd/WebTestApplication/userfiles/Image/PopMonographs/PopulationProjection.pdf. Accessed 11 Aug 2016

BBS (2016) Bangladesh Bureau of Statistics. http://www.bbs.gov.bd/PageWebMenuContent.aspx?MenuKey=243. Accessed 12 April 2016

BCPA (2016) Bangladesh Crop Protection Association. http://www.bcpabd.com/. Accessed 15 April 2016

BFSA (2015) Bangladesh Food Safety Authority (BFSA). http://www.bfsa.gov.bd/. Accessed 19 April 2016

Bhattacharjee S, Fakhruddin ANM, Chowdhury MAZ, Rahman MA, Alam MK (2012) Monitoring of selected pesticides residue levels in water samples of paddy fields and removal of cypermethrin and chlorpyrifos residues from water using rice bran. Bull Environ Contam Toxicol 89:348–353

Chowdhury MAZ, Jahan SA, Islam MN, Moniruzzaman M, Alam MK, Zaman MA, Karim N, Gan SH (2012) Occurrence of organophosphorus and carbamate pesticide residues in surface water samples from the Rangpur district of Bangladesh. Bull Environ Contam Toxicol 89:202–207

Chowdhury MAZ, Fakhruddin ANM, Islam MN, Moniruzzaman M, Gan SH, Alam MK (2013a) Detection of the residues of nineteen pesticides in fresh vegetable samples using gas chromatography–mass spectrometry. Food Control 34:457–465

Chowdhury MAZ, Islam MN, Moniruzzaman M, Gan SH, Alam MK (2013b) Organochlorine insecticide residues are found in surface, irrigated water samples from several districts in Bangladesh. Bull Environ Contam Toxicol 90:149–154

DAE (2016) Department of Agricultural Extension of Ministry of Agriculture, Government of Bangladesh. http://www.dae.gov.bd. Accessed 12 April 2016

Dasgupta S, Meisner C, Wheeler D (2007) Is environmentally friendly agriculture less profitable for farmers? Evidence on integrated pest management in Bangladesh. Rev Agric Econ 29:103–118

Dewan G (2014) Analysis of recent situation of pesticide poisoning in Bangladesh: is there a proper estimate? Asia Pac J Med Toxicol 3:76–83

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Action in the field of Water Policy, Official Journal of the European Communities L327/1, 22nd Dec 2000. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:EN:NOT

DoE (2007) Department of Environment, Ministry of Environment and Forests, Government of Bangladesh. 2007. Bangladesh National Implementation Plan (NIP) For Management of Persistent Organic Pollutants (POPs). http://www.pops.int/documents/signature/signstatus.htm. Accessed 18 April 2016

FAO (2005) Proceedings Asia Regional workshop implementation, monitoring and observance. International Code of Conduct on the Distribution and Use of Pesticides. Country report: Bangladesh http://www.fao.org/docrep/008/af340e/af340e06.htm. Accessed 15 April 2016

FAOSTAT (2016) http://faostat3.fao.org/download/R/RT/E. Accessed 22 April 2016

GOB (1971) The pesticides ordinance. http://bdlaws.minlaw.gov.bd/print_sections_all.php?id=364. Accessed 12 April 2016

Grama M, Adams F, Siretanu L, Cincilei A, Bulmaga P (2013) Analytical study of obsolete pesticides stockpiles in the Republic of Moldova into Nato Science for Peace Project "Clean-Up Chemicals—Moldova. In: Simeonov LI et al (eds) Environmental security assessment and management of obsolete pesticides in southeast Europe, NATO Science for Peace and Security Series C: Environmental Security. Springer, Berlin. doi:10.1007/978-94-007-6461-3_34

Hossain MS, Chowdhury MAZ, Pramanik MK, Rahman MA, Fakhruddin ANM, Alam MK (2014) Determination of selected pesticides in water samples adjacent to agricultural fields and removal of organophosphorus insecticide chlorpyrifos using soil bacterial isolates. Appl Water Sci 5:171–179

ICDDR, B (2012) Outbreak of illness and deaths among children living near lychee orchards in northern Bangladesh. ICDDR Bull Health Sci B 10:15–22

Jansen K (2008) The unspeakable ban: the translation of global pesticide governance into Honduran national regulation. World Dev 36:575–589

Kabir MH, Rainis R (2014) Adoption and intensity of integrated pest management (IPM) vegetable farming in Bangladesh: an

approach to sustainable agricultural development. Environ Dev Sustain 17:1413–1429
Katalyst (2010) Amendment of pesticide rules—a milestone to promote Integrated Pest Management (IPM). http://katalyst.com.bd/wp-content/uploads/2014/11/News_Issue_20.pdf. Accessed 21 April 2016
Lal A, Israel E (2006) An overview of microfinance and the environmental sustainability of smallholder agriculture. Int J Agric Resour Gov Ecol 5:356–376
Lesueur C, Knittl P, Gartner M, Mentler A, Fuerhacker M (2008) Analysis of 140 pesticides from conventional farming foodstuff samples after extraction with the modified QuECheRS method. Food Control 19:906–914
Martin CA et al (2011) Investigation of an outbreak of unintentional acute pesticide poisoning: assessment of exposure to carbamate and organophosphate insecticides, rural Bangladesh, 2009. Epidemiology 22:S115
MinLaw/GOB (2010) Bangladesh Constitution. Legislative and Parliamentary Affairs Division, Ministry of Law, Justice and Parliamentary Affairs. http://bdlaws.minlaw.gov.bd/print_sections_all.php?id=367. Accessed 12 April 2016
MoA/GOB (1985) Ministry of Agriculture of Government of Bangladesh. "The Pesticide Rules-1985". https://www.ippc.int/static/media/files/cnpublications/2013/06/05/1336289405_pesticide-rules-19851_201304232116en.pdf. Accessed 12 April 2016
MoA/GOB (2002) National Integrated Pest Management Policy. http://moa.portal.gov.bd/sites/default/files/files/moa.portal.gov.bd/policies/0256d1b3_ad07_46c8_adc4_6bb2543cdd93/IPM.pdf. Accessed 12 April 2016
National Parliament of GOB (2009) The Pesticides (Amendment) Act, 2009. http://www.parliament.gov.bd/index.php/en/parliamentary-business-3/business-of-the-house/bill-and-legislation/acts-of-parliament/acts-of-parliament-9th-parliament/acts-of-3rd-session/1774-2-the-pesticides-amendment-act-2009. Accessed 12 April 2016
National Parliament of GOB (2010) Environmental Conservation Act 1995, Amendment 2010. http://moef.portal.gov.bd/sites/default/files/files/moef.portal.gov.bd/page/6e61206f_0b3b_47f7_9461_0f49b0fdd129/beplaw-2010.pdf. Accessed 12 April 2016
National Parliament of GOB (2010) Environmental Court Act 2000, Amendment 2002, Amendment 2010. http://moef.portal.gov.bd/sites/default/files/files/moef.portal.gov.bd/page/6e61206f_0b3b_47f7_9461_0f49b0fdd129/court-act-2010.pdf. Accessed 12 April 2016
National Parliament of GOB (2013) The Food safety act 2013. http://www.bfsa.gov.bd/images/pdf/one-Safe-Food-Act-2013.pdf. Accessed 12 April 2016
Paireau J et al (2012) Litchi-associated Acute Encephalitis in Children, Northern Vietnam, 2004–2009. Emerg Infect Dis 18:1817–1824
PAN International (2016) PAN international consolidated list of banned pesticides. http://pan-international.org/pan-international-consolidated-list-of-banned-pesticides/. Accessed 25 April 2016
Panuwet P, Siriwong W, Prapamontol T, Ryan PB, Fiedler N, Robson MG, Barr DB (2012) Agricultural pesticide management in Thailand: situation and population health risk. Environ Sci Policy 17:72–81
Parveen S, Nakagoshi N (2001) An analysis of pesticide use for rice pest management in Bangladesh. J Int Dev Coop 8:107–126
Planning Commission of GOB (2015) Agriculture Sector Development Strategy: background paper for preparation of 7th Five Year Plan. http://www.plancomm.gov.bd/wp-content/uploads/2015/02/17_-Agriculture-Sector-Development-Strategy.pdf. Accessed 12 April 2016
Puech C, Baudry J, Joannon A, Poggi S, Aviron S (2014) Organic vs. conventional farming dichotomy: does it make sense for natural enemies? Agric Ecosyst Environ 194:48–57
Rahman MM (2007) Mirroring obsolete pesticides issues of Bangladesh through international standards. In: Vijgen J, Plesca V, Barbarasa I, Cupecea L (eds) Forum Book on the 9th International HCH and Pesticides Forum for Central and Eastern European, Caucasus and Central Asian Countries held during 20–22 September, 2007 at Chisinau
Rahman S (2013a) Pesticide consumption and productivity and the potential of IPM in Bangladesh. Sci Total Environ 445–446:48–56
Rahman MM (2013b) Insecticide substitutes for DDT to control mosquitoes may be causes of several diseases. Environ Sci Poll Res 20:2064–2069. doi:10.1007/s11356-012-1145-0
Rahman M, Malek M, Matin M (1995) Trend of pesticide usage in Bangladesh. Sci Total Environ 159:33–39
Rahman MA, Chowdhury MAZ, Moniruzzaman M, Gan SH, Islam MN, Fardous Z, Alam MK (2012a) Pesticide residues in tobacco leaves from the Kushtia district in Bangladesh. Bull Environ Contam Toxicol 89:658–663
Rahman MM, Weber R, Tennekes HA, Sanchez-Bayo F (2012b) Substitutes of persistent organic pollutant (POP) pesticides in Bangladesh and the need for a sustainable substitution process. Organohalogen Compd 74:1178–1181
Robinson EJZ, Das SR, Chancellor TBC (2007) Motivations behind farmers' pesticide use in Bangladesh rice farming. Agric Hum Values 24:323–332
Rouf KA (2012) Green microfinance promoting green enterprise development. Int J Res Stud Manag 1:85–96
Royster MO, Hilborn ED, Barr D, Carty CL, Rhoney S, Walsh D (2002) A pilot study of global positioning system/geographical information system measurement of residential proximity to agricultural fields and urinary organophosphate metabolite concentrations in toddlers. J Expo Anal Environ Epidemiol 12:433–440
Sabur SS (1999) Pesticide marketing system in Bangladesh. Bangladesh J Agric Econ 22:57–78
Schreinemachers P, Tipraqsa P (2012) Agricultural pesticides and land use intensification in high, middle and low income countries. Food Policy 37:616–626
Schreinemachers P, Schad I, Tipraqsa P, Williams PM, Neef A, Riwthong S, Sangchan W, Grovermann C (2012) Can public GAP standards reduce agricultural pesticide use? The case of fruit and vegetable farming in northern Thailand. Agric Hum Values 29:519–529
Schreinemachers P, Wu MH, Uddin MN, Ahmad S, Hanson P (2016) Farmer training in off-season vegetables: Effects on income and pesticide use in Bangladesh. Food Policy 61:132–140
Shammi M, Chowdhury MAZ, Ferdous N, Rahman MA, Islam MN, Sultana A, Chowdhury AKMA, Alam MK (2014) Pesticide contamination of rice field agroecosystem: hazard perspectives of surface water quality and aquatic lives from Gazipur District, Bangladesh. JU Environ B 3:11–22
Sharma D, Nagpal A, Pakade YB, Katnoria JK (2010) Analytical methods for estimation of organophosphorus pesticide residues in fruits and vegetables: a review. Talanta 82:1077–1089
Shidhu SS, Mudahar MS (1999) Privatization and deregulation needed policy reforms for agribusiness development. Springer, Berlin
Thuy PT, Van Geluwe S, Nguyen VA, Van der Bruggen B (2012) Current pesticide practices and environmental issues in Vietnam: management challenges for sustainable use of pesticides for tropical crops in (South-East) Asia to avoid environmental pollution. J Mater Cycles Waste Manag 14:379–387. doi:10.1007/s10163-012-0081-x

UNEP (2016) http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/1608. Accessed 18 April 2016

Villaverde JJ, Sevilla-Moran B, Sandin-Espana P, Lopez-Goti C, lonso-Prados JL (2014) Biopesticides in the framework of the European Pesticide Regulation (EC) No. 1107/2009. Pest Manag Sci 70:2–5. doi:10.1002/ps.3663

Wadud MA (2013) Impact of microcredit on agricultural farm performance and food security in Bangladesh. Inst Microfinance 14:47

Waterfield G, Zilberman D (2012) Pest management in food systems: an economic perspective. Ann Rev Environ Resour 37:223–245. doi:10.1146/annurev-environ-040911-105628

WB (2015) Population density (people per sq. km of land area). http://data.worldbank.org/indicator/EN.POP.DNST. Accessed 12 April 2016

Wesseling C, Corriols M, Bravo V (2005) Acute pesticide poisoning and pesticide registration in Central America. Toxicol Appl Pharmacol 207:697–705

WHO (2009) WHO recommended classification of pesticides by hazard and guidelines to classification 2009. International Program on Chemical Safety. http://www.who.int/ipcs/publications/pesticides_hazard_2009.pdf

WHO/FAO (2014) The International Code of Conduct on Pesticide Management. http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Code/CODE_2014Sep_ENG.pdf. Accessed 22 April 2016