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Sustainable Development and Chemical Product Processing: Issues of Pesticide Usage and Health Implications

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Abstract

The industrialization of the agricultural sector has increased the chemical burden on natural ecosystems. Pesticides are agrochemicals used in agricultural lands, public health programs, and urban green areas in order to protect plants and humans from various diseases. However, due to their known ability to cause a large number of negative health and environmental effects, their side effects can be an important environmental health risk factor. The urgent need for a more sustainable and ecological approach has produced many innovative ideas, among them agriculture reforms and food production implementing sustainable practice evolving to food sovereignty. However, the principles of the Rio Conference (1992) and Agenda 21 address the pressing problems of today and also aim at preparing the world for the challenges of this century. The conservation and management of resources for development are the main focus of interest, to which chemistry will have to make a considerable contribution. Since basic chemicals are produced in large quantities and important product lines are synthesized from them, their resource-saving production is especially important for a sustainable development. This paper intends to discuss about pesticides, their types, usefulness and the environmental concerns related to them, Pollution as a result to overuse of pesticides and the long term impact of pesticides on the environment and humans. The paper recommends to including others, public education, and more intensive promotion of the Integrated Pest Management Scheme, green technology, and the use of natural pesticides.

Keywords: *Sustainable Development, Chemical Product, Pesticide, Health Implications*

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Background to the Study

The agricultural production is highly dependent on the ecosystem and the industrialization of agricultural sector has increased the burden on the natural ecosystem. For example, a healthy environment contributes to better crops through natural pest control, pollination, and soil fertility, among others (Power, 2010). However, this fragile system is being compromised by the excessive usage of pesticides.

According to Food and Agricultural Organization (2016), the decline in the population of bees and other pollinators attributed to pesticides is a major concern, because some of the important plants grown for human consumption depend on bees and pollinators, including cocoa and coffee. Pesticides are also a cause of water pollution, often spreading extensively from the original location and contaminating both surface and ground water. However, sustainable production cannot come at the expense of the health of people or the environment.

Indeed, pesticides are widely used in agriculture to increase the yield, improve the quality and extend the storage life of food crops (Fernandea - Alba and Garcia – Reyes, 2008). Pesticides are also used worldwide to protect crops before and after harvest in agriculture, gardening, homes and soil treatment. Varieties of pesticides are used in current agricultural practices to manage pests and infections that spoil crops (Conacher and Mes, 1993). The controlled pesticides uses in agriculture will not affect the environment where as uncontrolled pesticide use will cause adverse impacts on the environment such as water, soil and air which causes unbalance in ecosystem.

Many of these chemical leaves residues on or in food after they are applied to food crops (Walter, 2009). These chemical residues especially derivatives of chlorinated pesticides, exhibit bioaccumulation which could build up to harmful levels in the body as well as in the environment. (Walter, 2009). Persistence chemicals can be magnified through the food chain and have been detected in products randing from meat, poultry and fish to vegetable oils, nuts and various fruits and vegetables consumed by humans (Stephen and Benedict, 2011).

Pesticides are classified according to chemical structure such as organophosphate compounds, organ chlorines, synthetic pyrethroids, carbamates, bio- pesticides e.t.c based on their different chemical structures. The World Health Organization (WHO) has classified pesticides according to the acute toxicity. The classification includes class 1a- Extremely harzadous, demarcated red; class 1b- Highly harzadous, symbolized by a yellow triangle; class II - moderately harzadous, marked by a blue triangle. Class III is known as "slightly harzadous" while the remaining class is supposed to be "slightly harzadous".

Pesticides

The term "Pesticides" are used for all toxic chemicals used as pest control agents. Also, according to United State Department of Agricultural (USDA, 1998) and (Arendseand Mes, 1989) refers to pesticides as a term broadly used to include synthetic organic chemicals used for destroying or preventing the activities of harmful insects, weeds, and diseases in the fields and mites that feed on crops and food crops. Pesticides can be classified differently. One of the ways in which pesticides can be classified is by the type of pest or diseases against which it in very effective, insect, fungi, slugs, and rodents (Arendseand Mes, 1989).

Natural Pesticides

Various plant extracts and other natural materials are used that repel pests, reduce their feeding or reproductive activities, reduce proliferation of diseases or act as bio pesticides. Some of them, however also have unwanted side effects. The most commonly used natural pesticides are:

i. Neem, the extract of the seeds of a free common in tropical and sub-tropical areas, reduces proliferation of insect pests while having little impact on beneficial insects.
ii. Pynethrum, the extract of a chrysanthemum species decomposes rapidly in the environment, but affects beneficial insects and in toxic to aquatic life.
iii. Copper is widely used to control for fungi diseases, but it accumulates in the soil.
iv. Sulphur, soap and paraffinic oil preparations are used to control mites, aphids and other pests, but they also affect beneficial insects.

Bio-Control and Natural Pesticides

Bio-control makes use of pathogens (bacteria, fungi, viruses) insect predators or parasitoids, pheromones and insect traps to keep pest populations low (IAASTD, 2009). The total eradication of a pest, which results from the use of synthetic pesticide, would reduce the food supply of the pest's natural enemies, undermining a key element in system resilience. The aim, therefore should be to manages insect pest populations operation in a balanced way and crop losses to pests are kept to an acceptable minimum (FAO, 2011). The following are the most widely used bio-control methods.

i. Conservation and augmentation of natural enemies of pest through flower strips, hedge rows and other natural habitats.
ii. Release of predators and parasitoids of pests such as trichogramma, lady bird becties lacewings and predatory mites.
iii. Sprays with pathogens of pests such as Bacillus thuringiensis, Beauvaria, Trichoderma and nematodes species.
iv. Pheromone dispensers to disrupt mating of pests.
v. Traps like sticky coloured boards, pheromone traps and light traps to catch insect pests.

Pesticide Classification

There are hundreds of pesticides, which have been classified by the World Health Organization (WHO) in different ways according to (Arendse and Mes,1989) which includes:

i. By their chemical classes such as organophosphates, organ chlorines, pyrethroids and cabamates etc
ii. By active ingredient required to kill half of the number of test animals (lethal dose for 50% = LD 50) to classify the degree of hazard in their toxicological classes such as

class 1a-extremely hazardous, demarcated in red; class 1b-highly hazardous, demarcated in yellow, class II-moderately hazardous, demarcated in blue, class III-slightly hazardous demarcated green, which the remaining class is II supposed to be not likely to be harzardous in normal use.control or eliminate insects that affect plants, animals or people

iii. By types of pest or disease, against which it is effective such as insectides, fungicides, herbicides, nematodes, acaricides, molluscides, bactericides, and rodenticides etc as shown in Fig 1.

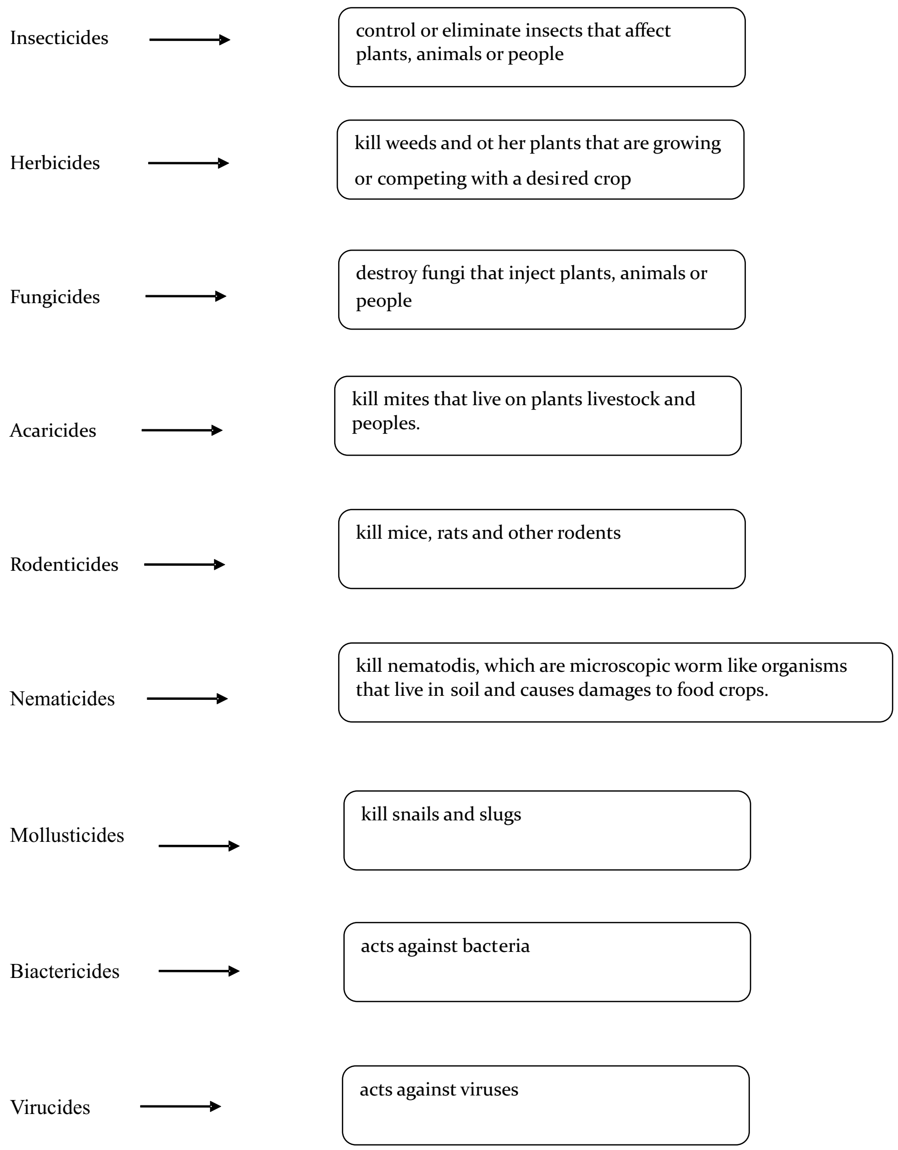

Figure 1: The classification of pesticides according to the type of pest they control (Toros and Maden as cited in Yucel, 1997).

Classification Based on Chemical Class

Organochlorines (OCS)

Organochlorine pesticides are organic compounds with five or more chlorine atoms. They were the first synthetic organic pesticides to be used in agriculture and in public health. These are large class of multipurpose chlorinated hydrocarbon chemicals. Many organ chlorine pesticides are persistent organic pollutants (POPS), a class of chemicals known to break down very slowly and bioaccumulates in lipid rich tissue such as body fat. Organ chlorine pesticides break down slowly in the environment and accumulate in the tissues of animals. Thus, they stay in the environment and food web long after being applied (Swackhamer and Hites, 1988). The properties of chemicals in this class such as DDT and many other organ chlorines were not discovered till the late 1930's and are not unduly toxic to man, but they break down slowly, and some like the soil insecticides aldrin, dieldrin are very persistent in the environment (van Emden, 1989). Some of the commonly used organ chlorines pesticides are DDT, lindane, endosulfan, aldrin, and chlordane.

Organophosphates (OPS)

This group of insecticides such as parathion, diazinon, malathion, diamethoiate and many more have been in existence since the 1940's with high acute mammaliam toxicity or toxic to man but easily breaks down and are much less persistent than the organ chlorines (Van Emden, 1989). The basic structure of organosphosphorus pesticides consists of ester or thiol derivatives of phosphoric, phosphonic or phosphoramidic acids.

Carbamates

Insecticides and Nematicides are carbamates (derivatives of carbamic acid) which were introduced in 1956 with the compound carbaryl. These groups of insecticides, nematicides such as aldicarbs, benomyl, and carbofuran are more persistant than the organophosphates, highly toxic to man. Fungicides such as maneb and mencozeb are under carbamates and are not acutely toxic (Van Emden, 1989).

Synthetic Pyrethroids

Pyrethroids insecticides are a class of lipophilic esters, with an alcohol and an acid moiety (Grant *et al.,* 2002). Cypermethrin belongs to the pyrethoids. They are low in persistence, moderately toxic to man and have very high acute toxicity to aquatic organisms (Van Emden, 1989).

Ideal Pesticide

The ideal pesticides according to Kumar (1984) in the product that stays confined to the location of application through its active period, is toxic to particular pests but harmless to other organisms including human in easy to use, ability to break down into harmless products in the environment within a reasonable time and must be cheap to produce. He further stated that pesticides are yet to achieve the totality of these properties.

Effects of Pesticide on Environment

Pesticides affect the environment by point-source pollution and non-point-source pollution. Point-source pollution is the contamination originated from a specific and identifiable place;

including pesticide spills, wash water from cleanup places, leaks from storage sites and improper disposal of pesticides and their containers. Non-point source pollution is caused by contamination of a wide area including the drift of pesticides through the air, pesticide run off into water ways, pesticide movement into ground water. (Cessna *et al.,* 2005 in Tiryakil and Temur, 2010). Environmentalists, agriculturalists and scientists are all aware of the long-term effects of pesticides as they contaminate streams and water courses other water sources. Air may also be contaminated with pesticides because of application drifts, post-application vapour loss and wind erosion of treated soil, vegetation and water bodies within the field margins may become contaminated due to wet and dry atmosphere deposition of pesticides and through surface run off from pesticide-treated agricultural land (Cessna *et al.,* 2005 in Tiryakil and Temur, 2010).

Fortunately, most of the modern pesticides are organic and they are subjected to biological decomposition. Through decomposition, pesticides compounds progressively breakdown to their component compounds, ions and elements which in turn form simpler and generally less toxic compounds. Some decomposition products may incorporate into their organic substances via biological chemical transformation mechanism (Büyüksonmez *et al.,* 1999). Important processes, which determine the fate of a pesticide in soil, waters and the air, are:

i. Volatilization.
ii. Absorption by plants and minerals mailer.
iii. Sorption by organic and solid phases.
iv. Chemical and biological transformation and degradation. All of these processes are influenced by pesticide properties (e.g. solubility vapour pressure, soil and environmental conditions (e.g. temperature, moisture and soil pH), type of pesticide formulation and method of pesticide application (Kookanaa and Simpson, 2000).

Generally, before entrance to the soil, pesticides undergo photodecomposition, adsorption by plants leaves and transport in the air arising from vitalization pesticides undergo many transformations and transportation processes after their entrance into the soil. The factors affecting pesticides behaviour in the soil include.

i. The ratio of liquid, solid and gaseous phases.
ii. Availability of applicable reactants.
iii. Physic-chemical properties of the soil and pesticides.
iv. Climatic conductions such as moisture and temperature, simple degradation process like hydrolysis and oxidation and composition and activities of microorganisms in the soil.

Effect of Pesticide Residues on Animals

Pesticide residues inflict extremely widespread damage to biota, and many countries have acted to discourage pesticide usage through their biodiversity. Animals may be poisoned by pesticide residues that remain on food after spraying, for example when wild animals enter sprayed fields or nearby area shortly after spraying (Palmer, Bromly and Brandenburg, 2007). Widespread application of pesticides can eliminate food sources that certain types of animals need, causing the animals to relocate change their diet or starve poisoning from pesticides can travel up the food chain for example; bird can be harmed when they eat insects and worms that have consumed pesticides (Cornell University, 2007). Earthworms digest organic matter and increase nutrient content in the top layers of soil. They aid in protecting human health by ingesting decomposition litter and serving as bio-indicators in soil activity while creating a richer environment. A number of studies have shown that pesticides have had harmful effects on growth and reproduction on earthworms, which are in turn consumed by terrestrial vertebrates such as birds and small animals (Yasmin and Doris, 2010). Some pesticides can bio-accumulate or build up to toxic levels in the bodies of organisms that consume them over time, a phenomenon that impacts species high on the food chain.

Effect of Pesticides on Humans

Pesticides are chemicals used to protect agricultural crops from biological hazard such as insect, weeds fungi and other pests. In addition to their use in agriculture, pesticides are also used to protect human health from the vectors of tropical diseases such, as mosquitoes (WHO, 2015). However, pesticides are also potentially toxic to humans they many induce adverse health effect on reproduction, immune or nervous and cancer. Before they can be authorized for use, pesticides should be tested for all possible health effect to uses any risk to humans.

Hazardous chemicals according to potential health effects can be classified as carcinogenic (to cause cancer), neurotoxic (to cause brain damage) or teratogenic (to cause damage to fetus). This classification process called hazard identification is the first step of risk as assessment. An example of hazard identification is the classification of substances according to their carcinogenicity to human carried out by the International Agency for Research on Cancer (IARC) the specialized cancer agency of world health organization (WHO).

Also, according to WHO (2015) the same chemical can have different effects at difference doses, depending on the quantity of a person exposed to. It can also depend on the route dry which the exposure occurs for example, ingestion, inhalation or injection.

Hence, continued exposure to these chemicals for a long period many result in symptoms of mild cognitive dysfunction (including problems in identifying words, colours or numbers and unable to speak fluently) and hormonal imbalances heading to infertility, breast pain, menstrual disturbances, adrenal gland exhaustions and early menopause. Eventually these toxins are stored in the fatty body tissues and in cells of the brain. These stored toxins may be slowly released and re-circulated in the blood, contributing too many chronic illnesses. Whenever the body is under stress, the stored fat is released along with the toxins and circulates freely throughout the body. The resulting exposure can target various organs and body systems, contributing too many chronic illnesses. The nature of health effects depend on the type of pesticide, dose timing duration of exposure and the susceptibility of the exposed individual (Xavier *etal.,* 2004).

Although, risk assessment for pesticides residues in food as conducted by the Joint Food and Agricultural Organization of United Nations (FAO)/WHO Meeting on Pesticide Residues (JMPR) establishes a safe intake level. Acceptable Daily Intakes (ADIs) are used by government and international risk managers such as the Codex Alimentarium Commission (CAC) to establish maximum residue limits (MRLs) for pesticide in food. MRLs are enforced by national authorities to ensure that the amount of pesticide that consumers are exposed to in the food and they eat over a lifetime will not cause any adverse health effects.

IARC's hazard identification and the JMPR's risk assessment are complementary. For example, IARC may identify new evidence from scientific studies on the carcinogenicity of a chemical and when necessary, JMPR conducts an evaluation or re-evaluation of the safety of that chemical as it is used in food (WHO, 2015).

Sustainable Development

The Brandlond Commission (Word Commission Development, 1987) defined sustainable development as the process in which the exploitation of natural resources, the allocation of investment, and the process of technological development and organizational change are in harmony with each other for both current and future generation. Based on this context "sustainability" is a path forward that allows humanity to meet current environmental and human health, economic, and societal needs without compromising the progress and success of future generations (world commission on environment and development, 1987; Graedel and Allenby; 1995). Sustainable practices refer to products, processes, and systems that support the path. For example, such processes might involve developing new energy resources to meet societal needs; but to be sustainable, they must also be economically competitive and not cause harm to the environment or human health. Addressing sustainability necessarily cuts across all disciplinary boundaries and requires a broad system views to integrate the different and competing factors involved. This include "strategic connections between scientific research, technological development, and societies" efforts to achieve environmentally sustainable improvements in human well – being "(National Research Council, 1999) and involves the creative design of products, process, systems and organizations, and the implementation of smart management strategies that effectively harness technology and ideas to avoid environmental problems before they arise" Therefore, in this paper, the role of chemistry in the industrialization is considered within these broader efforts to address sustainability especially in the chemical industries.

According to the American Chemistry Council (Graedel and Allenby, 1995) "the business of chemistry (in the united states) is in $450 billion enterprise (about 26 percent of the global chemical production) and is a key element of the nation's economy. It is the nation's largest exporter, accounting for ten percents out of every dollar in U.S exports). For example, from two principal raw materials, petroleum and natural gas, the organic chemical industry produces phenol and acetic anhydride, the two main intermediate chemical used in the manufacture of the well – known end product asprin (acetyl salicylic acid). According U.S Environmental Protection Agency, approximately 15,000 chemicals are manufactured in the United State in quantities of over 10,000 products (4,500kg) each per year.

The chemical industry is central to modern world economy, converting raw material (oil, natural gas, air water, metals, minerals) into more than 70,000 different products (Encyclopedia Americana International Edition, 2006).

However, the chemical industry is faced with a major conundrum – the need to be sustainable (balance economically, the socially in order not to undermine the natural systems on which it depends) – and a lack of a more coordinated effort to generate the science and technology to make it all possible. As the feed stock industry for modern society, the industry plays a major role in the sustainability effort – to advance the science and technology to support the design, creation, processing use, and disposal of chemical substances that provide a foundation for sustainability.

Rio Declaration: Selected Principle

Principle 1: Human beings are at the center of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature.

Principle 2: States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other states or of areas beyond the limits of national jurisdiction.

Principle 3: The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations.

Principle 4: In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it.

Principle 5: All states and all people shall cooperate in the essential task of eradicating poverty as an indispensable requirement for sustainable development, in order to decrease the disparities in standards of living and better meet the needs of the majority of the people of the world.

Principle 6: The special situation and needs of developing countries, particularly the least developed and those most environmentally vulnerable, shall be given special priority. International actions in the field of environment and development should also address the interests and need of all countries.

Principle 7: States shall cooperate in a spirit of global partnership to conserve, protect, and restore the health and integrity of the earth's ecosystem. In view of the different contributions to global environmental degradation, states have common, but differentiated responsibilities. The developed countries acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressures their societies place on the global environment and of the technologies and financial resources they command.

Principle 8: To achieve sustainable development and a higher quality of life for all people, states should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies.

Principle 9: State should cooperate to strengthen endogenous capacity building for sustainable develop by improving scientific understand through exchanges of scientific and technological knowledge, and by enhancing the development, adaptation, diffusion, and transfer of technologies, including new and innovative technologies.

Principle 11: States shall enact effective environmental legislation. Environmental standards, management objectives, and priorities should reflect the environmental and developmental context to which they apply. Standards applied by some countries may be inappropriate and of unwarranted economic and social cost to other countries, in particular developing countries.

Principle 14: States should effectively cooperate to discourage or prevent the relocation and transfer to other states of any activities and substances that cause severe environmental degradation or rare found to be harmful health.

Principle 15: In order to protect the environment, the precautionary approach shall be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost – effective measures to prevent environment to prevent environmental degradation.

Principal 16: National authorities should endeavor to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment.

Principle 17: Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have to have a significant adverse impact on the environment and are subject to a decision of a competent national authority.

Integrated Pest Management

The FAO defines Integrated Pest Management (IPM) as the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment()

Generally, the farmer requires following a system of IPM, which combines different management strategies and practices to grow healthy crops and minimize the use of pesticide. Farmers must prioritize prevention, followed by non- chemical control, and using chemical control only as a last resort. (Pretty and Barucha, 2006).

1. **Prevention**

Strong focus is on pest prevention by applying good agronomic practices and using resistance varieties, pest identification and monitoring and biological pest control. However, the first line of defence against pests and diseases should be preventation. That is, a healthy crop is less likely to get infected by a disease or attacked by insects. Therefore, measures are needed to guarantee good conditions for the crop development. For example, pruning and weeding to optimize nutrient and water uptake.

2. **Non – Chemical Control**

If pest control is needed, the first step should by using non –chemical control methods which includes; Control methods: practices to make the environment less favourable for pest e.g shade regulation and cover crops. Mechanical methods: direct removal or killing of pests and lastly by Biological methods: the use of natural enemies of pest and diseases.

3. **Chemical Control**

Chemical controls should only be used if cultural, mechanical control and/or biological controls have been applied and pests or disease still reach threshold levels. As soon as the economic threshold is achieved- the point at which the cost of pesticide use pays off (cost of expected loss in harvest exceeds the cost of treatment), then chemical pest control becomes profitable. Furthermore, in the case that pesticide are used, there are extensive requirements that regulate their use to ensure protection of the environment.(Pretty and Barucha, 2006).

Conclusion

Pesticides play a sensitive role in food system. On the one side they contribute to ensuring sufficient food production and on the other side they pose risks to food safety, and environment. For society as a whole it would be desirable to gradually reduce pesticide use to a level where negative impacts- externalities like, health hazards, biodiversity loss or water pollution – at least do not outweigh the value added in terms of yield or cost saving in production. Today there is a consensus among a wide range of stakeholders that pesticide use needs to be gradually reduced to a level that is effectively required to ensure crop production, and that risk of pesticide application need to be reduced as far as possible (Shabeer, *et al.,* 2015). Conclusively, true sustainability means that farmers can run a productive, economically viable business, while at the same time the health of farmers, workers and the consumers in general is protected, and natural resources are safeguarded. Lastly, by promoting integrated IPM, and banning the hazardous substances altogether, the farmers must take steps towards greater sustainability.

Suggestions

It is suggested that

- i Extreme exposure to pesticides during application should be avoided.
- ii Use of natural pesticides should be encouraged.
- iii Banned pesticides into the country should be properly checked by the regulatory bodies so as to enhance complete phase out of this highly hazardous pesticides.

iv Government should institute measures to consciously liberate our food industry from the unprofitable and unsustainable high dependence on chemicals , as it has become the order of the day in our country, which could be implemented in phases, through the popularization and enlargement of the commendable Integrated Pest Management (IPM) scheme.

v Green technology approach could also help in minimizing pesticide effects in our environment

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