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# Water Pollution from Agricultural Activities: A Critical Global Review

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**Abstract**

Agricultural water pollution has far-reaching consequences on the environment, human health, and food security, impacting aquatic ecosystems and water quality. It is caused by contaminants such as fertilizers, pesticides, sediment, and others from both point and non-point sources. The global population growth and food consumption patterns increase the pressure on agriculture, making decisions to control pollution necessary. A comprehensive approach to integrated water quality management requires the participation of numerous organizations and stakeholders, including government agencies, NGOs, farmers, and others. It comprises the application of best management practices, alternative solutions, laws and regulations, research, and monitoring programs to reduce the effect of pollutants such as new toxins, metals, illnesses, organic matter, and pesticides. Future priorities in research include identifying the origins of pollution, exploring novel toxins, providing economic incentives for decreasing pollution, understanding the effect on biota, and gathering additional data. A healthy and sustainable ecosystem can be achieved through a combination of on-farm and off-farm responses, including integrated water resource management, conservation tillage and agroforestry, crop rotation and cover cropping, irrigation water management, and enhanced nutrient management and pesticide management, and precision agriculture technology. Regulations, technology usage, monitoring, and economic incentives should also be implemented to control and reduce the impact of agricultural water pollution.

**Keywords:** Agricultural water pollution, global population growth, on-farm and off-farm responses, control

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## 1. Introduction

The rising global population (Fig. 1) and food consumption patterns (Fig. 2) provide evidence of the importance of agricultural water pollution worldwide. The pressure on agricultural systems to generate food will rise with the anticipated rise in world population and food consumption, increasing the risk of water pollution. Making decisions in agriculture to lessen the influence of agricultural activities on water quality is necessary to control non-point source pollution. Water pollution in agriculture is a global problem that affects both developed and developing countries. Agriculture is a significant source of water pollution in developed countries because of the use of fertilizers, pesticides, and other chemicals in farming practices. These pollutants have the potential to leach into nearby rivers and lakes, causing eutrophication and harming aquatic life. Furthermore, runoff from agricultural land can pollute groundwater, a critical drinking water source for many communities[1].

The situation is often worse in developing countries. Agriculture is an integral part of these economies and is frequently the primary source of income for millions of people. However, many farmers in these countries cannot implement sustainable and environmentally friendly practices due to a lack of resources and technology. This causes widespread pollution of water sources, degradation of local ecosystems, and health problems for communities that rely on them [2]. Despite the significance of the problem, there is a dearth of information and a thorough understanding of agricultural water contamination in emerging nations. By offering a critical assessment of the causes and effects of agricultural water pollution on a global scale and by highlighting the open research topics and goals, this review article seeks to close this knowledge gap. Agriculture-related water pollution has far-reaching consequences that impact the environment, human health, and food security. As a result, developed and developing countries must collaborate to address this issue and implement policies and technologies to help mitigate agriculture's impact on water resources [3].

The causes and impacts of water pollution due to agricultural practices vary from country to country. Each country has a different population and land area, necessitating various livestock and agricultural management methods and techniques. Agricultural activities release chemicals and nutrients like phosphates and nitrates into the water, which results in nutrient and chemical pollution. Overuse of chemicals in the soil causes soil sedimentation, and using chemicals in water causes eutrophication, killing plants and animals, reducing biodiversity, and having health consequences when drinking water. In the US and Australia, heavy use of fertilizers and pesticides causes runoff from fields and leaches into groundwater [4]. In India and other

developing countries, old and traditional agricultural practices, lousy infrastructure, and uneducated farmers are the leading causes of agricultural pollution. In the US, livestock operations such as CAFOs produce large amounts of manure, and their improper management significantly contributes to nutrient pollution of fresh water sources. The scope is further influenced by population growth, agricultural intensification, and increasing food demands. Therefore, there is a need to address this problem of ensuring sustainable agriculture and protecting water resources [5].

Various contaminants contribute to agricultural water pollution, including excess nitrogen and phosphorus levels that in water can lead to eutrophication and the growth of harmful algal blooms, resulting in oxygen depletion and fish kills. Pesticides used in agriculture can end up in bodies of water via runoff and leaching, affecting aquatic life and potentially contaminating drinking water. Soil erosion from agricultural fields can transport sediment into bodies of water, reducing water clarity and negatively impacting marine life [6]. Agricultural operations can also release pollutants into bodies of water, such as bacteria, heavy metals, and salts, and cause pollution and barren land, which results in a food shortage. The map (Fig. 3) shows the percentage of food shortages in 2018 in different countries of the world, including the United States (2.3%), Canada (4.6%), the United Kingdom (8.2%), Germany (2.6%), Japan (2.9%), Ethiopia (23.4%), Niger-Ivory Coast (22.4%), Bangladesh (12.7%), Pakistan (17.2%), Haiti (45.6%), and India (14.3%). These pollutants can come from both point and non-point sources, such as agricultural operations and livestock facilities. Pollution sources are easily identified and frequently regulated, whereas non-point sources are diffuse and more difficult to control. Addressing both types of sources is required for a comprehensive approach to agricultural water pollution [6].

The availability and quality of data on agricultural water pollution is a data problem in addressing the issue, particularly in developing countries. Here are some solutions to this problem: to collect data and precisely access it for improvement by collaborating with private and public sector organizations. standardize methods by analysing the quality and comparing different regions. To share data on accessible portals and promote data transparency, develop new techniques by analyzing available data and its interpretations. More effective strategies will provide more understanding and information[7].

There should be a well-structured strategy to manage agricultural practices like integrated pest management and conservation tillage. There should be and investment in research fields, and various policies and regulations should be implemented to reduce water pollution through education and outreach to farmers. Agencies and the government should collaborate with farmers and stakeholders to find innovative solutions. Data monitoring is used to keep agricultural water pollution under control. In developed countries, such as the United States and Australia, decisions regarding the use of chemicals in agriculture, such as fertilizers and pesticides, are critical to reducing non-point source pollution. This may involve regulations on the use of chemicals, restrictions on the application of certain substances near water sources, and investment in alternative agriculture practices that minimize harmful chemicals [8]. In Asian countries, decisions regarding waste management practices should be made. And globally, irrigation decisions are essential. A combination of regulation, education, and investment is required to solve this problem [9].

## 2. Causes of Agricultural Water Pollution

As everyone requires food to survive, in addition to non-vegetarian foods such as chicken, fish, eggs, and so on, man also requires vegetables, lentils, beans, and other legumes, and so on, so there is an urgent need to establish additional agricultural production. As a result, artificial methods are used to increase growth, and because of these agricultural activities, pollution has increased at an alarming rate in recent years. This primarily has a negative impact on water. Because the world contains less than 1% fresh water, and if it is contaminated, water scarcity will occur concurrently with fulfilling food needs. Agricultural water contamination is a severe problem that impacts communities and ecosystems worldwide [10]. With agriculture using more than 70% of the world's freshwater, we must address the sources and causes that contribute to this problem. This article will look at the numerous sources of agricultural water pollution and the underlying mechanisms that lead to its persistence. This agricultural water pollution came from both point and non-point sources. Point sources such as field runoff, animal feedlots, and concentrated animal feeding operations (CAFOs) can be identified. Non-point sources, as opposed to point sources, are difficult to identify, such as fertilizer and pesticide runoff from agricultural fields [4].

Agricultural activities in developed and developing countries can contribute to point- and non-point-source pollution of water resources. Point-source pollution from CAFOs and large-scale animal feedlots in developed countries can release nutrients and chemicals into water-bodies, causing eutrophication, decreased water quality, and negative impacts on aquatic life. Agriculture-related non-point-source pollution, such as fertilizer and pesticide runoff, can also contribute to water pollution in developed countries [11]. Agricultural activities such as irrigation have degraded freshwater resources in Latin American countries such as Mexico. Pesticide including herbicides, fungicides and insecticides used in agriculture, for example, has resulted in groundwater contamination and surface water pollution (Fig.4). Poor agricultural practices, such as over-fertilization and over-grazing, have contributed to soil erosion and sediment pollution of rivers and lakes in African countries such as Nigeria [12].

Excessive use of chemical fertilizers and pesticides is a significant source of agricultural water contamination. These chemicals can seep into adjacent water sources, harming aquatic life and posing a danger to human health if ingested or used for irrigation. While chemical fertilizers and pesticides are essential for raising agricultural yields and protecting crops from pests, they must be used responsibly and sustainably.

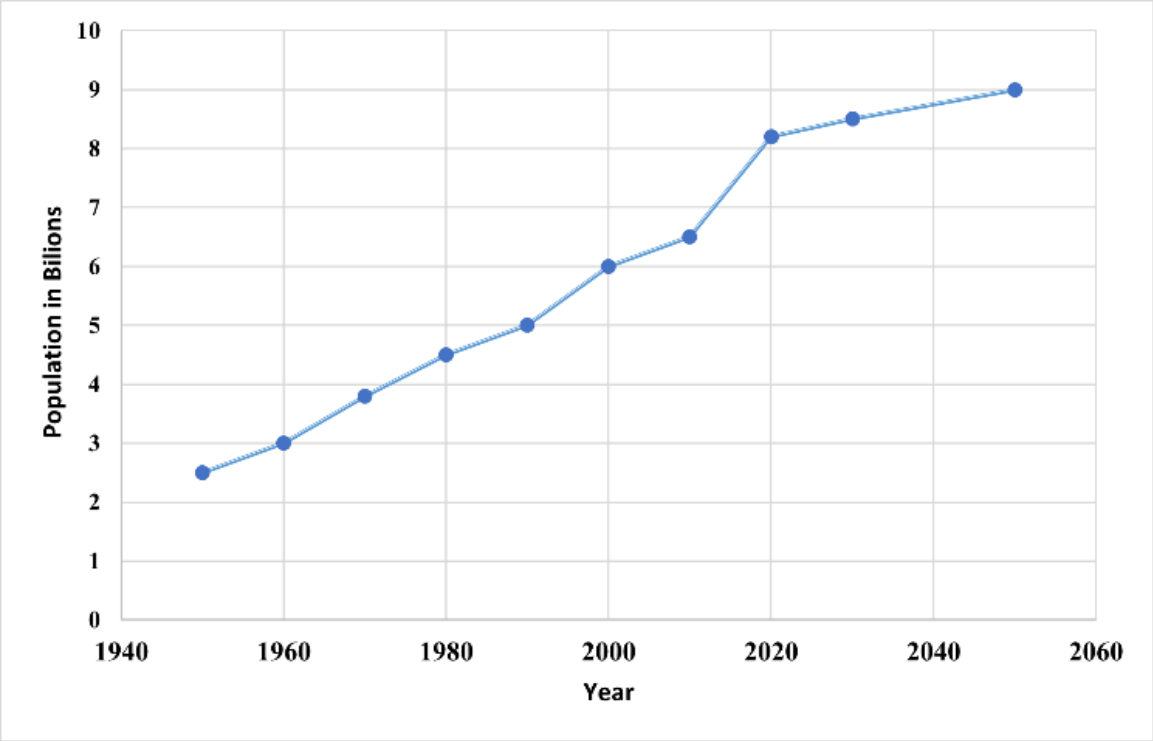


**Figure 1.** Population Growth in Billions

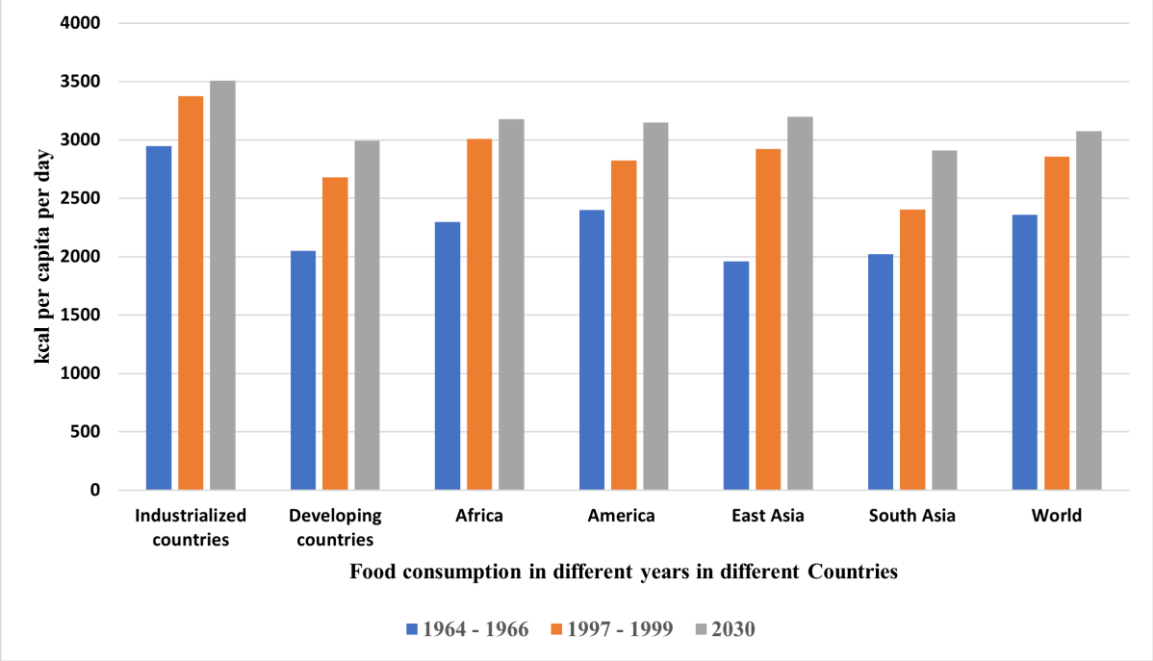


**Figure 2.** Global Food Consumption (kcal per capita per day)


**Figure 3.** Proportion of Population Classified as Hungry in 2018

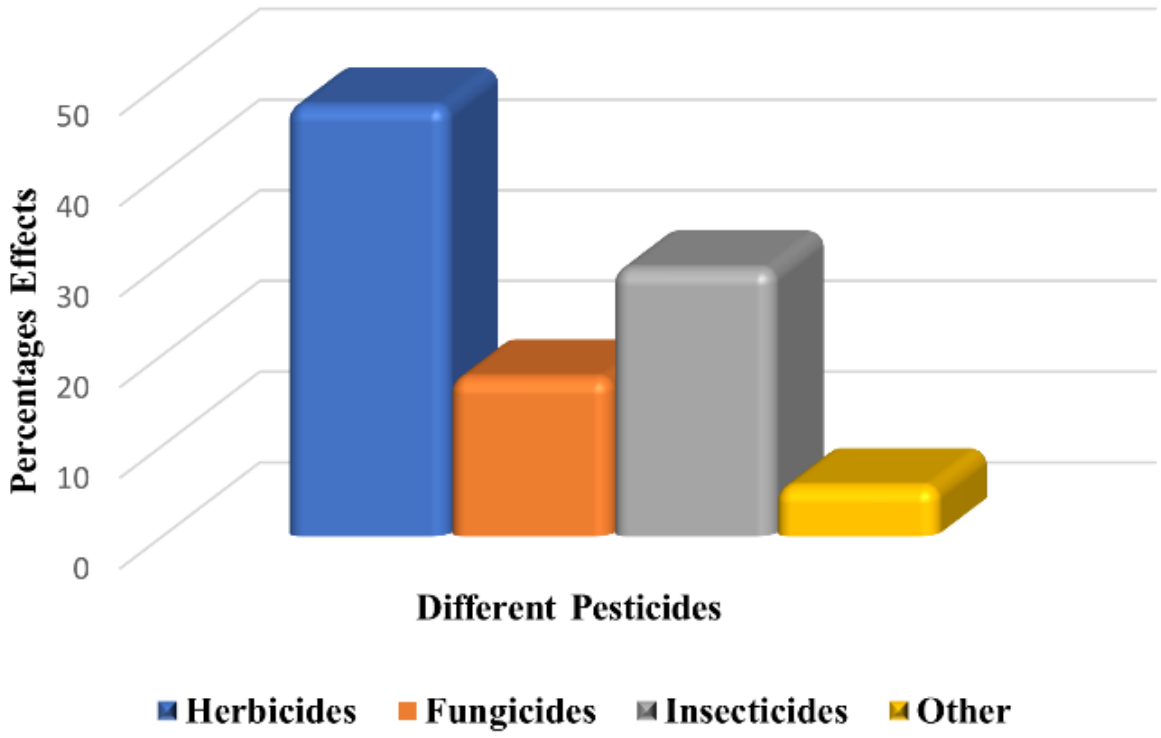


**Figure 4.** Effects of pesticides used in agriculture

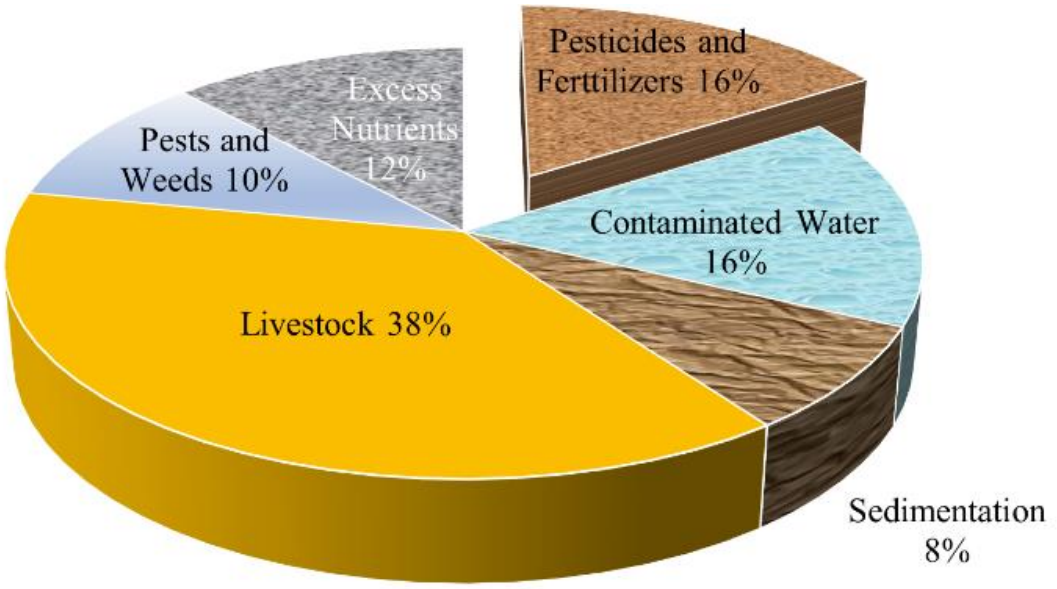


**Figure 5.** Percentage Effects of different sources of water contamination

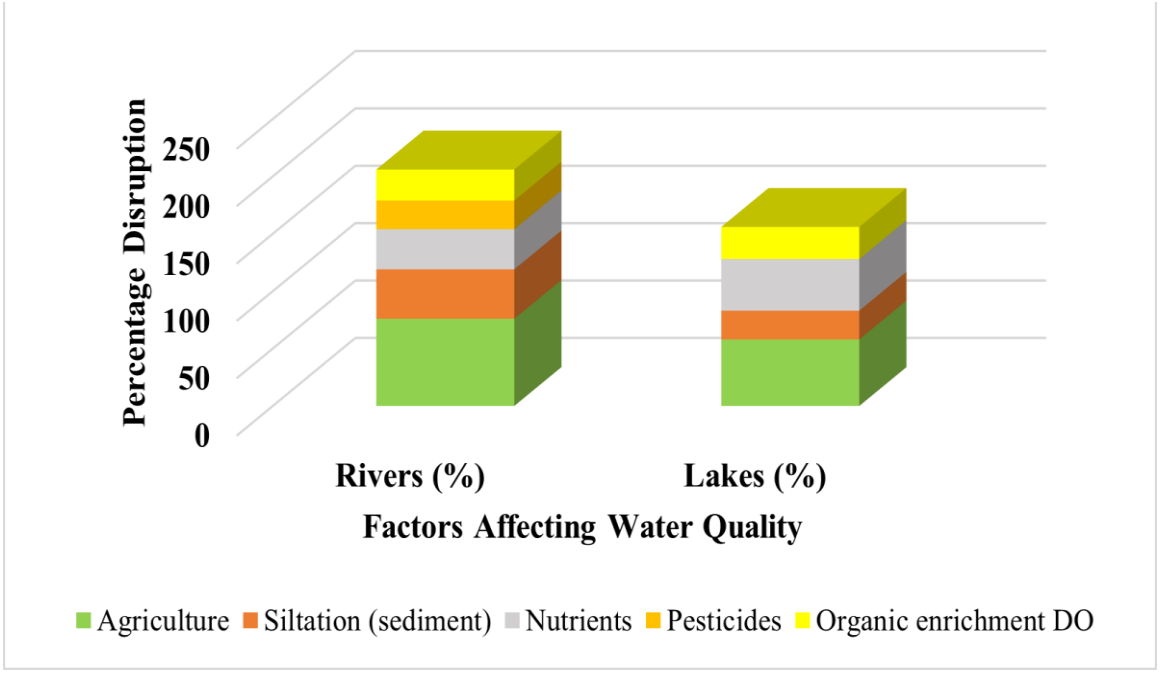


**Figure 6.** Water Quality Disrupting Factors

In developing countries, the lack of regulation and farmer education often results in overuse and high levels of contamination, especially in places like India, China, and Bangladesh. On the other hand, developed countries such as the United States, Australia, and the United Kingdom have strict regulations to reduce the environmental impact of these chemicals. Overusing chemical fertilizers and pesticides can lead to eutrophication, algal blooms, and other adverse effects on water sources [13]. Insecticides are usually sprayed on crops and in fields to control the growth of pests that harm the crops, but it was observed that when these sprays were used, they also killed the pollinators and other beneficial insects. It was one loss, but with it, when this sprayed food is eaten, it causes health problems, that was not the end, but when the washed water from agricultural land was moved to rivers and canals, it took these chemicals with it. Which then reached human hands for drinking purposes and again was used for plant production, and a never-ending cycle started in the food chain [14]. For example, neonicotinoid insecticides have a significant impact. Agricultural intensification has led to a loss of biodiversity, particularly among insects. Neonicotinoids are highly soluble and persistent, contaminating broad areas around agricultural fields through movement in surface water. They have been linked to reductions in terrestrial and aerial insects and have a cascading impact on other species, such as birds, bats, and amphibians, that depend on insects. Scientists and experts are calling for removing neonicotinoids' most damaging uses, many of which are considered unnecessary [15].

Animal waste from factory farms and large-scale livestock and poultry farming operations is another major cause of agricultural water pollution, particularly in rapidly expanding industries in countries like Brazil, Mexico, and China. Inadequate waste management and disposal facilities and the use of large lagoons that are prone to leakage contribute to water contamination. Animal excrement is another primary source of agricultural water contamination. This can contain animal dung, other organic elements, and waste from fish and other aquaculture activities. When vast amounts of this garbage accumulate, it may constitute a substantial source of pollution, poisoning neighboring water supplies and endangering human health and the environment.

Irrigation systems, while crucial for agriculture, can also cause water pollution by over-extracting water from rivers and aquifers and contaminating groundwater with elevated levels of salts in countries like India and China. Soil erosion from agricultural lands, exacerbated by poor land management practices and deforestation in developing countries like Brazil, Indonesia, and Nigeria, also contributes to water pollution. Irrigation methods can potentially contaminate agricultural water. Irrigation systems that are poorly maintained can result in water waste and soil erosion, which can transfer contaminants into surrounding water sources. Furthermore, irrigation can create salt accumulation in the soil, deteriorating it and decreasing agricultural output. Effective irrigation management, as well as the use of sustainable techniques such as drip irrigation and rainwater collection, can help reduce the impact of irrigation on water resources [16].

Another element that leads to agricultural water contamination is a lack of farmer education. Farmers may be unaware of optimal procedures for utilizing pesticides and managing irrigation systems, resulting in inefficient practices that wastewater and cause soil erosion. Providing farmers with information and tools can help them understand sustainable farming practices and lessen the impact of agricultural water pollution on water resources [17]. Runoff from industrial and urban areas and using genetically modified organisms (GMOs) in agriculture can also contribute to water pollution. In developing countries, the lack of regulations and infrastructure can result in high levels of industrial and urban runoff, and the use of GMOs can lead to the leaching of chemical residue into water sources. The presence of nitrates in groundwater has been a focus of research in recent years, with studies performed worldwide to determine the concentration of nitrates in groundwater sources such as wells, boreholes, and springs. The World Health Organization has established a threshold of 50 ppm for nitrate concentration in groundwater to guarantee excellent quality. Results show that Europe has the highest percentage of regions with nitrates above 50 ppm, followed by Asia and America [18].

## 3. Sources of water contamination

Metals are a substantial factor in agricultural water contamination. These compounds can come from a variety of sources, including metal-containing herbicides and fertilizers, runoff and leaching from mining and industrial operations, and metal-containing animal feed additives (Fig. 5). It may have serious consequences for water quality and human health. Some metals, such as lead and mercury, are poisonous and can impair human health. Furthermore, large quantities of metal pollution can affect aquatic life and animals. Strategies for managing and reducing metal pollution in agriculture include best management practices for fertilizer and pesticide application, integrated crop management and conservation practices, alternatives to metal-containing inputs, policies and regulations to control metal pollution from agricultural activities, water treatment and sanitation systems, and research and monitoring programs for metals in agricultural systems [5-19].

Pesticides are frequently used in agriculture and other industries to control pests and diseases. Even though their use has altered agricultural production and pest management, it has also prompted concerns about their fate and potential environmental and human health effects. Pesticides have been used for thousands of years since Sulphur was first used as a pesticide in the Roman Empire. Pesticide use has expanded considerably over the last century because of technological developments and rising customer demand for food supply. OPPs are among the most often used pesticides and are critical for decreasing pathogen contamination and increasing production.

Long-term use of these chemicals has prompted concerns about their impact on animal health and the ecology of the environment. OPP harms the environment and human health, and both rich and developing countries struggle to balance public health, environmental conservation, and food security. Pesticides' fate and effects are influenced by several physical, chemical, and biological elements, including the pesticide's chemical characteristics, the weather, and the type of soil or water they penetrate. Pesticides can have an impact on both ground and surface water through runoff, leaching, and spray drift. Pesticide use

poses considerable dangers to human health and can lead to pesticide resistance. Toxins are especially dangerous to children and expecting mothers. Pesticides have the potential to harm non-target species, contaminate soil and water, and create pests resistant to them. As a result, biodiversity is declining, and critical ecological services are being lost. Surface water pesticide monitoring is critical for detecting and tracking pesticide presence in the environment.

Regular monitoring can aid in the detection of trends and changes, as well as inform management and control measures. While certain pesticides can be broken down naturally through photolysis, hydrolysis, and microbial degradation, many can linger in the environment for a long time. Best management techniques such as integrated pest management, pesticide minimization, and the application of rules and monitoring systems can all contribute to effective pesticide management and control. Pesticide registration and licensing are also essential stages in ensuring that only safe and effective pesticides are used. The European Union has taken the lead in pesticide regulation, implementing strong rules and monitoring programs to protect the environment and human health [20]. The Danish example is particularly significant, with the government taking a cautious approach to pesticide use and implementing pesticide exposure reduction measures for both the environment and human health.

To summarize, while pesticides have changed agricultural and food production, their usage also poses major health and environmental dangers. To protect the safety of human health and the environment, we must continue to monitor and control pesticide use. We can balance food security and environmental conservation by using pesticides with caution and protecting future generations' health [21]. A study on the impact of industrial wastewater disposal in the agricultural drain in Egypt showed that heavy metal levels in the drain's water samples exceeded the limits set by the WHO. The metals were found in the following order: Pb > Zn > Cr > Cd > Ni > As. Most samples showed carcinogenic health risks and soil contamination. The bioaccumulation factor showed heavy metal accumulation in plants that exceeded critical levels. The study highlights the need for environmental monitoring and solutions for present challenges in similar agricultural regions. Industrial wastewater is a significant cause of surface water degradation globally and is a concern for Egypt due to the increase in population and industrial activities in the Nile Delta [7]. Egypt is taking steps to preserve its water sources from pollution but faces challenges from industrial drainage, which consumes 7% of its water resources and disposes of pollutants that negatively affect the quality of wastewater. Evaluating water resource quality is crucial in developing a new watershed management strategy [5].

Sediment refers to the presence of soil particles and other debris in rivers, lakes, and other bodies of water carried by water and deposited. Sediment is a physical pollutant that can clog aquatic habitats and cause turbidity. Pesticides, fertilizers, and heavy metals are among the chemical pollutants in it, which can harm aquatic life and human health. Best management practices (BMPs) can be implemented to reduce the impact of sediment pollution. Sediment pollution has a significant impact on aquatic life and human health. Poor water quality can harm fish and wildlife populations while also lowering the quality of recreational activities like fishing and swimming. Sediment pollution is a major environmental concern that has an impact on water quality and aquatic habitats. We can reduce its impact by understanding its causes and consequences and implementing effective best management practices [22]. When fertilizers are misused, these chemicals move to bodies of water like rivers and lakes (Fig. 6), resulting in eutrophication. The environment, water quality, general health, and aquatic life may all be negatively impacted by this process. There are two types of fertilizers: organic and mineral. Organic fertilizers are made from natural materials like compost and animal waste. Mineral fertilizers, which use chemical fertilizers like nitrates and phosphates, are regarded as a less sustainable option. Eutrophication can be brought on by pollution from both non-point sources and point sources [23].

Improving fertilizer management and storage involves using the best management techniques to stop runoff and leaching into surface waters. Non-point sources of pollution are thought to be the main cause of eutrophication since they are difficult to find and manage. "Non-point source pollution" refers to contamination from diffuse sources such as agricultural runoff. Crops can be rotated to reduce the impact of fertilizer runoff on water quality. Significant volumes of nitrogen and phosphorus can be discharged into surface waterways when mineral fertilizers are utilized excessively, which encourages an excessive development of algae and aquatic plants [24].

## 4. Effects

Water pollution from agricultural activities is a critical issue in the 21st century and will be impacted by global changes such as climate change and shifts in agricultural technologies and practices. The use and emission of chemicals in agriculture, such as pesticides and biosolids, will affect the persistence, fate, and transport of chemicals in the environment and contribute to water pollution. Contamination of vital drinking water sources by agricultural water pollution has become a critical issue due to its detrimental effects on the environment, human health, and the economy. When this water flows into rivers, animals drink it, and it then enters the food chain one by one. In addition to the health effects, it causes fertilizer runoff, which causes an imbalance in algae and crop growth, resulting in infertile land and dead zones in the water. When algae growth increases, it spreads on the water's surface, stopping the entry of sunlight and oxygen production by aquatic plants. The lack of oxygen causes the death of plants and animals, resulting in decreased biodiversity [13].

People residing near or working in farms may face skin irritation, respiratory difficulties, and other health problems due to exposure to chemicals utilized in agriculture. Climate change has brought about alterations in precipitation patterns, increased evaporation, and rising temperatures, leading to changes in the water balance in watersheds and fluctuations in water quality. Due to differences in weather patterns and water availability,

farmers must adapt their practices, leading to new pollution problems and exacerbating existing ones. Rising temperatures and changing precipitation patterns increase the likelihood of flooding, leading to the runoff of pollutants from agricultural land into nearby waterways. Climate change may also result in changes in the distribution of pests and diseases, affecting crop production and quality and contributing to agricultural water pollution. Recent studies reveal that moderate to heavy pollution in rivers reduces GDP growth by 1.4% to 2.5% in 17 countries between 1990 and 2014. This emphasizes the frequently underestimated cost of environmental degradation and the need for more effective pollution control measures [9].

To mitigate the impacts of agricultural water pollution, a comprehensive approach must be taken, encompassing agricultural practices, regulations, and education changes. With a growing world population and the intensifying effects of climate change, the problem of agricultural water pollution is only expected to worsen in the future. Research gaps include an improved understanding of the relationships between global change and chemical emissions, a better understanding of environment-microbe interactions in chemical degradation, and better methods for modelling intense precipitation events for chemical fate and transport. The proposed Agricultural Chemical Exposure (ACE) scenarios can be used as a framework for forecasting chemical exposure in European agriculture and supporting sustainable development strategies Enabling forecasts of environmental exposure to chemicals in European agriculture under global change [3].

## 5. Current knowledge and future research

Spatial expansion and intensification of agriculture have had tremendous environmental impacts on agricultural landscapes. Modern agriculture is contributing to water degradation, increased energy use, and greenhouse gas emissions, as well as widespread pollution and the loss of biodiversity. These impacts take place beyond the field and farm levels. Assessment of agricultural landscapes is challenging and requires modeling approaches. Different modeling approaches can be used for designing and/or assessing landscape performance in the face of change. Modeling allows complex processes to be simplified to investigate the effects of potential changes (land use, cropping, and practices). Different methods can be used to design alternatives, ranging from simulation studies to participatory approaches. Scenarios describe "possible futures that reflect different perspectives on past, present, and future developments." The design of alternative landscapes can be performed by the research team or in a participatory approach involving stakeholders [25].

Agriculture is one of the leading causes of water pollution globally and is responsible for the discharge of agrochemicals, nutrients, organic matter, drug residues, sediments, saline drainage, microplastics, and pathogens. The increase in the contribution of agriculture to water pollution is due to population growth, changes in demand for food and fuel, and climate change. Future research priorities include source attribution, emerging contaminants, costs, and incentives for the adoption of pollution reduction measures, identification and testing of locally appropriate markers, modeling the effects of contaminants on biota and pathways of microbial contaminants, harmonization of data collection, and calculation of the economic costs of AWP. The paper focuses on inland surface water pollution and considers the global picture [6].

## 6. Recommendations and Solutions

To effectively address the causes of agricultural water pollution, a combination of laws, regulations, and best practices must be implemented. These include efficient use of fertilizers and pesticides, conservation tillage and cover cropping to reduce soil erosion, best management practices for farms, improved waste management and disposal facilities for animal and poultry waste, upgrades to irrigation systems and better water management methods, stricter controls, and enforcement of agricultural chemical usage. In conclusion, non-point sources of agricultural water pollution pose a significant threat to our water resources. It is essential that we take action to prevent and mitigate this issue in both developed and developing countries to ensure the sustainability of our water resources for future generations.

The four widely used insecticides are an anthranilic diamide (chlorantraniliprole), neonicotinoids (imidacloprid and thiamethoxam), and a carbamate (pirimicarb). The presence of insecticides in soil and lettuce when irrigated with non-reclaimed agricultural wastewater and reclaimed agricultural wastewater treated with solar technology ($TiO_2/Na_2S_2O_8$) at a pilot facility in Murcia, Spain, was studied. It was found helpful for controlling the negative impacts. Solar photocatalysis with $TiO_2/Na_2S_2O_8$ was used to remove the insecticides and their transformation products (TPs) from contaminated water. Results showed that photocatalytic treatments effectively removed most of the insecticides and their TPs. The study found that using reclaimed water as an irrigation source did not lead to detectable levels of target insecticides, or TPs, in the soil and lettuce samples. Reclaimed water can be a sustainable solution to water scarcity in areas with high solar radiation and contribute to water utilization in drought areas. The impact of using reclaimed water on the quality of the crop was also assessed, with barely any significant difference observed [16].

The world is currently experiencing a freshwater shortage crisis, with agriculture using 70% of this precious resource. Irrigation is critical for ensuring food security and increasing agricultural yields, accounting for 40% of global food production (according to FAO). Traditional irrigation techniques, on the other hand, result in excessive water use, low water productivity, and groundwater pollution. To address these issues, new water-saving strategies such as deficit irrigation (DI) and partial root-zone drying (PRD) have been developed for ensuring food security and increasing agricultural yields, accounting for 40% of global food production. Traditional irrigation techniques, on the other hand, result in excessive water use, low water productivity, and groundwater pollution. To address these issues, new water-saving strategies such as deficit irrigation (DI) and partial root-zone drying (PRD) have been developed. PRD is thought to be more effective and environmentally friendly than DI because it increases yield and water use efficiency without reducing output. This irrigation method is compatible with drip, furrow, and micro-sprinkler irrigation systems. However, its application

is limited by the hydraulic properties of the soil, the amount and frequency of irrigation, and the seasonal precipitation. The purpose of this study is to conduct a literature review on PRD irrigation and investigate how it affects crop physiology and agronomy [26].

## 7. History

Research was conducted to investigate the relationship between urbanization and agricultural non-point source pollution (ANPSP) in the Taiho Lake Basin, China. The paper found that while urbanization can lead to improved ANPSP control at a certain stage, it can also contribute to pollution and cause a rebound. The study used various analytical methods, including the vector autoregressive model, decoupling index, and logarithmic mean divaric index decomposition method, to examine the dynamic interrelation between urbanization and ANPSP and to determine the impact of factors such as pollution intensity, economic structure, output level, and population on ANPSP. The results indicated that the decoupling between urbanization and ANPSP was achieved, but the level of decoupling varied between total nitrogen and total phosphorus. The study concluded that the intensity and structure effects were responsible for strong decoupling, while the output and population effects resulted in the relationship evolving into adverse states [27].

Pollution is a serious global public health issue that causes over 9 million deaths per year, with air pollution being the leading cause of death. Lead and other chemicals also cause significant harm. Most countries have not effectively addressed this issue, and it receives little attention from official development assistance or philanthropy. Pollution, climate change, and biodiversity loss are linked, and addressing one will benefit the others. Air pollution caused 6.7 million deaths in 2019, water pollution caused 1.4 million deaths, lead caused 900,000 deaths, and toxic occupational hazards caused 870,000 deaths. The impact of pollution on health would be larger if more comprehensive health data were available. Lead pollution remains a threat to public health, and air pollution has serious consequences for human health, driven by emissions from fossil fuels and biofuels. Chemical pollution is a silent threat and undercounted, with only a fraction of chemicals tested for safety, leading to developmental neurotoxicity, reproductive toxicity, and immunotoxicity. Pollution knows no borders, with transboundary pollutants affecting human health and the environment. The economic losses due to pollution amount to 6.2% of global GDP, and the human capital approach shows it has a significant impact on economic growth and societal development in six countries [28-30].

## 8. Limitations

According to research, agricultural water pollution is a major environmental problem with far-reaching economic implications [31]. Despite its importance, there are many unanswered questions about the long-term effects of agricultural water pollution that necessitate additional research. A gap that needs to be filled is the lack of studies on the financial impact of agricultural water pollution, particularly in developing countries. Understanding the financial costs associated with agricultural water pollution is critical for policymakers to develop efficient and effective solutions Furthermore, research on the effectiveness of various agricultural water pollution control measures and policies is required [32]. Future research should focus on the interactions between agricultural water pollution and other environmental issues, such as climate change and land use change. To gain a better understanding of the problem, novel monitoring and assessment technologies and methodologies for agricultural water pollution are required. It is also critical to investigate how to implement and enforce sustainable agricultural practices that reduce water pollution. Additionally, research into the socio-economic implications of agricultural water pollution needs to be conducted, and effective policies and interventions must be designed that are tailored to meet local conditions and demands. Agricultural water pollution endangers the health and happiness of communities that live in agricultural areas by contaminating their drinking water supply. A variety of solutions, such as implementing sustainable agricultural practices, developing new technologies, providing incentives to farmers, enforcing strict government regulations, and educating the public, can help address the problem of agricultural water pollution and ensure communities in need have access to clean drinking water.

The major problem of agricultural water pollution affects both developed and developing countries worldwide. Agricultural water pollution is a big concern in developing Asia and Africa due to poor management, limited access to technology, and insufficient farmer education. On the other hand, developed countries in Europe and North America are struggling to control agricultural water contamination caused by the widespread use of chemical fertilizers and pesticides, as well as the densely packed production of cattle. Agricultural water pollution in the form of nutrient contamination is a typical cause of contaminated agricultural water. This occurs when rivers become oversaturated with nutrients such as nitrogen and phosphorus because of intensive farming practices, the excessive use of chemical fertilizers, and manure. This causes aquatic ecosystems to degrade and harmful algal blooms to form [17-33].

China and India suffer from high levels of nutrient pollution because of intensive agriculture and the widespread use of fertilizers and pesticides in these areas. Pesticide pollution is a substantial additional problem in many regions where agricultural water pollution is a problem. As pesticides are used increasingly frequently in agriculture, water sources become poisoned, threatening the health of aquatic creatures as well as human health. A lack of rules and poor farming methods in Africa are to blame for high levels of pesticide pollution in surface and groundwater. Pathogen pollution the presence of harmful bacteria and viruses is a major concern in many locations where agricultural runoff impacts water quality. This endangers both human and animal health in developing countries where clean water is rare. Sediment pollution is a major issue in areas prone to soil erosion and deforestation. Agricultural techniques such as tilling, ploughing, and the use of big machinery contribute to increased soil erosion. Sedimentation in bodies of water jeopardizes the health of aquatic ecosystems [34]. Significant levels of silt

contamination have been discovered in Latin American surface and groundwater because of the usage of fertilizers, pesticides, and poor land management strategies [3-35].

## 9. Agriculture-related water pollution in Pakistan

Although agriculture is the backbone of the Pakistani economy, it also contributes significantly to the country's water pollution concerns. The use of pesticides, fertilizers, and inappropriate irrigation practices has resulted in high levels of nutrient pollution and eutrophication in surface and groundwater. It is critical to put real solutions to this problem in place, such as proper waste management, improved farming methods, and greater farmer education. Major cities of Pakistan, such as Karachi, Lahore, Peshawar, Rawalpindi, Sialkot, Hyderabad, and Faisalabad, play a significant role in producing a large amount of wastewater. This contamination of water with industrial waste and municipal sewage, combined with poor water disinfection practices and inadequate quality monitoring at treatment plants, is one of the main reasons for the high prevalence of waterborne diseases in the country. The lack of proper record-keeping makes it difficult to determine the exact number of waterborne diseases in Pakistan, but it is estimated that 20–40% of patients in hospitals are suffering from water-linked illnesses, which account for one-third of all deaths in the country. The situation worsens with the onset of monsoon season, resulting in outbreaks of diseases such as hepatitis, typhoid fever, cholera, and diarrhoea. Lack of effective prevention and control measures exacerbates the situation. In Karachi alone, unclean water is the cause of renal infections that lead to the deaths of 10,000 people every year [8].

Epidemics caused by contaminated water have been reported across the country, such as the outbreaks of Hepatitis E in Abbottabad and Islamabad, typhoid fever in Nek Muhammad village near Karachi, and gastrointestinal illness in rural Sindh. In certain areas of Punjab, high fluoride concentrations in drinking water have resulted in problems such as skeletal fluorosis and bone deformation in children. In the Khairpur district of Sindh Province, unclean drinking water has caused common occurrences of water-related diseases like typhoid fever, diarrhoea, and dysentery. The lack of proper sewage and water treatment facilities in developing countries like Pakistan remains a major cause of morbidity and mortality, with an estimated 0.2-0.25 million children dying every year due to water-related diseases. To summarize, both developed and developing countries are affected by the major problem of agricultural water contamination. Agricultural water contamination has serious and frequently lethal consequences, ranging from nutrient pollution to sedimentation and chemical toxicity. We must act immediately to ensure the health of aquatic ecosystems, the preservation of human and animal health, and the prevention of agricultural water contamination [36].

## 10. Solutions and Control Measures

In the Ebro River Basin of Spain, an hydroeconomic model was developed to analyze water scarcity and agricultural pollution, considering hydrological, economic, and water quality aspects. The study found that droughts increase nitrate concentrations and decrease water availability. Cost-effective policies such as manure fertilization, optimizing synthetic fertilizer use, and irrigation modernization were found to increase social benefits and reduce GHG emissions, while manure treatment plants had the lowest nitrate concentrations but reduced private and social benefits. The study highlights the trade-offs between water quantity and quality, and the interplay between environmental and economic objectives. The results emphasize the need for cost-effective policies to address the negative impact of agricultural water pollution.

Control and mitigation efforts for agricultural water pollution must address both point and non-point sources. Implementing best management practices on farms, improving the efficiency of fertilizer and pesticide use, and reducing soil erosion through conservation tillage and cover cropping are all examples of this. Point sources of agricultural water pollution include livestock operations, such as concentrated animal feeding operations (CAFOs) in the United States, and food processing and storage facilities are easy to identify, while non-point sources include runoff from agricultural fields, irrigation practices, and soil erosion. To solve agricultural water pollution, are difficult to identify. So it is vital to encourage sustainable agriculture methods, such as integrated pest management and precision agriculture, enhance waste management, and invest in water management infrastructure. By doing so, we can ensure that water supplies stay clean and secure for future generations and maintain the ecosystem for all living creatures [37].

Agricultural practices are crucial for feeding the growing world population but can also cause agricultural water pollution. This is when pollutants from agricultural fields, such as fertilizers, pesticides, animal waste, and soil erosion, enter water sources like rivers, lakes, and groundwater. To tackle this issue, there are numerous ways to reduce its impact and promote sustainable water resources. Effective solutions include integrated water resource management, best management practices in agriculture, conservation tillage and agroforestry, crop rotation and cover cropping, irrigation water management, enhanced nutrient and pesticide management, and precision agriculture technology. To enforce these changes and prevent pollution, control measures like regulations, technology usage, monitoring, and economic incentives should also be put in place. Education, community involvement, and a joint effort by all stakeholders are vital in creating a sustainable future for water resources [6].

## 11. Management policies

Policy instruments are measures implemented by governments, such as regulations and incentives, to limit the use of pollutants and encourage sustainable practices. Research and data analysis are crucial in informing policy and improving the design and implementation of control measures. On-farm responses refer to measures taken by farmers to reduce pollution on their land, such as conservation tillage and best management practices. Off-farm responses refer to measures outside of the farm, such as regulations on pesticide and fertilizer use and community-based water management programmes. An

effective approach to addressing agricultural water pollution will likely involve a combination of these responses. Agricultural activities are a significant source of water pollution, which can have serious consequences for the environment and human health. Preventing pollution at the source is crucial for maintaining a healthy ecosystem, and both on-farm and off-farm responses are essential for achieving this goal. On-farm practices play a crucial role in preventing water pollution. In crop production, measures such as limiting and optimizing the type, amount, and timing of fertilizer and pesticide applications can significantly reduce the risk of water pollution. Establishing protection zones around surface watercourses and within farms can also help prevent pollution migration to water bodies. Proper storage and disposal of pesticide waste and empty containers are also important for reducing pollution. Efficient irrigation schemes, conservation agriculture, and restrictions on the cultivation of steeply sloping soils are some of the best ways to reduce soil erosion. Manure management is a significant concern in livestock production. Manure needs to be stored, treated, handled, and disposed of safely, or preferably reused. Anaerobic fermentation and composting are some of the best ways to treat manure and produce valuable organic fertilizers and soil conditioners. Intensive livestock operations, such as feedlots, should be managed as point sources of pollution and must follow specific national regulations. The use of feed additives, hormones, and medicines should also adhere to national standards and international guidelines. In extensive livestock systems, overgrazing should be avoided to reduce land degradation and erosion. Aquaculture farms also have a responsibility to protect the surrounding aquatic environment. Good management practices such as standardizing feed inputs, using fish drugs correctly, removing and treating excessive nutrients, and promoting integrated multitrophic aquaculture systems can help reduce water pollution. While on-farm practices are crucial, avoiding or limiting the export of pollutants from the source is the most effective way of mitigating pressures on aquatic ecosystems and rural ecosystems more generally.

Simple off-farm techniques, such as the construction of riparian buffer strips or constructed wetlands, can effectively reduce loads entering surface water bodies. Remediation of contaminated waters such as lakes and aquifers is a long-term and expensive undertaking that may not be feasible in some cases. Buffer strips are a well-established technology in agriculture and forestry, and they are effective in decreasing the concentrations of pollutants entering waterways. Vegetated filter strips at the margins of farms and along rivers act as filters for sediment and their attached pollutants. Buffer strips can also perform other functions such as stream shading, carbon sequestration, biomass production, channel stabilization, water purification, and the provision of terrestrial and aquatic habitats. In conclusion, preventing water pollution from agriculture requires a combination of on-farm and off-farm responses. By following best practices in crop production, livestock production, and aquaculture, and by utilizing effective off-farm techniques such as buffer strips, we can work towards a healthier and more sustainable ecosystem.

Agriculture-related water pollution is a major contributor to the degradation of water quality, and it is important to take steps to mitigate its impact. The review article highlights the importance of internalizing costs at the farm level, integrating national water quality management, improving environmental capacity, and improving data collection and analysis. These are crucial steps in reducing the impact of agriculture on water quality and promoting a more sustainable future for agriculture [38].

## 12. Conclusions

To mitigate agricultural water pollution, best management practices, regulations, and policies must be implemented. The need for these measures is especially pressing, considering the numerous challenges faced in water quality management. For example, the difficulties in obtaining accurate and comprehensive data on water quality make it difficult to assess the effectiveness of control measures and to identify sources of pollution. Therefore, the need to improve data collection and analysis is vital to understanding the magnitude of the problem of agricultural water pollution and tracking progress over time. This would enable effective and sustainable water quality management. Furthermore, the importance of environmental capacity must be recognized, as healthy ecosystems, such as wetlands and forests, can play a critical role in reducing the impact of pollution on water quality. To tackle the challenges of agricultural water pollution, a coordinated and holistic approach is required that considers the interdependence of different sources of water pollution and their impact on both surface and groundwater. The review article stresses the importance of integrated national water quality management, which would enable consideration of this interdependence and lead to more effective solutions. Finally, the internalization of costs at the farm level would promote economic incentives for farmers to adopt practices that reduce environmental degradation and promote water quality. By implementing these measures, it would be possible to ensure that water remains safe and usable for future generations and promote a more sustainable future for agriculture. In conclusion, addressing agriculture water pollution is a complex and multi-faceted issue that requires a combination of policy, research, and on- and off-farm responses. To mitigate its impact, it is important to implement best management practices, regulations, and policies and to focus on improving data collection and analysis, environmental capacity, and integrated national water quality management. Additionally, the internalization of costs at the farm level would encourage sustainable practices that promote water quality and a more sustainable future for agriculture.

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