

Master's Thesis on

Effects of pesticide use in agriculture sector in Bangladesh: A one health approach

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57th Master of Public Health/International Course in Health Development

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Effects of pesticide use in agriculture sector in Bangladesh: A one health approach

A thesis submitted in partial fulfilment of the requirement for the degree of Master of Science in Public Health.

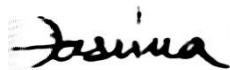
By

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Declaration: Where other people's work has been used (from either a printed or virtual source, or any other source), this has been carefully acknowledged and referenced in accordance with academic requirements. The thesis Effect of pesticide using in agriculture sector: A one health approach is my own work.

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List of Abbreviations

AEZ=Agro-ecological zone

BRRI= Bangladesh rice research institute

BARI=Bangladesh agricultural research institute

BINA= Bangladesh institute of nuclear agriculture

BSTI= Bangladesh standards and testing institution

COPD= Chronic obstructive pulmonary disease

DAE=Department of agriculture extension

DDT= Dichlorodiphenyltrichloroethane

EFSA= Euro péan food safety authority.

EU=European union

EPA =Environmental protection Agency

FAO=Food and agriculture organization

GDP= Gross Domestic Product

GAP=Good Agriculture practice

HCH= Hexachlorocyclohexane

IARC=International agency for research on cancer

IGF1=Insulin-like growth factor1

IPM=Integrated pest management

ICDDR'B= International Centre for Diarrheal Disease Research, Bangladesh

LBW=Low birth weight

MOA= Ministry of agriculture

MOH=Ministry of health

MAC= Canadian maximum acceptable concentration

MRL=Maximum residue level

NAS=National Academy of science

SDG=Sustainable development goals

USEPA=United states environmental protection agency

WHO=World health organization

Glossary

Pesticide= “Pesticide means any substance, or mixture of substances of chemical or biological ingredients intended for repelling, destroying or controlling any pest, or regulating plant growth”. (FAO/WHO 2016)

Pesticide residue= “Pesticide residue means any specified substance in food, agricultural commodities, or animal feed resulting from the use of a pesticide. The term includes any derivatives of a pesticide, such as conversion products, metabolites, reaction product, and impurities considered to be of toxicological significance”. (CODEX ALIMENTARIU)

Exposure to pesticides= “It means any contact between a living organism and one or more Pesticides”. (FAO/WHO 2016)

MRL= “A maximum residue limit (MRL) is the highest level of a pesticide residue that is legally tolerated in or on food or feed when pesticides are applied correctly in accordance with Good Agricultural Practice” (CODEX ALIMENTARIU)

MCL= “Maximum contaminant levels (MCLs) are standard for drinking water quality. An MCL is the legal threshold limit on the amount of a substance that is allowed to public water system under the safe drinking water”. (USEPA 1974)

Hazard= “Hazard means the inherent property of a substance, agent or situation having the potential to cause undesirable consequences (e.g., properties that can cause adverse effects or damage to health, the environment or property)” (FAO/WHO 2016)

Risk= “Risk is the probability and severity of an adverse health or environmental effect occurring as a function of a hazard and the likelihood and the extent of exposure to a pesticide” (WHO/WHO 2016)

Risk Management= “Risk Management is a technique for the systematic identification and implementation of all the measures necessary to limit the likelihood of risks occurring” (European Union).

Highly Hazardous Pesticide= “Highly Hazardous Pesticide means pesticides that are acknowledged to present particularly high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems such as WHO or GHS or their listing in relevant binding international agreements or conventions”. (FAO/WHO 2016)

One health= “One Health is an approach to designing and implementing programmes, policies, legislation and research in which multiple sectors communicate and work together to achieve better public health outcomes” (WHO 2017).

CODEX ALIMENTARIUS = “The *Codex Alimentarius* is a collection of internationally recognized standards, codes of practice, guidelines, and other recommendations published by the FAO and WHO relating to food, food production, labelling, safety, trade” (CODEX website).

Abstract

Introduction: Agriculture is an important sector for Bangladesh not only for contributing to food production but also for engaging a large number of jobs. Farmers of Bangladesh largely depend on different kind of pesticides to protect their crops from insects and disease. Regardless of the benefits of pesticides, they can have toxic impacts on human health and on the environment. This study examines the different outcomes of pesticides on public health and the environment in order to give recommendations to reduce the harmful effects.

Methodology: A literature review was conducted with relevant papers and grey literature. The data were analyzed using the EPA framework for human health risk assessment and the One health approach framework for policy, legislation, and governance.

Results: Pesticides are toxic substances that are hazardous for humans and the environment. The toxicity depends on the active ingredients and route of exposure to the human body. Farmers are at the front-line of the consequences and substantial exposure is also common in their family members. The general population can be affected by the residues of pesticides that remain in the environment and indirectly affect health. Most of the pesticides cause acute or chronic health problems as a consequence of the wrong application process and lack of protective measures while using them. Promoting best practices like Integrated Pest Management, focusing on Good Agriculture Practices, and increasing awareness in maintaining personal protection can help to manage the risk of exposure. Continuous monitoring and surveillance systems are needed to strengthen existing guidelines and translate them into practices.

Conclusion and recommendations: A multidisciplinary and cross-sector stakeholder involvement through a one health approach has the potential to address the adverse consequences of pesticide exposure to human health and ecosystems.

Key word: Pesticides, effect, public health, one health, Bangladesh.

Word count: 10,782

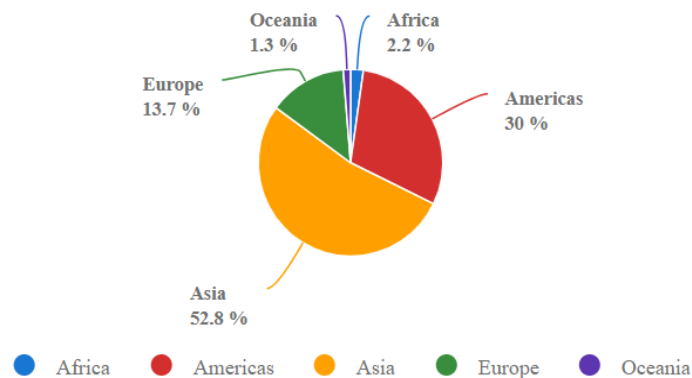
1. Introduction:

Agriculture plays a significant role in Bangladesh's economy for a longer period of time. According to the latest estimation, it contributes about 13.02 percent to the country's Gross Domestic Product (GDP) and employs around 40.6 percent of the total labor force (1). In spite of decreasing size of arable land, the growth of agriculture in the last decade has been significantly raising. The food grain production has increased to 36 million metric tons in 2019 which is 25% higher from 2008. Bangladesh also achieved significant progress in vegetable production (2). The farmers and the agricultural laborers are the key players in such achievements.

Farmers use pesticides in their farmland to protect their crops against different kinds of insects, weeds and living organisms intended to increase their production(3). Over the past two decades world trends of pesticide use have been increasing and Southeast Asia has the highest share (52.8%) of pesticide use worldwide.

Figure 1: Percentage of world pesticide use by continent

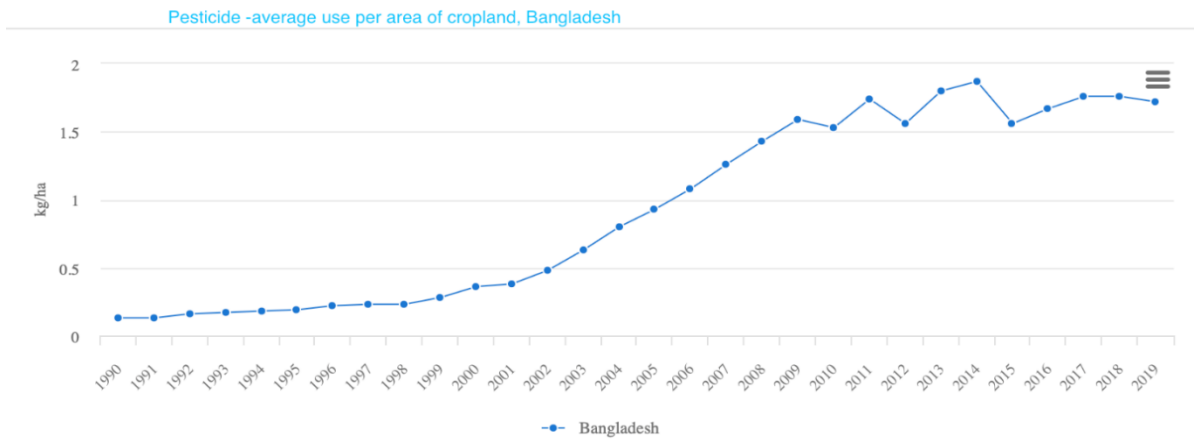
Pesticides (total) + (Total) by continent,
Average 1990 - 2019



Source: http://www.fao.org/faostat/en/?fbclid=IwAR27UKQBODdwt3aTZ4bzsFdmYL4W6I1r_2dTqWU6GxBwIfSvlJc9milxa94#data/RP/visualize

According to WHO 'Pesticides are chemical compounds that are used to kill pests, including insects, rodents, fungi and unwanted plants (weeds)'(4). Pesticides may be derived from organic or synthetic sources where the second one causes a most potential hazard for human health(5). The use of pesticides has been increased in Bangladesh per hector of agricultural land over past decade. The figure is showing that from 1990 it continuously raised the usage of pesticide which was decreased in 2012 and 2013, after one year it rose and remained same to the end.

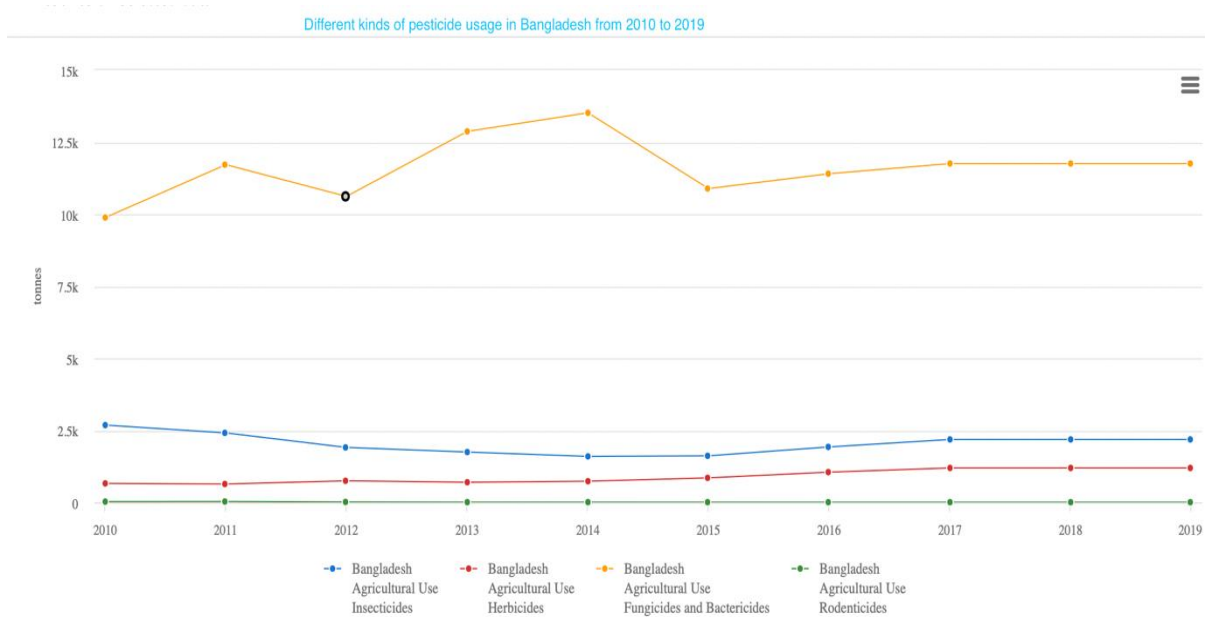
Figure 2: Trend of pesticide use (kg/ha) in Bangladesh from 1990 to 2019



Source: FAOSTAT, 2021(<http://www.fao.org/faostat/en/#data/RP/visualize>)

Generally four types of pesticides are used in agro-farm named insecticides, fungicides, herbicides and rodenticides(6). Farmers from Bangladesh is using all four kinds of pesticides for crop production, among them fungicide is using in highest amount followed by insecticide.

Figure 3: Using trend of four pesticide group in Bangladesh from 2010 to 2019



Source : FAOSTAT, 2021(<http://www.fao.org/faostat/en/#data/RP/visualize>)

Apart from the beneficial sides pesticide use is a rising concern for human health as well as the adverse effects on the environment (6). Human poisoning from pesticides has a long history, now about 44% of farmers are getting exposed to unintentional acute pesticide poisoning worldwide (7). It has the potentiality to create different diseases in human being specially those

who are handling it directly and come in close contact with it (8). Farmers or farmworkers are at the front line of the risk. People in general can also get exposed to its residual effects through on water or food if the safe application method and recommended dose are not applied the residue can remain in harvested foods and water bodies (9). Besides this, the family members like women and children are also considered in risk of the harmful effect of pesticides (10).

Pesticides have active ingredients and chemical compounds which are harmful to humans as well as the environment (11). Health, environment, and food safety are interlinked, improper handling and misuse of the pesticides can pose a great risk for human beings and the ecosystem directly or indirectly. There are international legislations by international organizations like WHO, FAO, European Union where the application procedures and safety measures are described. Although countries also make their own policies and guidelines, they also align with international recommendations.

Bangladesh National Agriculture Policy has as key objective to ensure food security through diversified crop production (12). Health is also an issue and the policy has a section (18.2) on labor welfare which indicates reducing risks in agricultural work. It also indicated to ensure good agricultural practice which can reduce the use of the harmful pesticide (12). Bangladesh signed the Sustainable Development Goals (SDG) declaration where goal 2 calls about food security and sustainable agriculture and goal 3 mentioned about ensuring healthy lives for all ages within 2030. SDG also promotes leaving no one behind, so it is important to focus on this vital sector to achieve food safety and well-being.

The one health approach is an integrated approach that looks at health from the perspective of the symbiotic relationships between humans, animals and the environment, from root causes and multiple sectors perspective, and in this thesis, the concept is applied to pesticide use in relationship to sustainable agriculture, human health and the environment (13).

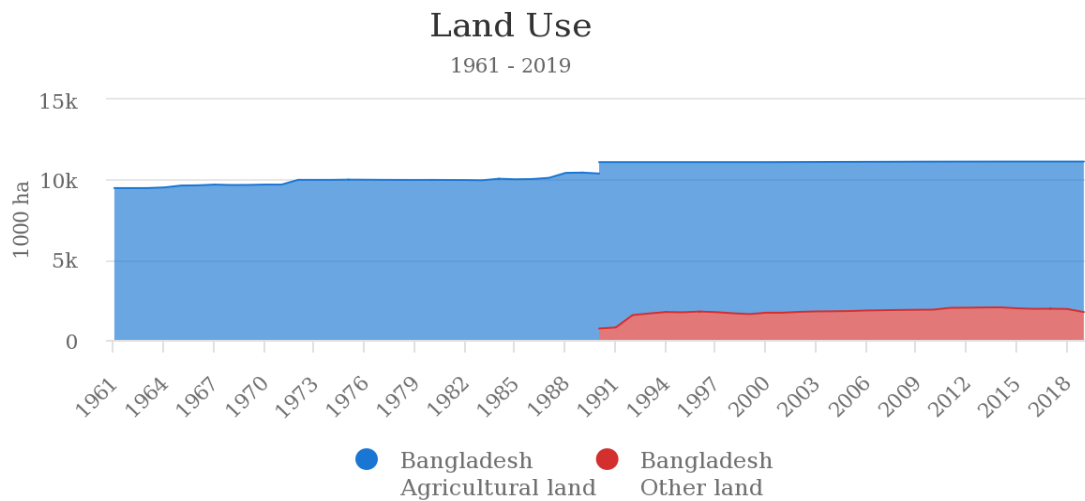
1.1 Background:

Bangladesh is located in the northeast part of South Asia covering an area of 147,570 square kilometers. It is the most populous country in the world with a 157.9 million population with a high density of population of 1070 per sq. km. The sex ratio of the population is 100.2 males per 100 females.

World Bank declared Bangladesh as a lower middle-income country based on the new income classification. The Gross National Income (GNI) and Gross Domestic Product (GDP) per capita in Bangladesh have increased to US\$2,064 and US\$1,970 respectively in FY 2019-20(14). Traditionally Bangladesh has a distinct agricultural setting. In spite of being a small country, Bangladesh has different land types in different areas. The total agricultural land is divided into 30 agro-Ecological Zone (AEZ) according to the nature of ecological and soil characteristics.

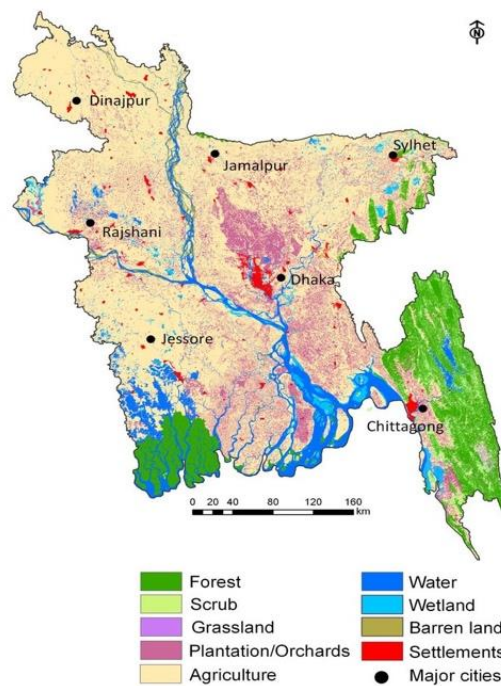
Rice is the main staple crop cultivated in 75% of the area of agricultural land, after that wheat, potato, vegetable, and oilseeds and fruits take place (14). The fig:4 is showing that the land is mostly using for agriculture purpose from the beginning and remained. The map of Bangladesh is showing the divided area among all over the Bangladesh which also indicates that agriculture is the large sector to use the land over the country.

Figure 4: Land use trend of Bangladesh from past decades



Source: FAOSTAT (Aug 08, 2021)

Figure 5: Maps of Bangladesh (Based on land usage)



1.2 Problem Statement

Pesticides are considered an easy solution to control pests and increase yields. It uses to kill harmful substances and insects but they can cause harm to non-target creatures such as beneficial insects and other plants(15).It can cause short-term, intermediate and long-term effects on human health by contact, inhalation or ingestion (16). Misuse of pesticides also affects the environment as soil and water. The pesticides can be washed off to the nearest water bodies and contaminate them. It can also happen by improper disposal and accidental leakages(15). So, Unregulated and often excessive use of pesticides is a rising concern for health in Bangladesh and similar agro-based countries.

Consideration to public health there is a threshold recommended by world regulatory bodies which indicate the upper limit of remaining residue in foods water or soil. Most of the country has its own administrative legislation align with global regulation for using pesticides properly(17). Now pesticide poisoning is a challenging problem all over the world specially in low- and middle-income countries. It is reported that Southeast Asia has the highest number of unintentional pesticide poisoning exposure cases compared to than other regions of the world (7). In India farmers are using pesticides carelessly, the residues of pesticides has been found in food commodities, human blood samples even in breast milk, above the maximum level. The adverse health effect is noticed from mild problems such as skin disease, weakness, eye irritations to severe non-communicable disease like cancer, lung defect, and respiratory problems.(18). In Nepal, pesticide use in the agricultural sector is comparatively low compared to than other low- and middle-income countries but farmers do not maintain the safety measures, a study found that about 51% of farmers are suffering acute health problems and one in ten farmers have chronic diseases like neuropathy (19). The adverse effects are not only found in human health also in environment like soil and water which can have indirect effects on health (15)(20). This will indirectly lead to the adverse effect to human health again.

In Bangladesh 63 % of people live in rural area (21) and most of them depend on agricultural livelihood (22) Pesticides are widely used in Bangladesh agriculture specially in the crop sector, from 2015 to 2019, a total of 1.56 to 1.76 kg of pesticide was used in per hectare cropland and total use of pesticide was 15144 ton(23).

Farmers are using pesticides in different crop fields but not following proper guidelines for example most of them are not wearing protective equipment. Moreover, they are not maintaining the recommended dose and after using pesticides they are not following the storage and decomposition rules for emptying cans of pesticide.(24). Most of them are ignoring the safety guidelines and as a consequence, it affects their health as well as the environment (24). Different surveys were conducted with vegetables and rice farmers and found that common vegetables like beans, eggplant, cauliflower contain high levels of pesticides residues(25).

Similar studies showed that farmers are using pesticides carelessly with bare hands and without protection, eating foods, drinking, water or smoking while using it. Some farmers have ideas about the adverse effect of direct handling of poisonous compounds but they are not able to purchase the protective equipment. Improper use of pesticides may lead to different disease as skin or eye problem, gastrointestinal tract diseases or even cancer(26). Bangladesh government has banned hazardous pesticides according to WHO guidelines but still is the illegal trade and improper use of hazardous pesticides are making the situation worse for health and the ecosystem. Ministry of agriculture have a project of farmers field school where they get training about farming system but this is not enough to cover such a wide sector. Moreover, the training content is not updated by public health effects of pesticides.

1.3 Justification:

Pesticide use and its negative impact is a rising concern. It affects directly to the human being by getting contact with it or indirectly through the residue from food and water. Agriculture workers are the most vulnerable for their occupational characteristics, their family members are also at high risk of the adverse consequences of pesticides. In Bangladesh a number of studies focused on the health risk of farmworkers and related people who are suffering from different kinds of acute and chronic diseases like respiratory tract infection, skin diseases, zoonotic diseases, and even risk of particular cancer(26) Also there are many unreported cases caused by long term pesticide exposure (7).

Pesticides are an important and reliable tool in pest management system to curtail crop losses. At the same time, their haphazard use can create acute and chronic diseases on user's health. It can also pollute the environment through the accumulation of residue in food, soil, water bodies, and air (27).

Pesticides can enter through contact by skin, ingestion by mouth or inhalation by the nose into the human body (16). Some pesticides are already banned from respected regulatory organizations because of their toxic characteristics and active ingredients which are considered a greater risk for human health and the environment. There is a classification of hazardous pesticides by WHO which are recommended not to sell, buy or use in the crop field (28). WHO and FAO also provide an international code of contact of highly hazardous pesticides guidelines where it is described how any individual country can classify the hazardous pesticides for public health. The guideline also helps to introduce the safe use of pesticides in the field (29).

Bangladesh government also banned some hazardous pesticides and there is a list of approved pesticides by the technical advisory committee(30). But still, there is the illegal trade of banned pesticides and they are used in the field which is a threat for human health and the environment.

There is a huge knowledge gap among the farmers use about the safety of pesticide for example wearing protective equipment or maintaining the recommended limit. Most people are not aware of personal hygiene and safety precautions before and after use of the pesticides. There is a lack of knowledge about the storage and disposal of pesticide containers (31). If the used cans are not managed adequately, it can be used for storing foods or water and causes poisoning. Moreover, the leftover pesticide from the abandoned containers can lead to pollution in soil and groundwater which indirectly affects human health(32). Sometimes farmers ignore the harvesting interval time after application of pesticide to the food commodities. It may cause an immediate effect on the consumers (33).

The knowledge and awareness can depend on geographical areas, education, training or experience. In Bangladesh there are legislations, laws, and acts regarding the safe use of pesticides, Bangladesh has published a gazette for using rules of pesticide (34). Department of agriculture extension (DAE) is giving awareness training to the farmers about using rules and regulations of pesticides but more workforce is needed to cover the huge numbers of farmworkers. Sometimes in spite of getting knowledge small scale farmers cannot manage the protection equipment for their poor economic condition. DAE published guideline manuals regarding good agriculture practices and integrated pest management which focus on the safe use of pesticides. Nevertheless, there is a lack of awareness, behavioral practice exists among on the users of the pesticides (35). More over a combine monitoring process is missing from respected authorities.

1.4 Objectives:

a. General objectives: To explore the impact on the health and environment of pesticide usage in crop production in Bangladesh and provide recommendations to prevent this problem in Bangladesh.

b. Specific Objectives:

- I.** To describe the burden of public health from pesticide use in Bangladesh.
- II.** To critically discuss the underlying mechanisms and risk factors associated with this the burden.
- III.** To review best practice and existing interventions and guidelines to mitigate the public health risk associated with pesticide usage.
- IV.** To recommend based on the findings the best practices to reduce the burden of health problems associated with pesticide usage in Bangladesh.

2. Methodology:

2.1 Search strategy:

This is an in-depth literature review and desk study. Literature searched in VU Library, google scholar, google, Vrije University (VU) library PubMed for review. Country-level journals were also searched for review. National and international strategy, policies, guidelines, reports articles and evidence-based documents are reviewed. Relevant and authentic articles or documents published on various sites are also extracted to review. At first, I searched the literature with keywords then I narrowed it down according to my objectives.

Use of specific words: Pesticides, health, environment, effect, Bangladesh.

Publication year: I used the publication from 2010 to 2021. But for some regulations, ordinances, acts and laws, I have to use older publications than 2010.

Language: The papers published in English were included.

Inclusion and exclusion criteria: I included the studies conducted in Bangladesh. However, sometimes, the study from other countries in the Asian region is also included because of the limitation of the data. Both gray literature and peer-reviewed articles were examined.

2.2 Limitations:

Some articles were not accessible so I excluded those and I only examined the paper published in the English language. There were many publications in another language that may very important I did not include.

2.3 Framework:

I used two frameworks for this study. One is Human health risk assessment by EPA and another is One health approach by the Lancet commission. The description of both frameworks is given below:

a. Human health risk assessment to inform decision making:

The conceptual framework of human health risk assessment to inform decision making from Environmental protection Agency (EPA), United States (36).

At first National Academy of science (NAS) of United States, developed the risk assessment framework in 1983. After that in 1984 US Environment Protection Agency developed another conceptual model aligned with the previous frame work. It added more components, emphasized the human health and named ‘human health risk assessment framework to inform decision making’. It also invoked community and stakeholders for decision purpose. There are several elements in this frame but I took the risk assessment part which describes for my study describes the link between risk assessment and decision making

The risk assessment framework consists below steps.

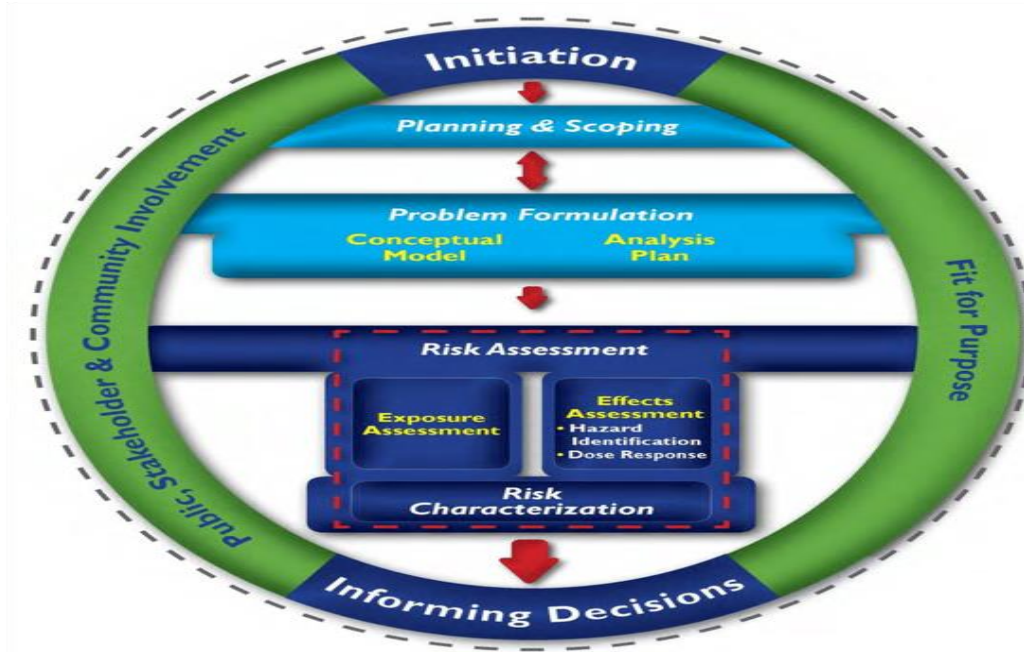
- Exposure assessment: It shows how human beings can come into contact with different hazardous substances, for example, the route of exposure and the different stressors like chemical, biological or physical compounds. It also focuses on those who are the most vulnerable or at higher risk. Moreover, it focuses on patterns of exposure for example frequency or duration of contact of the toxic compound.
- Effect Assessment: This is divided into two parts: hazard identification and dose-response relations. Hazard identification describes the type of human health problem caused by each agent for example disease or birth defect. It also shows the mode of action how the toxins work in the human body. Dose-response describes how the contaminants and health problems or outcomes relate.
- Risk characterization: It shows the existing condition of risk which may be counted by quantitative or qualitative estimates. It combines hazards and exposure risk to evaluate the true risk for potential health problems from a compound for a particular exposed group.

All these above steps lead to the last level of the framework which is informing decisions. It considers many factors such as cost, technology sustainability also focuses on limitations or uncertainty for decision making.

The outer layer describes the engagement of stakeholders for example public, the community, or other partners. People’s participation is too important to achieve any mission to protect human health and the environment. I did not take the initiation part which consists of planning and scoping because it will not match with my current analysis.

Figure 6: Human health risk assessment to inform decision making from EPA (Environmental protection Agency),

Source: USEPA,1984

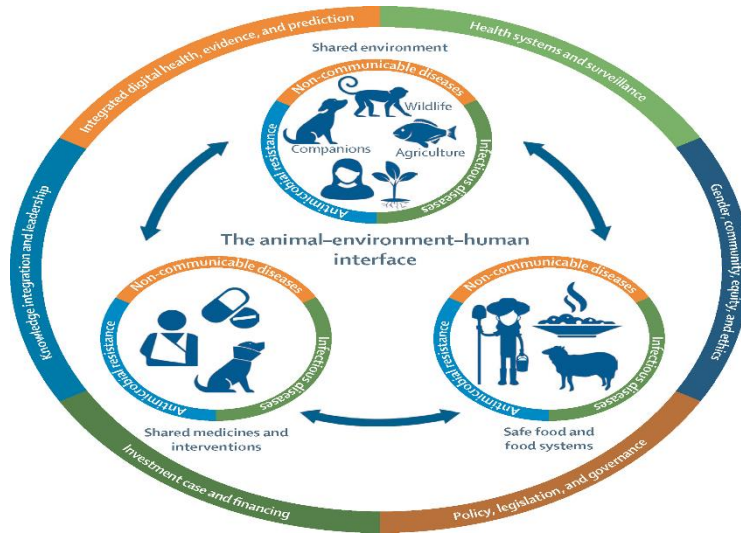


b. One health approach by Lancet commission

The second framework I used is ‘one health approach’ from the Lancet commission(37). I took this framework for the recommendations section of my research to put them in a wider intersectoral and societal perspective. However, the primary focus of this thesis is more in relation to risks from pesticides and interventions and policies to reduce these risks, which are best covered by the EPA framework. Humans, animals and the environment have interrelated connections. To manage the public health problem and achieve better public health outcomes it will need to address the one health approach because it includes food safety, different zoonotic, infectious and vector -born disease, antimicrobial resistance of pesticides or toxicosis. I used two dimensions out of three of this framework. The first dimension describes the shared environment where human, and animal lives in the same habitat. It also focuses on the activity by human beings which impacts negatively on animals and the environment. The second dimension focuses on safety on the food and foods system. Human being relies on animal and environment for food. The dimension makes a bridge between good agricultural practice and human health. It will help to achieve safe food production and a sustainable environment.

One of the outer layers of the circle is policy legislation and governance which can help to involve public and private organizations and address multisectoral coordination. I did not use the first dimension of this framework because it does not match to this particular analysis.

Figure 7: One health approach by Lancet commission



Source: *The Lancet one health commission, 2020*

3. Results:

3.1 The burden of public health from pesticide using in Bangladesh

In this result chapter, I have analysed the findings from different selected articles according to the framework and specific objectives. In this review, I used most of the data from Bangladesh. But also, I have to use some information from both low- and middle-income and developed countries due to the limited availability of data in Bangladesh's perspective.

Bangladesh is a densely populated country. Agriculture is the second-largest source of the economy contributing to GDP and the crop sector obtains a large proportion of agriculture(38) Farmers are using different kinds of pesticides for a high yield of crop production. Despite the benefit of increased production, pesticides have direct or indirect disadvantages related to human health. Many studies revealed that agriculture workers, pesticides handlers and people who are close to the activities are at higher risk of different kinds of diseases, for example, cancer, neurological disorders, metabolic problem, kidney disease, DNA damage, birth problem. International Agency on Cancer Research (IACR) published a monograph where it categorized different kinds of substances that are carcinogenic for public health. They set the

priority and divided it into classes from low to high. Among them using some pesticides like organophosphate and carbaryl are recommended as high risk for human health. Here it is also mentioned that the exposure group like farmers should be taken into careful consideration due to their occupation related activities (39).

A cohort study was conducted among a couple of private and commercial pesticide applicators for nine years. In this study, they followed up different types of cancer where they found that the standard incidence rate is higher among the respondents who are working or living near the agricultural farm(40). Another cohort was conducted by the AGRICOH consortium at the same time in France, Norway, and the USA, they found a positive relationship between a group of pesticide use and development of non-Hodgkin lymphoid malignancies(41). A similar study found significant association between exposure to organochlorine and organophosphate insecticides and the development of prostate cancer risk(42).

Chronic kidney disease among farmworkers is also observed among them who are exposed to pesticides in crop production in devolved and developing countries like America, India, and Srilanka (43). Exposure to toxic substances can cause DNA methylation(44), a study in Pakistan found a significant association between DNA damage and pesticide exposure. In this study, they used a single-cell electrophoresis assay or comet assay which is a quantitative method to examine DNA damage (45). Many studies mentioned neurological disorders like Parkinson's disease or Alzheimer's disease of pesticide use (46). A study conducted in the Netherlands to see the direct association between pesticides exposure and Parkinson's diseases, the finding showed that occupational exposure to pesticides may increase the risk of the disease though the author is unclear about the particular active compound involved with developing the risk(47). Exposure to pesticides can cause respiratory problems like COPD, asthma and chronic bronchitis (47). A meta-analysis of studies also revealed the positive association between farmer's exposure to pesticides and respiratory problems (11) .

In Bangladesh, farmers are also experiencing lots of health problems due to pesticide exposure though data is too limited. One study was conducted in the Manikgonj district which area is famous for vegetable farming. The study found that farmworkers experienced immediate illnesses like vomiting, nausea and skin irritation, fatigue, eye irritation after using the pesticides in the field. Though the survey did not conduct clinical tests but some farmers self-reported that they were suffering from chronic asthma for a long time (40). A similar study was conducted in six agro-based regions of Bangladesh and the findings also support the previous study (48).

A similar study was found in three districts of Asam in India, in this region farmers are using a different range of hazardous pesticides for their rice and vegetable production. The study showed that a large (77%) number of farmers who are involved in spraying the pesticide substance have immediate signs and symptoms of asthma(49). Another study was carried out

in Comilla district of Bangladesh where a large number of vegetables are produced and exported out of the country. In this study among 120 respondents, all were suffering from at least one kind of health problem related to skin or eyes as well as 52% and 53% of farmers were suffering from headache and nausea respectively. Upazilla health officer of this region ensured that there are the number of patients increased who are involved in farming occupations(26). A similar study was found in India in the Maharashtra region where 70% of farmers are using moderate to highly hazardous pesticides and suffering many kinds of health problems for the long exposure of it(50). China is a large agro-industrial country which is using pesticides most intensively. There is a number of studies showing the adverse effect of pesticides on health in a different region of China (51). A similar study found in Thailand among rice farmers who are suffering extreme breathing problems due to not wearing the protective equipment (52).

Pesticide self-poisoning is another public health problem. According to WHO globally 20% of suicide caused by pesticide self-poisoning, most of the cases are in low- and middle-income countries in rural agricultural areas. Banning hazardous pesticides can reduce this mortality rate (53).

a. Effect on environment:

It is undeniable that pesticides are important substances for protection of plant and increase production but at the same time, it is a rising threat for food safety as well as human health. Soil and water may be contaminated by the drift of residue, air can be contaminated by volatile substances. All these residual substances of pesticides have the potentiality to create health problems at the end (27).

There are many regulatory jurisdictions established by different international organizations such as WHO, EU, FAO, Californian department of public health, Canadian national standards, African national standards, or U.S environmental protection agencies. Generally, regulatory guidance values (RGVs), maximum concentration levels (MCLs) and maximum residual limit (MRL) are applied for the regulatory jurisdictions for soil, water and food respectively (54).

3.2.1 Food:

According to FAO “Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (55). Ensuring safe food is one of the most important pillars for achieving food security. Pesticides residue in food commodities can cause serious health problems. Residue refers to the trace element which remains in the targeted product. Residual effects depend on different factors as the residual limit, poisonous characteristics of pesticides, and length of exposure (56). This residue must be at a safe level for the consumers which is called maximum residual limit (MRL). The main source of the database of MRL is CODEX ELEMETARIES which is established by FAO and WHO (56). If the recommended

dose or application method is not maintained the residue can deposit in the human body by consumption of the foods and lead can to cancer (57). A study showed that commercially produced vegetables like lady's finger, tomato, and eggplant have the highest percentage of organophosphorus residues than the recommended dose of the European Union. Organophosphorus pesticide is very harmful to human health because of their cumulative nature and toxic properties(58).

In Bangladesh, there is a guideline for harvesting time after application of the pesticides to decrease the residual effect but according to the department of Agriculture extension, more than ninety percent of farmers do not maintain the recommended interval time. So, the risk of consumption of pesticides is getting higher. Another study was conducted to observe the MRL in eggplant, tomato, and cauliflower in Pesticide Analytical laboratory Bangladesh Agricultural Research Institute (BARI) where the maximum level of residue was found which exceeds the recommended level by FAO (59). similar results were observed in a study conducted in Norshindi and Gazipur district, among cauliflower, country bean and long yard bean, the study found higher MRL than the recommended in cauliflower and country bean (60). Many farmers are used to spraying pesticides just before harvesting and take them into the market. The vegetables like tomatoes, cucumbers and some leafy vegetables are eaten raw so they have more potential to affect human health. A study findings from Iran revealed similar observations in cucumber from greenhouse production, they found more than higher MRL of pesticides recommended by CODEX (61). Another study found that 'the Chinese Kale, a popular vegetable in Thailand which they eat raw in salad has the higher percentage of MRL recommended by European Union (62).

Sometimes fruits are found higher pesticides, it is not only breaking of pesticide using rules also a food adulteration crime. It can lead to serious illness to death for the consumers. ICDDR'B investigated a death case of children after eating lichee in Dinajpur district, Bangladesh. The report showed that the garden caretaker sprayed pesticides three to four times just before harvesting the fruit and he mixed different hazardous compounds together. After eating the fruit children felt ill, increase the problem to convulsion and finally death occurred (63).

3.2.2 Water:

Ground and surface water both have the risk of contamination by pesticide and it is a big threat to the environment and health(64). Agricultural fields are mostly situated near the rivers and it is very common the used pesticides are washed off and mixed them into the water. So it is highly challenging to maintain the quality of the water specially in agro-industrial areas due to high exposure of pesticide residues. In Bangladesh several studies found a higher concentration of pesticide residues in water. For example, Savar and Dhamrai sub-districts are commonly used for crop production and the biggest source of vegetable supply to the capital city Dhaka. A survey was conducted of 25 surface water samples from different crop fields where 22% samples were found highly contaminated with pesticide residue above the recommended

concentration by EU (65). This study is supported by other findings from the Meherpur district where highly hazardous pesticide residue like organophosphorus and carbamate was detected above the recommended dose by WHO/FAO (66). Another study found similar results from tube-well, pond, and agricultural land water samples in Dhamrai district. They found organophosphorus pesticide residues in tube well water sample which is generally used for drinking water sources. Other samples were also contaminated by different hazardous pesticide residue which all exceeded the recommended MRL compared to Canadian maximum acceptable concentration (67). Surface and groundwater both are in threat for residual effect of pesticide in Bangladesh, a study showed that near urban area waters are mostly contaminated by organ thiophosphate pesticide like Diazinon and rural water body is contaminated by DDT. Some source of surface water has found higher concentrations of carbamate residues which are specially used for potato cultivation(68). A similar study was found in neighboring country India where the organochlorine pesticide is detected by Central Pollution Control Board, Delhi in surface water sample from some important river like Ganga, Sharashati and Yamuna which are already banned. They also found the residue in the pond and lakes near the main river. All the samples were above the recommended level of the EU. It is noticeable that in the winter season the highest concentration level was detected due to the greater use of pesticides in crop fields (69). China is an agro-industrial country that is a large pesticide producer and consumer. A meta-analysis paper showed that rivers of the most important agricultural province of China are contaminated by the different harmful residues of pesticides like DDT and HCH. In this study, the level of residue from four important river basins has been found higher than the recommended concentration by the European Union (70).

3.2.3 Soil:

Soil is the first recipient of pesticide residue. Unsafe use of pesticides can affect soil biomass and beneficiary organism of soil which impacts soil fertility. Microbial biomass is an organic matter which plays an important role in the nutrient cycle of soil (71). Excessive use of pesticides also impacts on soil enzyme which is a catalyst and very much important element for nutrient cycle and fertilization (72). In modern agriculture, the long term and frequent use of pesticide is affecting negatively on the soil microflora and soil ecology. The parameter of soil pollution from pesticides is regulated guidance values (RGVs) which are recommended by worldwide recognized bodies. They define the maximum amount of pesticide which can remain in the soil without inhibiting the soil quality (54).

In Bangladesh contamination of the topsoil by overusing of pesticides have reached to a big concern. A study showed that using one kg pesticides per hectare spoils topsoil to 30cm of depth(73) Another study was conducted to investigate the long-term effect of pesticide and fertilizer of rice field in Jhinaidaha and Kushtia district of Bangladesh. The respective findings showed that along with some fertilizer ten kinds of pesticides are used in concerned fields which are significantly decreasing the nitrogen and carbon content of the rice field(74). This

study is supported by similar research conducted by Rahman et al where they found that excessive use of pesticides can affect the nitrogen quality of paddy soil as well as the beneficiary soil bacteria in the paddy fields (75).

A study in Indonesia also found highly hazardous pesticide residue sedimentation in Wanasari sub-district which is harmful to soil fertility and kills the beneficial earthworm of the field (71). Another study was conducted in a laboratory condition to observe the effect on the microbial community using the organophosphorus pesticides. The results revealed that pesticides significantly inhibit the growth of microbes under a certain concentration and exposure time(76). Synthetic pesticides are not biodegradable so long-term use of pesticides can accumulate in the environment and enter the food chain and adversely affects public health (77). The poisoning of soil can contaminate the produced food and effect to human health, it also affects beneficiary organism of nature.

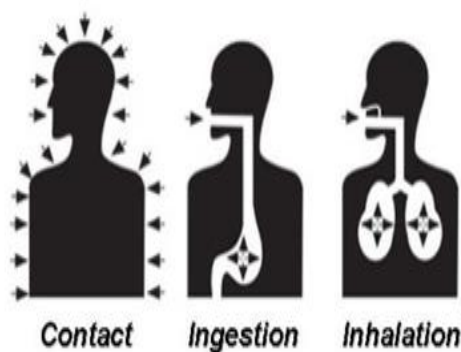
3.3 Mechanism of exposure:

Pesticides can generate acute and chronic toxicity on the human body. It can create a mild, moderate or serious problems that leads to death.

Acute toxicity: It depends on the dose of the substance and the duration of the exposure. Sometimes it results immediately or after few weeks. The example of acute impacts is headache, skin irritation, itching, rash and blisters, diarrhea, abdominal pain, nausea, vomiting, blindness, etc. Acute toxicity is measured by lethal dose (mg/kg body weight) when the mode of exposure is inhalation or ingestion. WHO and EPA both have the classification of endpoint according to the low and extreme hazard of the exposure element (16).

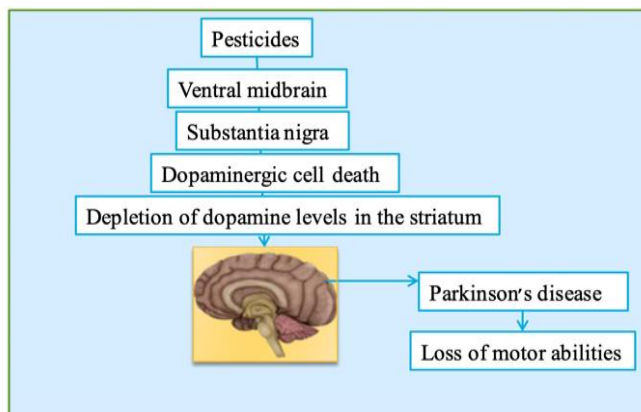
Chronic Toxicity: Long-term exposure and excessive dose can create chronic problems on human health. It includes cancer, chronic obstructive pulmonary disease (COPD) or damage of any other body organ like kidney or lungs, liver, brain. Chronic toxicity can be measured by the reproductive test, mutagenicity test or hormonal test (16).

Figure 8: Entry route of pesticides to human body(16) :



Generally, pesticides enter the body in three ways, ingestion, inhalation and direct contact. Ingestion of oral exposure can occur unintentionally while working or deliberately by self-harm. The unintentional problem occurs when farmworkers apply the substance in the field without any face mask or maintaining hygiene after handling pesticides. Contact can happen to people who are directly involved from transportation to apply it without wearing protective cloths. Inhalation takes place during fumigating, spraying, or formulating pesticides in the field(78) (16). The drift of pesticide enters into body fluid and is transported into various organs and tissues ((79). The pathogenicity of pesticides depends on how they enter the body. Low doses of pesticides can affect the nervous system, immune activation system or cause impairment of motoric functions. Many kinds of pesticides are responsible for Parkinson’s disease where degeneration of neurons, decrease motoric function (79). The mechanism of Parkinson’s disease is given below:

Figure 9: Mechanism of Parkinson’s disease due to pesticide exposure



Source : *Patel et al 2019*

3.4 Vulnérable groups :

It is obvious that agriculture workers are on the front line of the health risk exposed by pesticides. According to the ILO classification, farming is the most dangerous occupation due to work with heavy machinery and pesticide exposure(80). Apart from them, the adverse effect of pesticides affects the people who live around the adjacent area of farming for example the family members of the farmers. Women and children are largely exposed to the use of pesticides(78) Specially women used to work parallelly in the agricultural field and exposed by the drift(81) . General population is also in the circle of harmful effects due to consumption of food and water poisoned by pesticide residue (11).

In the pregnancy period exposure to the highly hazardous substance can increase the risk of adverse childbirth outcomes. Study revealed that there is a positive association between

pesticide biomarkers concentration in urine premature delivery (82). In a review article it is concluded that the people who are not involved with farming but lives near to the agro field, have more exposure of pesticide than the people who lives far(83) . Children are considered vulnerable to pesticide exposure; the effect can start from the fetus to developmental age. Studies show that some pesticides have neurotoxic properties that cause neurodevelopmental toxicity in the brain(84) Another study found a similar result, the author indicated that there is a strong association between pyrethroid insecticides and neonatal birth weight as well as head circumference (85).

A similar study showed that there is a positive association between low birth weight and maternal pesticide exposure. The study was conducted with the test of maternal umbilical serum levels of both exposed and non-exposed women during pregnancy. They found that pesticides can interrupt the growth hormone (IGF-1)(86). Pesticides exposure in the pregnancy period can also lead to functional abnormalities like congenital defects of a newborn child (87)

3.5 Awareness and perception of Bangladeshi farmers about pesticide use:

The widespread use of pesticides is a rising concern worldwide including in Bangladesh. Farmers are the front liners of pesticide application so their awareness and perception are the most important thing to consider for the safe use of pesticides. Most farmers are not using protective equipment, not following regulations or instructions, and even not maintaining the harvest interval timing after using it in field. Sometimes farmers tend to use excessively without considering the doses and application instructions and this is considered an important cause of residual problem. There are different types of PPE equipment for respiratory protection, body or face protection such as face shield, aprons, hand gloves, foot wear or goggles(88).

In Bangladesh, farmers are not aware of protecting gears and some of them are using traditional handmade cloths like cotton trousers or polyethylene as hand gloves(89). A study conducted in two districts of Bangladesh which are famous for crop production, the findings showed that 69% of farmers are not taking any protective measurement during handling the hazardous pesticides on the field. The study also indicated that they are already suffering from different types of health problems like eye irritation, fatigue, or excessive sweating.

Another important thing to consider is that farmers are not maintaining their personal hygiene before or after the application of pesticides (90). similar study conducted on vegetable farmers of the Burichang sub-district revealed that farmers do not care about the appropriate handling of pesticides, wearing protection during work, and even maintain hygiene measures after application. According to the Department of agriculture extension of Bangladesh, 95% of farmers do not maintain the recommended interval of harvest timing after pesticide use and it causes residual effects of food commodities (26). Another result was found in rice farmers of Mazandaran province of northern Iran where only 2.8% of respondents are using PPE and 2.7

% are following the personal hygiene instructions(91). A similar study conducted in Khlong seven community in Thailand supported the above findings, the paddy farmers in that community are not aware of pesticide toxicity, protective gears, and application procedure.

It is also reported that they are suffering from many poisoning symptoms(92). Awareness and behavior generally depend on some factors such as age, geographical location, education, experience, training and other practices. Farmers are experienced and they have an intuitive idea that pesticides are poisonous but they are not taking the corrective measures to mitigate the problem. A study showed that some farmers are not comfortable in using protective equipment in hot weather like Bangladesh, some of them are not maintaining because they are not able to buy all those protective equipment.(93).

Recommended doses are very much important to minimize residual effects but many farmers in Bangladesh are not following the instructions from respected authorities or the instructions from the labels. A study showed that seventy percent of farmers are using more pesticides than the recommended dose because they believe that insects will not be destroyed and production will not increase with low amounts of pesticides, about nine percent of them are doing so because of the instruction of suppliers. Some of them are not able to follow the instructions because of their literacy level or instructions are written in English, which is a foreign language. (94). A similar finding showed in India, the author found that seventy-one percent of farmers do not follow the maximum dose as and apply their own spraying schedule. Also, they think that overdose will kill the pests immediately. Forty percent of farmers listen to their supplier's instruction and only twenty percent of the respondents agreed that they maintain the dose according to respected authorities (95).

Another concern is farmers do not maintain the storage regulations, for example, they keep the leftover pesticides in beverage bottles which can create dangerous accidents even death. Moreover, if the containers don't store or dispose properly it will mix with soil and ground water (32).

Farmers in developed countries are more aware than in developing countries. Education is a great influencing factor to do something adequately. Though all farmers are aware of the harmful effect of pesticides higher educated farmers are eager to accept the new technology (96). A similar study showed in India found that higher education has a significant relationship with the safe use of pesticides. Also, educated farmers can read the instructions written on the label. Younger age people maintaining the protective equipment more than older one on the other hands, aged farmers have more experience than younger which help to understand the harmful effect of pesticides (95). Source of information has a great influence on pesticide applications. Many farmers rely on pesticide dealers, traders or retail sell agent's advice (94) .

3.6 Interventions to mitigate pesticide risks for public health:

Pesticides are important elements for reducing yield loss of agricultural sector. But the inappropriate use of the substances can play serious negative roles in public health and environment. So, it is crucial to protect human being and ecosystem from the adverse effect of pesticides through risk reduction.

3.6.1 Best practice, and international guidance:

Reducing the risk of pesticides depends on the management of pesticides throughout their lifecycle. There are number of recommended practices and guidelines to mitigate the problem. FAO recommended pesticide management in a holistic approach. The figure is showing that management of pesticides has to start from the policy and legislations to management of waste. It also recommends institutional capacity building for production, for trade regulation, the rational use of pesticides in the field and advocating for no adverse effect of the residues to human, animal, food and environment (97).

Figure 10: Management of pesticide throughout their lifecycle.



Source: FAO (<http://www.fao.org/pest-and-pesticide-management/pesticide-risk-reduction/pesticide-management/en/>)

Another approach introduced by FAO which is International Pest Management (IPM). It is a ecofriendly technique which encourages users to apply appropriate measures of pest control. It reduces the pesticide usage and minimizes the risks created by pesticides to human, animal and environment. IPM as programme integrates good agriculture practice, it applies some natural processes to pest control such as increasing beneficiary organisms in the field, crop rotation,

increase field biodiversity, and using manual traps to catch insects. So IPM promotes healthy crop practice with reducing the harm of public health and without disrupting the environmental balance(98).

Good agricultural practice (GAP) is another strategy that reduces harmful effects of pesticides. It consists of a set of principles during production to post harvest and processing of food without causing harm to environment, human and animals. There is a certification GAP option that follows up these procedures(99). Besides this, farmer can introduce organic food production because it does not require the synthetic chemical which is very good for human health and the environment.

Phasing out highly hazardous pesticides (HHP) is another approach which is important for risk management of pesticides. Some pesticides are very much hazardous for human health and environment, most contamination is occurring by using this kind of compounds. WHO and FAO have developed a list and guidelines for hazardous pesticides in the Rotterdam convention. The guidelines consist in how to identify the highly hazardous pesticides for human health and environment and also encourages to assess the risk of these pesticides in their own country context. And finally to take appropriate steps to stop the use and trade of these pesticides (29). There are also fake or counterfeit pesticides in the market which can control by the government surveillance and enforcement.

So, all the above practices can be established by adhering to international standards, and maintaining residue limits, communication and awareness raising, control of counterfeit pesticides, surveillance and regulation/enforcement. The government and public sector can plan to achieve these best practices by behavioral communication change training. It can be start from the home visit of farmers or making a farmer's school. Family or peer training is always fruitful for behavioral intervention. Another strategy can be the incentive intervention which can include giving money to buy protective clothes or directly give the PPE. Giving technological intervention can enhance the capacity building of farmers to apply the right approach for farming.

There are number of international guidance to conduct interventions and combat the harmful effects of pesticide residue. FAO, WHO and Rotterdam convention has developed the regulatory guidelines for application, risk management, registration, trade, export, import, and disposal. Montreal protocol emphasize into the climate pollutions by hazardous chemical.

USEPA has a center for the all information regarding pesticides. A listing of guidelines is given below:

Table 1: International laws, act, regulation of pesticide use

International laws, act, regulation of pesticide use	Year	Major content
FAO Guidelines on Pest and Pesticide Management Policy Development(100)	2010	guidance on pesticide management policy to reduce the risk of pesticide poisoning.
FAO/WHO Guidelines for the Registration of Pesticides (101)	2010	Regulatory guidelines for registering pesticides
WHO/FAO Guidelines on Developing a Reporting System for Health and Environmental Incidents Resulting from Exposure to Pesticide (102)	2009	assist governments to taking reporting program for health or environmental problem exposed by pesticide incidents
Guidelines on Management Options for Empty Pesticide Containers, FAO (32)	2008	Guidelines to manage the pesticides container adequately after use
Stockholm Convention (103)	Signed 2001, active 2004	Restrict about the manufacture and application of organic pollutants
Rotterdam Convention (104)	19998	international trade including export, import of hazardous chemicals and pesticides.
Montreal protocol (105)	2007	Agreement to decrease chemical use of for combat climate change
USEPA National Pesticide Information Center <i>(https://www.epa.gov/pesticides/forms/contact-us-about-pesticides)</i>	-	Government information center for pesticide use application
The WHO recommended classification of pesticide by hazard(28)	2019	Classification of pesticides by its hazardous characteristics.

3.6.2 Review of policies and interventions in Bangladesh

The government of Bangladesh has introduced many rules, ordinances and guidelines to reduce the harmful effect of pesticides. The rules and regulation also include use, marketing, import and management of pesticides. After establishing the pesticide ordinance in 1971, a committee named Pesticide Technical Advisory Committee (PTAC) was formed to help and give advice to the government on pesticide management issues. In 1985, the pesticide rules were established

where it mentioned the licensing authority. The plant protection wing of DAE is declared as an authority to give license to any kind of pesticide and authorization will depend on the director of the registration from MOA. Later in 2009 pesticide rules converted into the pesticide act(106). National agriculture policy was revised in 2018, emphasized on natural pest management system. The table is showing the list of government initiatives according to resist the misuse of pesticides:

Table 2: National rules, regulation and laws for pesticide management and control

Laws and acts policy regarding pesticide management	Year	Main content of laws and acts
Pesticide Ordinance(107)	1971	Production, trade, distribution, use, formulation, import
Amendment to Pesticide Ordinance	1980	Pricing, storage rules, formulation of PTAC committee
Pesticide Rules, MoA (108)	1985	Registration for pesticide use and buy, certification
Integrated pest management policy, MOA (109)	2002	Strategy and implementation of IPM to reducing the harmful effect of pesticide on human and environment.
National agriculture policy, MOA (110)	2018	Agricultural production, harvest, trade, and pest management
Bangladesh issues regulation on food safety(111)	2019	MRL of food commodities align with CODEX

Bangladesh government has banned highly hazardous pesticides according to WHO showed below but still these pesticides are sold and used through illicit ways (112) :

Table 3: Pesticides banned from agriculture uses in Bangladesh.

Year	Compounds	Reason for ban
1960	Endrin	Toxic for fish and water organisms
1997	Chlordane, DDT, dieldrin, heptachlor	Persistent organic pollutant
1998	Pyrethroids	Harmful to Fish and water
2000	Dichlorvos, dicrotophos, disulfoton, ehylparathion, methylparathion, mercury, monocrotophos, phosphamidon	Banned by WHO Class Ia and Ib for agro-use
2004	Methyl bromide	Banned by Montreal protocol for polluting ozone layer
2007	Hexachrobenzene, mirex, toxaphene	Stockholm declared pollutant

In spite of banning harmful pesticides, Bangladesh could not achieve their safe use until now. The frauds are selling banned pesticides like DDT, endrin to the farmers with new name and repackaging.(113) Department of agriculture extension gives training to the farmers on about the hazardous compounds but it needs to expand more. Many farmers don't care about the training, most of them listen to retailers or dealers. Sometimes farmworkers think that it is necessary to spray more pesticides to get higher yields and they don't care about recommended doses(31). There is a lack of testing facilities also that's why it is too hard to recognize the hazardous product during and after export. Some government governmental research institute like BIRRI, BARI, BSTI, atomic energy commission has the potential lab to test the pesticides but for the increasing demand it is not sufficient.

The problem is not coming from one side, GOB has to integrate different responsible ministries, research institutions, private partners and international organizations to work together against pesticide poisoning. Surveillance and monitoring are important in all necessary places and from all respective authorities. Ministry of health can collect surveillance data for the acute and chronic health problems occurring by pesticides.

The outer layer of the EPA framework indicates the public, stakeholder and community engagement" where different organizations can work from their won perspectives to achieve the same goal. Along with the ministry of agriculture, ministry of health can collect data for the acute and chronic health problems occurred by pesticides, food safety authority can monitor the food safety part, local government can strengthen monitoring programme in rural and urban areas. Ministry of information can help to raise awareness across the country from policymakers to end-users.

4. Discussion:

This in-depth literature review focused on the risks, the contributing factors, and the effects of pesticides on public health and on the environment in Bangladesh. The results show that multiple variables have to be taken into consideration to understand the problem.

Following the EPA framework, I discussed the exposure mechanisms and who are most at risk for this problem. After that in effect assessment I critically identified the type of health and environmental problems as well as how they are interrelated. According to the last part of the framework I analyzed what is the incidence or prevalence of the problems. I will explain the findings of my study, discuss my opinion and interlink with the framework I showed before.

Bangladesh is an agro-based country and pesticides are very commonly used in crop land for control of pests or insects. Use of pesticides also minimizes crop loss and helps to get better yields. Pesticides are generally hazardous substances of different kind of mixed compounds.

Irregulated and excess use of the substances can convert to risks for human health as well as to the environment.

In the framework 'exposure assessment' refers to the way problems occur and focuses on individuals or groups most at risk for exposure. Farmers or farm workers are the key person to be exposed with harmful effects because they are directly involved with the use of pesticides. Apart from the farmers, the immediate adverse effects go to their family members for example spouses, children or any other people who live close to them. Non-occupational risks can be posed to general people by the residual effect of pesticides which accumulate in food and water. Moreover, pesticides generally destroy the targeted insects or vectors which are harmful for the agricultural production, but it also kills non-targeted organisms such as beneficial bacteria or earthworms.

So, it is clear that pesticide exposure is very dangerous for public health and ecosystems, now we will focus on how it reacts or what is the mechanism of action of this hazardous substance. Pesticides can enter to human body by ingestion, inhalation or contact (fig :1). It can create long term or and short-term effect includes dermatological problem, neurological disorders, carcinogenic or respiratory problems. The severity depends on the exposure route, the time length and the characteristics of substances used. It also depends on the health status of the individual who comes into contact with it. Sometimes low doses can be dangerous depending on the structure of the chemical compounds such as organophosphorus pesticides. Other than unintentional effects of pesticide, people also cause harm by self-poisoning with it. Though it depends on individual's mental health but the availability of toxic substance can make it easier.

In the framework 'effect assessment' understood the category of the problem such as disease or defect and how the toxin relates to the disease. The number of papers I analyzed here, gave a complete insight of different type of diseases caused by pesticide exposure in human health. The problem effects mild to severe according to compound and length of exposure. Many reports showed that farmers experienced burning of eyes or skin irritation immediate after use of the pesticide. Nausea, headache and vomiting are also common when they mix the pesticide, formulate it and spray without any precaution. Excessive sweating, dizziness, fatigue is also common in the pesticide handlers. Most of the studies found respiratory tract problems among the farmers which is related to breathing difficulty, chest pain, cough. Some findings from different countries including Bangladesh found that many farmers are suffering of COPD or chronic bronchitis specially those who are dealing with organophosphate pesticides. Cancer is another dangerous disease considered as a consequence of pesticides. The common forms of cancer are lung, prostate, liver, skin. Some agriculture health cohort studies confirmed long exposure of pesticide compounds can develop cancer due to the accumulations of pesticide drift in the body. The adverse effect also damages the DNA at the same time it decreases motor functions of neurons which is responsible for Parkinson's disease. Other than this kidney failure or liver disease is also mentioned by many studies. Mostly the problem takes place not

wearing protective equipment, ignoring personal hygiene before and after use of hazardous compounds, or not maintaining the rules and regulations of pesticide application.

The health problems not only occur in those directly involved with pesticide applications but also other people nearby them. There is strong evidence of birth defects of newborn child when pregnant mothers are exposed to pesticides. And children who live in the respective areas also suffer from many complications.

The health problems not only occur in those directly involved with pesticide applications but also other people nearby them. There is strong evidence of birth defects of newborn child when pregnant mothers are exposed to pesticides. And children who live in the respective areas also suffer from many complications.

The framework 'risk characterization' expressed the current scenario of the problem. It describes the nature of the problem including who is most susceptible to get at risk. The framework also indicates the most vulnerable groups and subgroups. It is estimated by WHO that annually about one million people get poisoned unintentionally by pesticide residue in the world, among them, a major proportion is from south-east Asia. In Bangladesh, a number of studies revealed that farmers are facing many kinds of health problems after long exposure though the actual incidence and prevalence is very hard to identify because of underreporting of the situation. As pesticide use is rising over decades the health impact is also in threat for the farmers and related people. Acute problems are very common among the agricultural workforce, at the same time numerous people are facing chronic life-threatening problems like cancer or respiratory disease. General population is also suffering due to the indirect contamination of pesticides through food water and soil.

Risk characterization indicates informing the decision part of the framework. The scenario will help to make decisions to mitigate the problem of pesticides throughout their lifecycle(fig: 10). It is needed to manage the problem from making regulations to production, quality control, trade, safety use and disposal management of pesticides. There is a number of regulations, laws and rules about the user application of pesticides by international organizations and local authorities. (Table1). WHO banned many pesticides which are harmful to human health and the environment. There exist guidelines for good agriculture practice, integrated pest management systems or alternative cropping methods. Bangladesh government also published related acts, ordinances and rules aligned with international recommendations (Table 2). There are rules for transport, import buying and selling of hazardous pesticides. Still, the illegal trade and use of banned products exist in this sector. So, this part of the framework will help make for risk management by analyzing the actual scenario of the problem.

The outer layer of EPA framework describes stakeholder engagement which is very important for coordination, harmonization and cooperation for measures to mitigate the problem. The

intra- and intersectoral collaboration of different ministries and organizations can help to improve the surveillance system and make appropriate information available. Community engagement is a key to the success of any kind of intervention who the part essential part of stakeholders.

The cause of the above analyzed situation first goes to lack of awareness of the people who are involved through the entire life cycle of pesticides. As agriculture workers are the main actors in the application process, their level of understanding is very much important for reducing the adverse effects of it. In Bangladesh, farmers are not wearing protective gear while applying pesticides to the field. Wearing PPE is a great tool to keep safe from hazardous compounds. Both educated and uneducated farmers are ignoring the safety measures due to a lack of awareness. Personal hygiene after spraying is mandatory to keep safe but many of them are not doing this. Moreover, they are spraying pesticides with bare hands and taking food immediately after work without handwashing. Some of them feel uncomfortable wear in the tropical weather, others think that it is not a big issue for health. Many farmers are not capable to buy protective equipment. The dose of pesticide is very important to maintain at recommended level but some farmers think it will work better if they apply more pesticides to the field. The wind direction is important to consider when pesticides are applied in the field manually but most of the time, they are not maintaining the rules. Also, application of pesticides shortly before harvesting is strictly prohibited, but farmers are not following the instructions they are applying pesticides frequently, harvest them and sell to consumers. So, the risk of getting poisoned by the drift of residue is increasing among general people.

Studies showed that most of the farmers listen to the sellers or agents about the instructions rather than respected authorities. Lack of hands-on training and inadequate personal behavior is the immediate cause of the problem. Many people cannot read or understand the instructions from the product label due to foreign language, extension workers can make them understand by giving on hand training Furthermore, most of the users are not destroying the containers properly after use. Disposal of pesticide containers is very important otherwise people may re-use the containers to store foods or beverages which is can lead to poisoning and even death.

Department of agriculture extension is trying to teach farmers the best practices for pesticide applications. But the training facilities are not sufficient duet insufficient workforce. . Monitoring and surveillance are necessary for decreasing the unsafe use and illegal trade hazardous pesticides.

I used one health framework for policy-making and legislations. Though the EPA framework also covers the decision-making process, one health approach has the broader context of interrelations between humans, animals. As humans and animals are living in the same environment and depend on each other for food so it is important to consider all of them regarding interventions. The one-health framework goes beyond the problem of pesticides and

looks at other threats to human health, like antibiotic resistance, climate change, newly emerging infections, the influence of our environment on non-communicable diseases and mental health. One health emphasizes the management of health in a hostile environment. Because ignoring of the environment is a barrier to secure human health. In the case of pesticide poisoning, different sectors need to come together to reconcile food security and human health. The framework also shows the need for transdisciplinary and intersectoral action to tackle the problems, for example the government can synchronize the respected departments like crop, livestock, veterinaries to work together to reduce the risk of poisoning.

5. Recommendations

Recommendations based on the findings the best practices to reduce the burden of health problem associated with pesticide using in Bangladesh

It is certain that there is no single solution for reducing the harmful effects of pesticides. It needs to address different steps in the life cycle of pesticides and their use; and it needs to include the perspectives from multiple stakeholders.

5.1 Policy maker's level:

- **Re-evaluate existing rules and regulations:** Revisiting current rules and regulations is important to identify gaps. Rules should be updated according to newly emerging problems while strengthening existing ones. Bangladesh has not published own residue limits (MRL) of their country context. They use CODEX database for it, but there are many local rice and vegetable varieties which are not covered by common international standards. Government should strengthen pesticide registration rules and punishment criteria for failure of registration. Only monetary punishment is not enough to control fraudulent activities.
- **Collaborative actions from multiple disciplines:** Reduction of the harmful effects of pesticides depends on a joint effort. Government can take the one health approach to address the problem from a multidisciplinary and cross-sectional perspective. One health connects environment, animal and human health and engages different expertise from different sectors to work together. The entry point can be Ministry of agriculture and ministry of health. In the rural area community health workers can work together with agriculture extension workers to address the health-related problems. Local government can help to enforce pesticide registration, ensure good governance and transparency of the procedure. They can also operate mobile courts for monitoring the banned and counterfeit pesticides. Government can establish regional lab for testing the pesticide residue with the collaboration of research institutes, food safety authorities and ministry of agriculture and ministry of food.

- Capacity building and awareness raising on best practice: One health mentions the importance of educating communities and strengthen capacity building of respected institutions to sustain the intervention. Government can play an important role to do advocacy and create awareness on alternative farming practices for pest management through training programmes, farming education, or using public media. For example, integrated pest management is an environmentally sensitive, cost-effective useful strategy that can reduce the unnecessary use of pesticide applications. Government can also give financial incentives or logistic support specially for small-scale farmers capacity building to promoting new technology and good agricultural practice. PPE can be distributed through farmers community with subsidized price because many people have the awareness but unable to buy the protective gears. It is equally important to give on-hand training to farmers and their family members to maintain personal hygiene and protection training for the behavior change communication (BCC).
- Information database for risk management: One health approach focuses on strengthening the surveillance systems which can help to monitor actual scenarios of the problem. Government should develop a national database with the help of expertise from MOA and MOH. It will consist of all information about pesticides including all information of pesticide use, incidence and prevalence of health problems against exposure to pesticides per sub-district. Database can be used by policymakers as well as in the field level at help desk of agriculture extension office and community clinics. Director general of health (DG Health) can introduce a service desk for occupational health service in community level. The database will also contain the inventory of expired, banned and outdated pesticides from different regions of Bangladesh.

5.2 Researcher's level:

- According to the results and discussions there are only a few studies conducted in Bangladesh about association between pesticide exposure and health problems of end-users. It is very important to take further research to understand the situation in order to orient appropriate interventions. Research should be conducted with various perspectives. For example, it is needed to clarify which pesticides are responsible for what kind of diseases. Research can be conducted on both the situation analysis for baseline information or in-depth analysis for biomarkers level. Research on food and water for determining pesticide residues is also important. To a certain extent, international literature and reviews can be used for analyzing the problem but local research may also be needed. Surveillance and research on comparative incidences of pesticide exposure problems across farmers who are more or less exposed to pesticides can be done, to look at relative risks. The cost benefit research is required for analyzing alternative farming processes instead of pesticide use. Also, research institutes can conduct more research on different kinds of pests resisting new varieties.

5.3 End users' level:

- Farmers and consumers are the last users of pesticides. Both of them have some responsibilities of their own. Farmers should accept the new technology and take into account the advice from respected authorities for good farming practice due to reducing the risk of adverse health effects. They also maintain the protective measure during the handling of pesticides. Consumers also should be aware during the purchase and consumption of food commodities. They should check the GAP mark before buying the food commodities. They should maintain hygiene practice when preparing food for example washing vegetables in running water before eating raw or maintaining hygiene throughout the cooking process

6. Conclusion:

Pesticides play a vital role in the food production system in Bangladesh. On one hand it increases the yield and on the other hand, it impacts on health and the environment. Irrational application of pesticides and lack of monitoring from the government system is making it hard to reduce their harmful effects on health and the environment. It is possible to minimize the risk of hazardous exposure by increasing the awareness of proper application methods and translate it into practice. A multidisciplinary action under one health can help to address the problem through good governance, monitoring and coordination system.

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