A REVIEW ON ENVIRONMENTAL POLLUTION FROM THE USE OF PESTICIDES IN BANGLADESH

M. F. R. Zuthi[1*], M. H. Mazumder[2], M. Billah[1] & M. T. Islam[1]

[1]*Department of Civil Engineering, Chittagong University of Engineering and Technology, Chittagong, Bangladesh*
[2]*Department of Disaster and Environmental Engineering, Chittagong University of Engineering and Technology, Chittagong, Bangladesh*
[*]*Corresponding author: fzuthi@yahoo.com*

ABSTRACT
Pesticides are mainly used for agricultural use in Bangladesh to prevent vector-borne diseases of crops or plants that are common in the tropical climatic condition of the country. However, the long term use of pesticides on agricultural lands may have toxic effects on environment and public health. Depending on the typical physico-chemical and persistent properties of pesticides, it may travel far along different pathways to contaminate surrounding air, soil and water. In this backdrop, this paper presents a review done on several aspects of pesticide use in agriculture such as the fate of pesticides in environment, their persistent and detrimental effects on environment and several other relevant issues. The factors governing the leaching and transportation potentials of the toxic chemicals of pesticides to surface and groundwater are especially addressed. Attention has also been paid to reveal trends of pesticide use in Bangladesh based on different research findings and following discussions. This review also provides outlook on future actions necessary to protect agriculture and environment of Bangladesh from harmful effects of pesticides emphasizing on raising community awareness for limited use of pesticides, alternative organic agriculture options wherever feasible, national environmental legislations, regulations and monitoring mechanisms about pesticide use etc.

Keywords: Pesticide; environmental pollution; degradation; physico-chemical properties

INTRODUCTION
Pesticides are synthetic organic chemicals intentionally used for protecting crops, preserving foods and controlling plant pests (Chowdhury et al., 2013). These chemicals are used to control weeds in fields and unwanted or harmful pests siuch as insects and mites that feed on crops (USDA NRCS, 1998). Despite their ability to enhance the production and yield of food and fibers by preventing vector-borne diseases, intensive and unrestricted use of pesticide may pose serious threat to the environment and public health (Sitaramaraju et al., 2014; Damalas and Eleftherohorinos 2011; Dey 2010; Rahman and Alam, 1997).
There are various types of pesticides depending on the types of pest they control, and the majority of pesticides do not target the pest only but also affect non-target plants and animals during their application. Most of the pesticides are persistent in the environment for years without degradation due to the chemical, biological or photolytic processes. The pesticide residues, after taken up by the target organisms or being degraded, may be transported to groundwater aquifer, may be transported to surface water bodies, volatilize to atmosphere depending on their physico-chemical properties (Bernardes et al., 2015). A small group of pesticide residues may however be trapped within the environmental system of the place of their application without causing potential harm to surrounding environment. Depending on their chemical properties they may enter the organism, bioaccumulate in food chains and consequently affect human health. In general, intensive pesticide application for agricultural use results in several negative effects on the environment that cannot be ignored.
Being dependent on an agro-based economy, Bangladesh uses varieties of pesticides to protect crops from different pests and consequently to increase crop yield. The widely cultivated and high-yielding

plant varieties of Bangladesh (rice, wheat, jute, potato, sugarcane, vegetables and tea) are highly vulnerable to pests and diseases. Therefore, the use of pesticides has been taken as an obvious and preferable option to the pest control strategies in the agricultural sector of Bangladesh since the demand for agricultural products continually increased to meet the demands of huge population of Bangladesh. However, a very small quantity of pesticides was typically used for agricultural use in the country until 1970s. It is evident from recent research findings that there has been a dramatic increase of pesticide use in the country over the past four decades (Rahman, 2013; Rahman and Thapa, 1999).

A significant number of researches have been conducted on productivity and trend of pesticide use, occupational and environmental health hazard and risk assessment of using pesticide, including field surveys that dealt with assessing effects of pesticide use and widespread use of banned pesticides including incidences of pesticide poisoning (e.g., Dasgupta et al., 2005; Mahmoud and Shively, 2004; Rahman and Hossain, 2003). Few studies have been performed on assessing the leaching potential of pesticides or its residues in either surface water or groundwater, in the soil, and their adverse impacts on aquatic systems (Anwar and Anika 2010; Hasan et al., 2012; Chowdhury et al., 2012, 2013; Zaman et al., 2012; Sumon et al., 2016; Rahman ,2013). However, the study on the factors/properties of pesticides affecting their transport and leaching potential of harmful components of pesticides is still at the rudimentary level in Bangladesh.

In this backdrop, this paper presents a review on the effect of pesticide on environment, public health, environmental fate of pesticide after consumption and their pollution potential in the various components of environment. The discussion follows further on the assessment of the current status, trend and types of pesticide use in agriculture of Bangladesh during the period of 1993-2016 to forecast associated environmental risk potentials. A few suggestions are made at the end of the paper to supplement current practices of pesticide management in Bangladesh which might help minimize potential hazards to environment and human health due to improper use of pesticides for agricultural use in Bangladesh.

PESTICIDES IN AGRICULTURAL USE

Pesticides are divided into different categories such as insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides etc. depending on the target species. Nutritional value of food could be improved by pesticide, and therefore, its use is generally viewed as an economically feasible and efficient tool for pest management (Rahman, 2013; Damalas and Eleftherohorinos, 2011). The main use of pesticides in Bangladesh is for rice (70%) and the remaining 30% is on tea, sugarcane, potato, mango, banana and vegetables (Aziz, 2005). A synthetic group of insecticide named organophosphate (OP) has been introduced in the 1960s while carbamates introduced in 1970s, pyrethroids in 1980s and the introduction of herbicides and fungicides in the 1970s–1980s contributed greatly to pest control and agricultural output (Aktar et al. 2009). A typical pattern of pesticide usage in Bangladesh is presented in [Fig.1 (a)]. In Bangladesh insecticide usage rate (46% of total usage) is the highest (16985 metric ton in 2014) which is very close to overall global use, 44%. (Mathur, 1999). The use of fungicides in Bangladesh is almost similar to insecticide (16138 metric ton, 43% of total pesticide). Oraganochlorine (OC), a group of insecticides used successfully in controlling a number of diseases such as malaria and typhus, were banned or restricted after 1960s in most of the technologically advanced countries. DDT, one of the mostly used OC insecticides, is banned in Bangladesh since 1993 because of their very high toxic potential.

The pesticide consumption in Bangladesh during the period of 1984 -2014 is presented in [Fig. 1 (b)]. Pesticide poisoning is more widespread in developing countries like Bangladesh as compared to developed countries (Hou and Wu, 2010) which might be due to the lack of users' awareness and knowledge on selection or proper use of pesticide. A steady and sharp increase in pesticide use since 1980s, as shown in [Fig. 1(b)] might be due to government's preference to adopt chemical control measures to increase crop production as well as to prevent pre and post-harvest crop losses (Aziz, 2005; Matin, 2003; Rahman, 2013). However, it is also noteworthy from the figure that there is a decrease after the year 2008. The reduction in the usage may be ascribed to the people's increasing awareness about health or environmental hazards and government policies or regulations on limiting use of pesticide in agriculture.

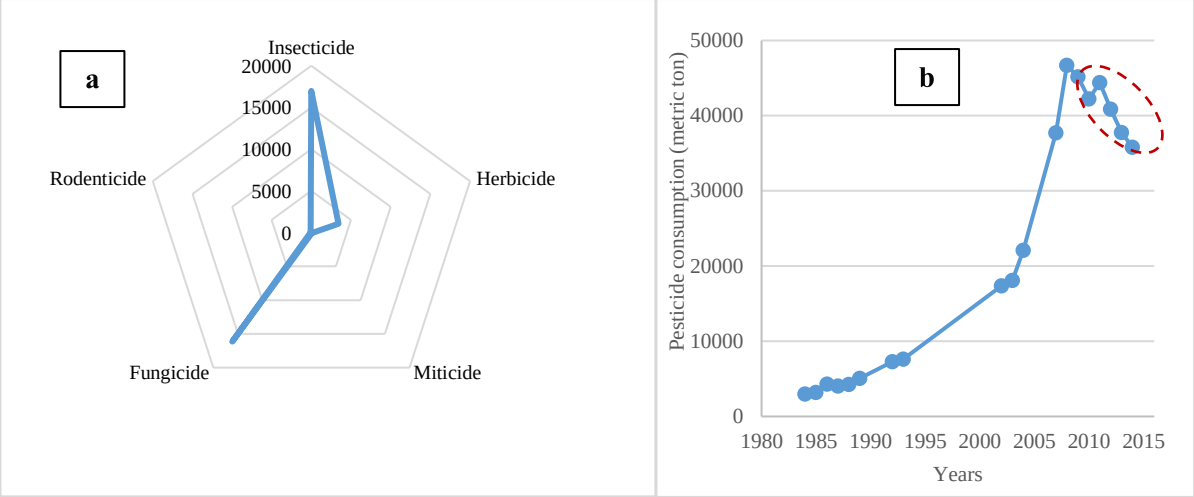

Fig1: (a)Typical pattern of pesticide consumption (metric ton) in Bangladesh in 2014 (Data Source: BCPA) (b) Pesticide consumption in Bangladesh (Data Source: BCPA; Aziz, 2005; Rahman and Alam 1997)

FATE OF PESTICIDES IN THE ENVIRONMENT

Pesticide enters into the environmental cycle through different pathways during its preparation and also during the period of its application or intended use in agriculture. Pesticides are taken up by target organisms, the residues degraded and leached through the soil and transported to the groundwater. They may reach surface water bodies by runoff during rainfall and may also volatilize to the atmosphere, or ingested by non-target organisms. The degradation potential of pesticides determines the behavior and fate of these compounds in the environment. In ideal conditions, they remain in the area of application long enough to achieve desired effects after which they are degraded into harmless products. The fate of pesticides in the environment is shown in [Fig. 3]. The three basic modes of degradation of pesticides in the environment are biological (breakdown by micro-organisms present in the soil), chemical (hydrolysis, redox reactions etc.) and photochemical (breakdown by ultraviolet or visible light) processes (USDA NRCS, 1998). The type and extent of transport from the point of application or degradation in the environment depends on its physicochemical properties (chemical formulation, persistency, water solubility, DT_{50}) of pesticides, soil types and formulation (texture, permeability, organic matter, plant uptake, sorption capacity, volatilization etc.), environmental conditions (e.g., frequency and timing of rainfall or irrigation and depth to ground water, temperature, moisture) etc. (Lourencetti et al., 2008; USDA NRCS 1998, Bernardes 2015).

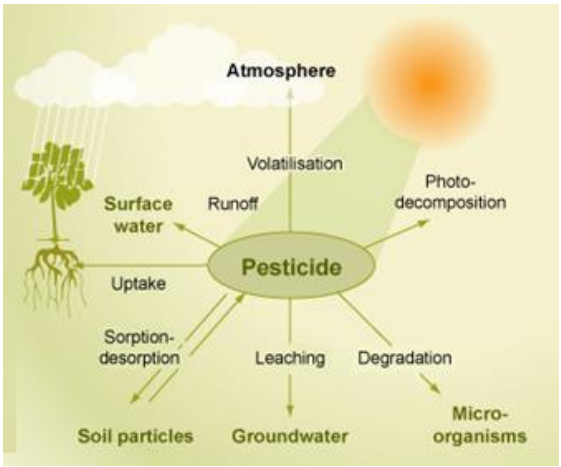

Fig. 3: Fate and degradation of pesticide in the environment (Source: Cromedia)

The solubility of pesticides mainly determines their transport in surface runoff and their leaching capacity to groundwater. The higher the solubility, the greater the carrying and leaching potential. Several researches have been performed to identify the factors contributing to pesticide leaching

(Anwar and Yunus, 2010; Gish et al., 1991; Truman and Leonard, 1991; Agertved et al., 1992). However, detailed study on factors influencing the fate of pesticide is still very limited. Meisener (2004) and Sumon et al. (2016) used the LD_{50} or DT_{50} value to quantify the risk associated with the use of extremely hazardous pesticides. Leaching potential of various of pesticides was studied in a shallow unconfined aquifer located in Northwest Bangladesh (Anwar and Yunus et al., 2010). There was no trace of known pesticide residues in the soil-water found in the study except for a few unknown peaks were detected in the analysis indicating illegal use of some unknown chemicals or some other organics coming from unknown area. The physico-chemical properties of different insecticides which are being used in Bangladesh has been summarized in Table 1.

Table 1: Physico-chemical properties of insecticides mostly used in Bangladesh

Chemical Class	Common Name of Products	Class (WHO, 2010)	LD_{50} (mg/kg) (WHO, 2010)	DT_{50} (days) (Chowdhury et al., 2012)	Water Solubility (mg/L) (Anwar and Yunis, 2010; Vogue et al., 1994)	$DT_{50\_wtaer\ hydrolysis}$ (days) (Sumon et. al., 2016)
Organo-phosphates	Diazinon	II	300	7-15	60	----
	Malathion	II	----	0.49-107	130	6.1
	Chlorpyrifos	II	135	16-72	0.4	25.5
	Cypermethrin	II	c250	----	0.004	179
	Fenitrothion	II	503	----	30	----
Carbamate	Carbofuran	Ib	8.0	13-14	351	37
	Carbaryl	II	c300	0.15-35	120	----
Organo-chlorine	Heptachlor	O	----	----	0.056	----
	Endosulfan	II	80	----	0.32	----

DT_{50}: degradation time for 50% of a compound; **LD_{50}**: lethal dose for 50% of the population $DT_{50\ water\ hydrolysis}$: Half-life in water at pH=7 and 20°C; WHO Classification of Active Pesticide Ingredients: Ib = Highly hazardous; II = Moderately hazardous; O = Obsolete as pesticide, not classified.

WATER POLLUTION DUE TO USE OF PESTICIDES IN AGRICULTURE

Many pesticides may contaminate soil, water, turf and other vegetation particularly due to their unrestricted use in agriculture. Besides killing harmful insects or weeds, pesticides can be toxic to a host of other organisms including birds, fishes, beneficial insects, and non-target plants. Insecticides are generally the most acutely toxic class of pesticides, but herbicides can also pose risks to non-target organisms (Aktar et al., 2009). As water is a vital element of the physical environment, and the quality of water is directly related with human wellbeing, the water pollution because of pesticide has been especially discussed in the paper.

Contamination of water by pesticides is widespread now-a-days, and some of the key-findings of recent researches regarding impact of pesticide on water and aquatic environment have been summarized in Table 2. It is reported in a study done in USA (Aktar et al, 2009) that at least 143 different pesticides and 21 transformation products have been found in groundwater, including pesticides from every major chemical class, and pesticides residues were found in all samples from major rivers with mixed agricultural and urban land uses (USGS, 1995). Different types of herbicides such as 2,4-D, diron and promenton, and insecticides chlorpyrifos and diazinon were detected most often in surface water and groundwater across USA (USGS, 1995). A few studies performed in Bangladesh were mainly aimed at identifying trace of pesticide residues in surrounding water source of an area of application of pesticides (Chowdhury et al., 2012, 2013; Zaman et al., 2012; Hasan et al., 2012; Uddin et al., 2013) and assessing their effects on the aquatic systems (Hasan et al., 2012; Sumon et al., 2016). Although DDT was banned in 1993, its concentration exceeding the guideline value of WHO was found in surface water in several districts of Bangladesh (Chowdhury et al., 2013). Organochlorine insecticide residues are typically found in surface water, irrigated water samples from several districts of Bangladesh. Water samples from from surface water in five locations (Feni, Nawabganj, Putia, Burichang and Chatak) were contaminated with DDT and the water from Natore, Sikderpara, Chatak and Rajoir were contaminated

with heptachlor residues and the highest level detected was 5.24 mg/L, which is above the maximum contaminant level recommended by the World Health Organisation. Sumon et al. (2016) concluded in a risk assessment study that chlorpyrifos, cypermethrin, alpha-cypermethrin, and malathion may pose a high to moderate acute and chronic risks for invertebrates and fish in all evaluated spray drift scenarios and these may have severe consequences for the prawn production yields.

Table 2: Effects of pesticide in water and aquatic environment

Types of pesticides	Name of pesticides	Effect	References
Insecticides	Organophosphates	• toxic effect on aquatic organisms: reduces abundances of invertebrates in the pond	Shahjahan et al., 2016
	Pyrethroids	• Loss of ecological balance: causes death of fishes	Mondal et al., 2015
	Carbamate	• affect water temperature and alkalinity • affect fish size and increase mortality of fish	Altinok et al., 2007
	Chlorinated Hydrocarbon i.e. DDT	• Causes acute toxicity in plants; interferes with growth of oysters, higher residues cause declination of mollusks and shrimps	Goldberg et al.,1971
Herbicides	Bipyridyls	• toxic effect on vegetable seedlings	Mullison 1970
	Phenoxy Hormone	• affects fish, plankton and other water inhabitants	Mullison 1970
Fungicides	Benzimidazoles	• Exhibits toxic effect on aquatic organisms, causes ecological hazard	Wagil et al., 2015
	Dithiocarbamate	• affects breathing of fishes, and hypo- and hyperactive behavior of fishes • loss of ecological balance	Srivastava and Singh, 2014

CONCLUSIONS AND FUTURE OUTLOOK

The freshwater source in many districts of the country is already polluted by the pesticide residues. A comparative fact chart is presented in this paper highlighting consequential toxic effects of human, animal, aquatic lives, plant species and other living organisms. Realizing the fact of long-term adverse effects of using certain group of pesticides, the government of Bangladesh has already started some practices across the country e.g., integrated pest management options (IPM), farmers' awareness programs, formulating and adopt regulations and legislations on proper application of pesticides etc. However, more detailed study should be conducted in all different regions of the country to assess the pollution risk on different phases of environment through different pathways. The presence of few banned pesticides in different environmental components indicates weakness in regulatory practices. Therefore, a combined and focused approach to minimize the explosion in pesticide usage is a pressing demand. Raising countrywide community awareness, promoting organic farming and organic pest management wherever feasible, strict enforcement and monitoring of existing pesticide regulations and expansion of IPM are recommended to make the agricultural sector more sustainable and more protected against the harmful effects of pesticides.

REFERENCES

Agertved, J., Rugge, K. and Barker, JF., 1992. Transformation of the herbicide MCPP and atrazine under natural aquifer conditions. *Groundwater*, 30(4), 500-506.

Aktar, MW; Sengupta, D; Chowdhury, A, 2009. Impact of Pesticides Use in Agriculture: Their Benefits and Hazards. *Interdisc Toxicol*., 2(1), 1–12.

Altinok, I and Capkin, E. 2007. Histopathology of Rainbow Trout Exposed to Sublethal Concentrations of Methiocarb or Endosulfan. *Toxicol. Pathol.*, 35(3), 405-410.

Anwar, AHMF and Yunus, A., 2010. Pesticide Leaching Potential in a Shallow Unconfined Aquifer. *J. Water Environ. Technol.*, 8 (1), 1-16.
Aziz, MA; 2005. Bangladesh Country Paper. Proceedings of the Regional Workshop on Implementation Monitoring and Observance: International Code of Conduct on the Distribution and Use of Pesticides. FAO-RAPA, Thailand.
BCPA (Bangladesh Crop Protection Association). Pesticide consumption 2007-2014. http://www.bcpabd.com/pesticide-consumption.php (Last date of Access: 3 December 2016)
Bernardes, F; Furio, M; Lilian, MP; Pereira, C and Dorta, DJ. 2015. *Toxicology Studies - Cells, Drugs and Environment*, INTECH; p195-233.
Chowdhury, MAZ; Banik, S; Uddin,B; Moniruzzaman, M; Karim, N. and Gan, SH, 2012. Organophosphorus and Carbamate Pesticide Residues Detectedin Water Samples Collected from Paddy and Vegetable Fields of the Savar and Dhamrai Upazilas in Bangladesh. *Int. J. Environ. Res. Public Health* 9, 3318-3329.
Chowdhury, MAZ; Islam, MN; Moniruzzaman, M; Gan, SH. 2013. Organochlorine Insecticide Residues are Found in Surface, Irrigated Water Samples from Several Districts in Bangladesh. *Bull. Environ. Contam. Toxicol*., 90 (2), 149-154.
Cromedia. Pesticides Fate and Degradation. http://www.chromedia.org/chromedia?waxtrapp=emorjDsHonOvmOlIEcCUtC&subNav=noomrDsHonOvmOlIEcCUtCH. (Last date of access: 3 December 2016).
Damalas, CA; Eleftherohorinos, I.G. 2011. Pesticide Exposure, Safety Issues, and Risk Assessment Indicators. *Int. J. Env. Res. Public Health*. 8:1402-1419.
Dasgupta, S; Meisner, C. 2005. Health Effects and *Pesticide* Perception as Determinants *of* Pesticide Use*:* Evidence from Bangladesh. *Washington, DC: The World Bank Policy Research Working Paper #3776.*
Dey, NC. 2010. Use of Pesticides in Vegetable Farms and Its Impact on Heath of Farmers and Environment. *Env. Sci. Technol*. II: 134-140.
Gish, TJ., Isensce, AR., Nash, RG., and Helling, CS., 1991. Impact of Pesticides on Shallow Groundwater Quality. *Soil and Water Division, Transactions of the ASAE*, 34(4), 1745-1753.
Goldberg, ED., Bitler, P., Meier, P., Menzei, D., Paulik, G., Risebrough,R. and King, M.K., 1971.Chlorinated Hydrocarbons in the Marine Environment.Report Prepared by the Panel Monitoring Persistent Pesticides in the Ocean. National Academy of Sciences, Washington, DC, P-42.
Hasan, S., Rabbani, KA., Hossain, MA., and Rahman ML., 2012. Persistent Organic Pollutants and Pesticide Residues in Seasonal Waters of Rural Bangladesh *Int. J. Environ.*, 2(1), 41–47.
Hou, B and Wu, L., 2010. Safety Impact and Farmer Awareness of Pesticide Residues. *Food Agricul. Immunol*., 21, 191-200.
Lourencetti C; Marchi MRR; Ribeiro, ML., 2008. Determination of Sugar Cane Herbicides in soil and Soil Treated with Sugar Cane Vinasse by Solid-Phase Extraction and HPL CUV. *Talanta*, 77, 701-709.
Mahmoud, C and Shively, G. 2004. Agricultural Diversification and Integrated Pest Management in Bangladesh. *J. Int. Assoc. Agricul. Econ*., 30 (3) 187–194.
Mathur, SC., 1999. Future of Indian Pesticides Industry in Next Millennium. *Pesticide Information*,24(4), 9-23.
Matin, MA; Taylor, MD; Klaine, SJ; Carvalho, FP; Barcelo, D and Everaarts, J. 2003. Pesticide Residues in Coastal Tropical Ecosystems: Distribution, Fate and Effects. pp:137-158. Taylor and Francis Group, London.
Meisner, C., 2004. Report of pesticide hotspots in Bangladesh. Development Economics Research Group, Infrastructure and Environmental Department. The World Bank.
Mondal, K., Karmakar, B., Haque, S., 2015. A review on effects of Pyrithroids pesticides on fresh water fish behaviour and fish production. J. Global Biosci., 4 (6), 2594-2598.
MULLISON, WR., (1970). EFFECTS OF HERBICIDES ON WATER AND ITS INHABITANTS.*WEED SCIENCE*, 18(6),738-750.
Rahman S., Hossain M. Z., 2003 Pesticide Demand in Hybrid Seed Production Technology. *Food Agricul. Environ.*, 1(3-4), 174-179.
Rahman, M.H. and Alam, MJB. 1997.Risk Assessment of Pesticides Used in Bangladesh. *J. Civil. Engg. IEB*, CE 25(1), 97-106.

Rahman, S. 2013. Pesticide Consumption and Productivity and the Potential of IPM in Bangladesh. *Sci. Tot. Environ.*, 445–446, 48–56.
Rahman, S; Thapa, GB; 1999. Environmental Impacts of Technological Change in Bangladesh Agriculture: Farmers' Perceptions and Empirical Evidence. *Outlook on Agriculture*, 28, 233 – 238.
Shahjahan, M; Kabir, MF; Sumon, K.A., Bhowmik, LR; Rashid, H. 2016. Toxicity of organophosphorous pesticide sumithion on larval stages of stinging cat fish *Heteropneustes fossilis*. *Chinese J. Oceanol.Limnol*., doi.org/10.1007/s00343-016-5173-3
Sitaramaraju, S; Prasad, NVVSD; Reddy, VC; and Narayana, E., 2014. Impact of pesticides used for crop production on the environment. *J. Chem. Pharma. Sci*, 3: 75-79.
Srivastava, P. and Singh, A., 2014. Potential Effects of Fungicides (Mancozeb) on Fish *Clarias Batrachus. Res. J. Bio. Sci*., 9(4), 129-134.
Sumon, KA; Rico, A; Mechteld, MS; Horst, T; Paul, J; Brink, VD; Haque, MM. and Rashid, H., 2016. Risk Assessment of Pesticides Used in Rice-Prawn Concurrent Systems in Bangladesh. Sci. Tot. Environ., 568, 498–506.
Truman, CC., and Leonard, RA., 1991. Effect of Pesticide, Soil, and Rainfall Characteristics on Potential Pesticide Loss by Percolation - a GLEAMS Simulation. *Soil and Water Div, Trans ASEE*, 34(6), 2461-2468.
Uddin, M. A., Saha, M., Chowdhry, MAZ., and Rahman, MA., 2013. Pesticide Residues in Some Selected Pond Water Samples of Meherpur Region of Bangladesh. *J. Asiat. Soc. Bangladesh, Sci*. 39(1): 77-82.
USDA NRCS (USDA National Resources Conservation Services), 1998. Soil Quality Concerns:Pesticide. Soil Quality Information Sheet.
USGS (US Geological Survey), 1995. Pesticides in the atmosphere: current understanding of distribution and major influences. Fact Sheet FS- 152-95. http://water.wr.usgs.gov/pnsp/atmos/
Vogue, PA., Kerle, EA. and Jenkins, JJ., 1994. OSU Extension pesticide properties database. National pesticide information centre, Oregon State University (http://npic.orst.edu/ppdmove.htm)
Wagil, M; Białk-Bielińska, A; Puckowski, A; Wychodnik, K; Maszkowska, J; Mulkiewicz, E; Kumirska, J; Stepnowski,P; Stolte, S., 2015. Toxicity of anthelmintic drugs (fenbendazole and flubendazole) to aquatic organisms. *Environ. Sci. Pollut. Res*., 22 (4), 2566-2573.
WHO (World Health Organization), 2010. A Report on the WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification: 2009.
Zaman, M., Naser, MN., Hossain M., Husain, M., Islam, A., Islam, KA, and Sultana, N., 2012. Pesticide Residues and Harmful Organic Pollutants in Some Freshwater Fishes from Matlab Floodplain Area, Bangladesh. *Bangladesh J. Zool*., 40(1), 101-108.