ENVIRONMENTAL AND HEALTH CONSEQUENCES OF CHEMICAL FERTILIZER AND PESTICIDE USE

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ABSTRACT

Agricultural surpluses play a major role in the economic progress of any nation because they support industry, trade, and ensure food security for a rising population. To meet these increasing demands, many developing countries adopted the Green Revolution, which helped them reduce long-term food scarcity. By introducing high-yielding seeds, improved machinery, irrigation facilities, and different types of chemical fertilizers, agricultural production increased rapidly. However, this rapid progress also brought several challenges. The widespread and continuous use of chemical fertilizers and pesticides introduced many harmful substances into the environment. These chemicals were initially seen as a quick solution for boosting crop growth and controlling pests, but over time their negative impacts became clear. Excessive chemical use has degraded soil quality, polluted water bodies, entered the food chain, and affected biodiversity. Along with environmental damage, these substances also pose serious risks to human health through contaminated food, water, and air.

This article examines how chemical fertilizers and pesticides, though important in increasing agricultural output, have created significant environmental problems and health hazards. The discussion highlights the need for sustainable and balanced farming practices that protect both nature and human well-being.

Keywords: Green revolution, chemical fertilizers, pesticides, environment, human health.

INTRODUCTION

Agriculture plays a fundamental role in ensuring that society receives sufficient food and other essential products required for daily life. At the same time, agriculture is also expected to generate surplus commodities that can be exported to strengthen the national economy. To meet these growing demands, modern farming systems increasingly rely on various chemical inputs, especially pesticides. These substances, whether chemical or biological, are designed to eliminate or control insects, weeds, fungi, and other harmful organisms that can cause severe damage to crops and livestock.

The use of pesticides has become deeply integrated into modern agriculture because they help protect crops from diseases and pest attacks that could drastically reduce

yields. For many farmers, pesticides are not just supportive tools but essential inputs that enable them to produce more food using the same amount of land. Higher production improves national food security and helps address the risk of food shortages. In India, the Green Revolution played a major role in increasing pesticide usage because high-yielding crop varieties required greater protection from pests and diseases to maintain their productivity.

However, despite their contribution to enhancing agricultural output, pesticides also pose serious environmental and health concerns. Their excessive, indiscriminate, or careless use can lead to long-term ecological problems such as soil degradation, contamination of groundwater and surface water, and destruction of beneficial organisms like pollinators and soil microbes. Pesticides can enter the food chain and gradually accumulate in plants, animals, and humans. These effects may not appear immediately but can result in chronic health risks over time.

India is currently the largest producer of pesticides in Asia. Although the per-hectare consumption of pesticides in India is lower than in many developed countries, the issue of pesticide residues remains a major challenge. These residues can persist in soil and water bodies and may be present in food products consumed daily. As a result, environmental systems face continuous stress, and human health becomes vulnerable to hidden chemical exposure. It is therefore crucial to understand both the benefits and the harmful effects of pesticides so that safer and more sustainable agricultural practices can be developed and adopted.

Growing awareness about the harmful effects of chemical pesticides has encouraged the government to explore safer alternatives and promote new methods that reduce chemical dependence. The purpose of these initiatives is to ensure that agricultural production remains stable while minimizing the risks associated with exposure to toxic substances. Even at very low concentrations, pesticides have been shown to exert significant negative impacts on ecosystems and human well-being (Agrawal et al. 2010).

Studies conducted over the last two decades highlight that pesticide exposure can lead to a variety of serious human health complications. Many pesticides are known to cause neurological disorders and degenerative diseases; some interfere with fetal development, leading to congenital anomalies; while others are classified as carcinogenic to humans (Asghar et al. 2016). Over the past three decades, the indiscriminate use, misuse, and improper handling of pesticides in agriculture have contributed to severe health problems in many developing countries, where awareness, regulation, and safety practices are often insufficient (Dasgupta et al. 2007).

These concerns show that while pesticides cannot be eliminated immediately from agriculture, their use must be controlled, regulated, and replaced gradually with safer and more sustainable options. Approaches such as organic farming, integrated pest management

(IPM), and the adoption of bio-pesticides can help reduce the dependency on harmful chemicals. Only through such balanced practices can agriculture remain productive while also protecting the environment and human health.

Effects of Chemical Fertilizers and Pesticides on Human Health

Bhandari (2014) studied the impact of agrochemicals on the environment in Nepal. He explained that although fertilizers and pesticides are widely used in developing countries to increase agricultural productivity, they also create serious risks for human health. Many studies have found that exposure to these chemicals can lead to several diseases, including cancer.

Research has consistently shown that most farmers do not use basic safety equipment such as masks, gloves, or protective clothing while spraying pesticides. Because of this, the chemicals enter their bodies through inhalation and skin absorption. A study conducted on spray farmers in Bhopal, Madhya Pradesh, found a clear link between the amount of pesticide used and the symptoms of illness. Farmers who applied pesticides themselves were directly exposed. Those who had been exposed for around 18 months reported symptoms such as burning or stinging of the eyes (18.42%), blurred vision (23.68%), skin redness or itching (50%), excessive sweating or shortness of breath (34.2%), dry or sore throat (21.05%), and burning sensations in the nose (28.9%). The study clearly showed that these health problems increased with longer exposure and concluded that there is an urgent need for awareness programs and strict enforcement of protective gear (Choudhary 2014).

When fertilizers and pesticides are used on farmlands, they move directly or indirectly into crops like corn and vegetables, which then enter the human and animal body. Excessive fertilizer use, especially nitrates, can contaminate underground water. Drinking nitrate-contaminated water is extremely harmful because it reduces the oxygen-carrying capacity of hemoglobin in the blood. Organophosphate pesticides, which are now used more widely than organochlorine pesticides, are less persistent in the environment but cause acute health problems such as abdominal pain, dizziness, headaches, nausea, vomiting, and skin and eye irritations. Many studies have shown a possible link between pesticide consumption and cancer. Organophosphate residues on vegetables slowly accumulate in the human body and may contribute to cancer development (Miah et al. 2014).

Wimalawansa and Wimalawansa (2014) examined changing agricultural practices in Sri Lanka and found that excessive and careless use of toxic agrochemicals has contaminated the environment and the food chain. Soil and water contamination from fertilizers containing heavy metals, pesticides, and herbicides is a major concern. These pollutants are present in small amounts and cannot be seen or tasted, so their harmful effects appear only after

several years. This long-term exposure has contributed to an increase in chronic kidney disease among rural populations.

The Green Revolution made India self-reliant in food production, but the uncontrolled use of synthetic fertilizers and pesticides has polluted the environment. Punjab, known as the "grain bowl" of India, now faces serious issues such as nutrient imbalance in soil, water contamination, pesticide residues in food and milk, and a rising number of cancer cases among farmers (Rahman and Debnath 2015).

DDT was once considered the most effective pesticide and helped increase agricultural productivity. However, after its harmful effects became widely known, it was banned globally. Despite this, DDT is still used illegally in some developing countries. Because DDT remains in the environment for many years and accumulates through the food chain, it continues to affect human health. It has been associated with several types of cancers, nerve damage, lung injury, reproductive problems, immune and endocrine disorders, and birth defects (Thuy 2015).

Pesticides were introduced in India during the mid-1960s under the Green Revolution and malaria control programs. Although they helped reduce pests, they also caused health problems. Chemicals that accumulate in the food chain pose the greatest danger because consuming food with pesticide residues leads to exposure 103–105 times higher than exposure from contaminated air or drinking water. Pesticides are linked to health issues ranging from allergies, rashes, and breathing difficulties to neurological damage, reproductive disorders, and chronic diseases such as cancer. To reduce these risks, preventive strategies must be promoted, including sustainable agricultural practices and processing methods that reduce pesticide residues in food and water (Tomer et al. 2015).

Effects of chemical fertilizers and pesticides on environment

Soil is the foundation of all agricultural activities, yet it is becoming increasingly polluted due to the gradual accumulation of heavy metals from multiple human activities. Modern industrialization and rapid urban growth have introduced several pathways through which harmful metals enter agricultural lands. These include emissions from factories, mining operations, improper disposal of industrial wastes, leakage from gasoline and petroleum products, continuous application of chemical fertilizers, pesticides, insecticides, sewage sludge, and wastewater irrigation. Even residues from burning coal contribute significant amounts of toxic metals to the environment. Over the years, agricultural soils have received large quantities of synthetic chemicals, and as a result, harmful metals such as cadmium (Cd), lead (Pb), and arsenic (As) have risen to dangerously high levels (Atafar et al. 2010). These

metals do not break down naturally and stay in the soil for long periods, gradually entering crops and moving further into the human food chain.

Although the use of pesticides, insecticides, and chemical fertilizers is considered an easy, fast, and low-cost solution for controlling weeds and pests, the long-term consequences are extremely damaging. The routine use of these chemicals has contaminated almost every component of our environment. Their residues are consistently detected in soil, water bodies, the atmosphere, and even inside living organisms. As these chemicals accumulate year after year, they reduce soil fertility, harm soil organisms, and disturb the natural ecological balance. This contamination not only threatens crop productivity but also poses serious risks to human and animal health.

Kumar et al. (2013) further emphasized that pesticides, though widely used due to their convenience and affordability, have become one of the major environmental pollutants. Their study revealed that pesticide residues are found throughout the nation—in soil and air, and in both surface and groundwater sources. Urban areas, where pesticides are used in gardens, parks, and lawns, also contribute significantly to this contamination. Once released into the environment, pesticides do not remain confined to the area where they are applied. Wind, rainwater, and soil movement help carry these chemicals to nearby ecosystems.

This widespread contamination harms a variety of non-target organisms. Beneficial soil microorganisms that help maintain soil health and fertility are severely affected. Many insects, including pollinators like bees, are harmed by pesticide exposure. Aquatic organisms such as fish and amphibians suffer when pesticides wash into ponds, rivers, and lakes. Birds are also at risk because they may consume contaminated insects or seeds. In addition, the study highlighted that even herbicides—which many people assume are less harmful—can negatively impact the environment. Herbicides may damage soil structure, reduce plant diversity, and alter nutrient cycles.

Overall, the studies show that while pesticides and chemicals may provide short-term benefits in agriculture, their long-term environmental and health impacts are extremely serious. Continuous awareness programs, strict regulations, and sustainable agricultural practices are necessary to reduce the growing threat of soil and environmental contamination.

The study performed in the surface water of Sharda river region in Lakhimpurkheeri, Uttar Pradesh-India reports the concentration levels and distribution patterns of the 21 organochlorine pesticide residues in Solid Phase Extraction (SPE) is used for the extraction of organochlorine pesticide residues in water sample. The most commonly encountered Organochlorine pesticides in surface water were dieldrin, heptachlor epoxide, isomers of hexachlorocyclohexane and DDT. In some cases the concentrations detected were

higher than the quanlitative target levels set by the European Union, especially for γ-hexachlorocyclohexane&pp'- DDT. The concentration levels found are lower than the EU maximum acceptable concentration of 0.10 μg l-1 for all compounds examined, except for δ-HCH in seven samples (0.2772, 0.1950, 0.2210, 0.2045, 0.1994, 0.1523, 0.1390 μg l-1) and four samples (0.1877, 0.2365, 0.1478, 0.1269 μg l-1) of pp'-DDT during 2008-2010.

Maurya and Kumar (2013) reported that the presence of pesticide compounds in the surface waters of the Sharda River region is directly linked to two major sources: intensive agricultural activities in the surrounding areas and transboundary pollution coming from neighboring regions. Since the river flows across state borders, pollutants released upstream can easily travel downstream, worsening local contamination levels. This makes the river ecosystem more vulnerable, and the continuous entry of agricultural chemicals poses long-term ecological risks.

Pesticides today have contaminated nearly every part of our environment. Their residues are consistently found in soil, air, surface water, and groundwater. This widespread contamination is dangerous because pesticides do not only affect the targeted pests. They also pose serious risks to non-target organisms such as beneficial soil microorganisms, insects, plants, fish, birds, and other wildlife. Such environmental disruption can weaken food chains, reduce biodiversity, and degrade ecosystem health. According to Sitaramaraju et al. (2014), recent research clearly shows that the environment is chronically exposed to pesticides, and the level of biocidal contamination has increased at an alarming rate. The environmental deterioration caused by pesticides threatens future sustainability and raises serious concerns about the safety of soil, water, and living organisms.

Natraj and Katyal (2014) carried out a detailed soil analysis in the villages of Loni, Adgaon, Chinchpur, Sadatpur, and Gogalgaon located in the Rahata and Sangamneer Talukas. Farmers in this region have been using chemical fertilizers and pesticides continuously for many years to boost crop production and meet the growing demand for sugarcane, bajra, vegetables, and fodder. However, the excessive use of these chemicals has resulted in significant changes in soil quality.

Their study found that soil pH ranged from 7.46 to 8.9, which indicates moderate alkalinity. Although the soil was free from salt accumulation, the level of organic carbon was moderate to very low, showing that soil fertility has declined and needs improvement. Available nitrogen was low in about 80 percent of the samples, which signals severe nitrogen deficiency and the need for proper nitrogen fertilizer application.

About half of the samples showed very low phosphorus content, while the rest had moderate to low values. In contrast, more than 80 percent of the soil samples had very high potassium levels, up to 963.2 kg/ha. Micronutrient analysis revealed moderate to low levels of

zinc and copper, very low iron levels, and higher manganese levels in about 48 percent of the samples. This micronutrient imbalance is likely due to the moderately alkaline soil conditions.

Groundwater studies from the same region show increasing alkalinity, higher nitrate levels, and residues of fertilizers and pesticides. If soil contamination continues to rise, it will likely worsen groundwater pollution. According to the researchers, this situation demands immediate action such as controlled irrigation, reduced chemical inputs, and the adoption of biofertilizers and organic manure to restore soil health.

A study conducted in Moghan's irrigation and drainage network in Ardabil, Iran, evaluated the long-term effects of pesticides and chemical fertilizers on soil properties and heavy metal accumulation (Yargholi and Azarneshan 2014). The results revealed that long-term chemical use had significantly altered soil physical properties. Soil bulk density increased in comparison with non-contaminated control soil, indicating soil compaction and reduced aeration. The study also found that heavy metal accumulation had occurred in the soil, with cadmium levels rising above the standard safety limit for agricultural use. Fortunately, the concentrations of other heavy metals remained within acceptable limits. However, the presence of cadmium above safe limits shows that the region requires urgent management strategies. The researchers recommended that pesticide and fertilizer usage must be controlled, reduced, or replaced with safer alternatives to prevent further degradation of soil quality.

CONCLUSION

It has been consistently observed that many farmers still fail to follow proper safety measures while handling and spraying pesticides. The absence of basic protective equipment such as gloves, masks, and protective clothing exposes them directly to harmful chemicals. This continuous exposure has resulted in several short-term and long-term health problems among farmers, including skin irritation, eye disorders, respiratory issues, headaches, and, in severe cases, chronic diseases. Along with affecting human health, careless handling of pesticides has also contributed to the pollution of air, water, and soil. Since a major portion of India's population depends on agriculture for income and food production, pesticides are used extensively across farmlands to protect crops from pests and increase overall yield. However, this increased usage comes with significant environmental and health risks.

Given these risks, there is an urgent need to adopt proper strategies to protect both the environment and human health from the harmful effects of chemical pesticides. One of the most effective and sustainable alternatives is the adoption of organic farming. Organic agriculture avoids synthetic chemicals and relies on natural methods such as composting, crop rotation, biological pest control, and the use of organic manure. These practices help restore soil health, maintain ecological balance, and reduce pollution. By shifting toward organic

farming, communities follow a more traditional, natural, and sustainable agricultural path that improves food quality and ensures long-term health benefits for both people and livestock.

Organic farming also plays a major role in protecting natural resources such as soil, groundwater, and biodiversity. It supports long-term food security by maintaining soil fertility and preventing land degradation. Although the government has launched multiple programs and campaigns to promote organic agriculture, a noticeable gap still exists between the increasing demand for organic food and the limited supply available in the market. This gap is largely due to a lack of awareness, proper training, and financial support for farmers who wish to adopt organic techniques.

To bridge this gap, farmers need proper education and training that can help them understand organic methods and apply them effectively. As the number of organic food stores and markets in India continues to grow, it is clear that consumer demand for chemical-free, safe, and nutritious food is steadily increasing. Expanding organic agriculture can meet this rising demand while ensuring a healthier environment and a more sustainable agricultural system for future generations.

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