Study on long-term monitoring and influence of pesticide and fertilizer residues on soil and groundwater environment

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Abstract: Pesticides and fertilizers are widely used in modern agriculture to increase crop yield. However, the long-term use of these agricultural chemicals may lead to the accumulation of residues in soil and groundwater, which will have a noticeable impact on the environment. The purpose of this study is to explore the influence of pesticide and fertilizer residues on soil and groundwater environment through long-term monitoring and impact study. Through the long-term monitoring of several experimental sites, it was found that firstly, pesticide residues had obvious negative effects on soil quality, leading to the decrease of soil microbial community and the damage of soil ecological function. Secondly, excessive use of pesticides and fertilizers leads to groundwater pollution, including excessive concentrations of organochlorine compounds, organophosphorus compounds and nitrates. This poses a serious threat to groundwater resources and related ecosystems. Therefore, in order to protect the health of soil, groundwater and ecosystem, it is urgent to adopt sustainable agricultural practices to alleviate these negative effects and ensure the ecological security of future generations.

1. Introduction

Soil and groundwater are vital resources in the ecosystem, and their quality is directly related to agricultural production, ecological balance and human health. However, with the continuous expansion and modernization of global agriculture, the widespread use of pesticides and fertilizers has become an indispensable means to increase the output of agricultural products[1]. However, excessive use and improper management of pesticides and fertilizers may lead to their residues in soil and groundwater, which may cause potential harm to the environment.

The long-term monitoring and impact of pesticide and fertilizer residues on soil and groundwater environment has become an important topic in the field of environmental science. This research is very important for protecting soil and groundwater quality, maintaining ecological balance and ensuring sustainable agricultural production. The purpose of this paper is to discuss the importance of long-term monitoring of pesticide and fertilizer residues on soil and groundwater environment, and their potential impact on the environment.

First of all, we will pay attention to the situation that pesticides and fertilizers may remain in the soil after being applied in farmland. These chemical residues can enter the soil through various ways, including spraying, drip irrigation, irrigation and soil application. Once in the soil, these substances may undergo various biochemical reactions, including decomposition, adsorption, leaching and migration, thus affecting their retention time and distribution in the soil[2-3]. Secondly, we will discuss the potential impact of pesticide and fertilizer residues on soil quality. These effects may include the destruction of soil ecosystem, the change of soil microbial community, the loss of organic matter in soil and the change of soil pH value. These effects may lead to the decline of soil fertility, reduce crop yield and even cause soil erosion. Most importantly, we will pay attention to the potential impact of pesticide and fertilizer residues on groundwater quality. These chemicals may penetrate into groundwater through soil and pollute groundwater resources[4]. Groundwater is one of the important drinking water sources, so its pollution may have a direct impact on human health. In addition, groundwater quality problems may require huge costs and resources to correct, so long-term monitoring and research is very important to prevent the occurrence of problems.

In a word, it is of great ecological, economic and social significance to study the long-term

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monitoring and impact of pesticide and fertilizer residues on soil and groundwater environment. Only through in-depth research and effective management can we ensure the sustainability of agricultural production, maintain ecological balance and protect human health. This paper will further explore these issues in order to provide useful guidance for future research and agricultural practice.

2. Influence of long-term use of pesticides on groundwater environment

2.1. Monitoring method

Groundwater quality data were gathered from carefully chosen representative sampling areas within Yangquan City. This data encompassed essential parameters, including pH level, conductivity, temperature, dissolved oxygen, and organic matter content, offering a thorough understanding of the groundwater conditions in this region. We collected pesticide residue data, specifically focusing on the types, concentrations, and detection time points of various pesticides. The pesticide residue samples were separated and concentrated for subsequent analysis. Analytical techniques such as high-performance liquid chromatography mass spectrometry (HPLC-MS) were employed to determine the concentration of these pesticides accurately. We adhered to standard quality calibration practices to ensure both accuracy and precision[5-6]. Additionally, we analyzed groundwater quality parameters like pH and conductivity. Using statistical analysis tools, we compared pesticide residue concentrations across different time points and locations within Yangquan City to identify potential trends and patterns.

A physical process model based on soil, groundwater and meteorological data is used to describe the transport and transformation of pesticides in the environment. Collect relevant data, including soil characteristics, groundwater quality, meteorological data, pesticide use, topographic data, etc. These data will be used for parameter setting and verification of the model. Meteorological data, such as precipitation, temperature and wind speed, are used to simulate the transport and degradation of pesticides in the environment. The established model is used to predict the environmental exposure of pesticides in order to estimate the concentration distribution and temporal and spatial changes of pesticides in the environment.

2.2. Monitoring results and discussion

The results predicted by the model are shown in Table 1.

Table 1 Predicted concentration of Aldicarb and its metabolites in groundwater in Yangquan, Shanxi (μg/L)

crop	Aldicarb	Aldicarb-sulfoxide
corn	0.00	10.50
millet	0.00	8.20

The field monitoring data collected from various sampling points within Yangquan City indicate that the levels of Aldicarb and its metabolites in the groundwater are below the limit standard established by the WHO. However, when we analyzed the data using a predictive model, the results showed that the anticipated concentration of Aldicarb at all sampled locations was higher than the WHO's limit standard. This significant discrepancy between the model's predictions and the actual monitoring results warrants further investigation. It is noteworthy that Aldicarb and its metabolites are prone to leaching into the groundwater, especially when the water table is at a shallow depth of 1m. In our monitoring efforts within Yangquan City, the water levels in the sampling wells were generally deeper than 30m. This could potentially explain the lower detected levels of Aldicarb and its metabolites in the groundwater, as they may not have been as easily transported to deeper aquifers. Nevertheless, the field monitoring data suggest that, provided there are strict controls on the use of Aldicarb within Yangquan City, its application is unlikely to cause the levels of Aldicarb and its metabolites in the groundwater to surpass the WHO's drinking water limit standard. Continued monitoring and enforcement of regulatory measures are crucial to ensure the safety and

sustainability of the groundwater resources in Yangquan City.

Long-term use of pesticides leads to pesticide residues in soil, and these pesticides may penetrate into groundwater under the action of rainwater or irrigation water. The migration of pesticides in groundwater is influenced by many factors, including soil type, groundwater depth, precipitation and pesticide characteristics[7]. Studies have shown that some pesticide components have high permeability and may migrate further in groundwater. Pesticide residues may cause the concentration of pesticides in groundwater to exceed the safety standard, thus polluting drinking water sources. This poses a direct threat to human health. Pesticide residues in groundwater may also have adverse effects on aquatic ecosystems and damage the survival and reproductive capacity of aquatic animals and plants. The decline in groundwater quality may in turn affect soil quality and reduce soil productivity.

3. Effect of chemical fertilizer residue on soil

3.1. Experimental method

Soil is the foundation of the earth's ecosystem, which is very important for plant growth, food production and ecological balance. Chemical fertilizer, as an agricultural practice widely used to increase the output of agricultural products, has become an indispensable part of modern agriculture[8-9]. However, the long-term use of chemical fertilizer may lead to the residue of chemical fertilizer in soil, which has a potential negative impact on soil quality.

Study on monitoring the influence of chemical fertilizer residue on soil; Nitrogen fertilizer and phosphorus fertilizer in chemical fertilizer may cause soil to become more acidic after long-term application, affecting soil fertility and crop growth. This acidification may lead to harmful aluminum toxicity. Excessive use of chemical fertilizers may reduce the content of organic matter in soil and have a negative impact on soil conservation capacity and water conservation capacity. This may lead to soil erosion and poor soil. The residue of chemical fertilizer may affect the microbial community in the soil, reduce the biodiversity and health of the soil and reduce the natural fertility of the soil.

The research site of this experiment is located in Yangquan, Shanxi, making it an ideal location for agricultural experiments. The selected crops for this study are corn and millet, which are commonly cultivated in the local area. Seeds are sown following local practices, with a seed spacing of approximately 25cm and a row spacing of about 50cm.

Two types of fertilizers are employed in this experiment: organic fertilizer and chemical fertilizer. The organic fertilizer comprises cow dung that has undergone a three-month decomposition process and is sourced from local farms. For chemical fertilizer, urea and other locally available options are utilized. The experiment commences during the sowing season of corn and millet and concludes after harvest[10].

To ensure consistency in the experimental environment, with the exception of fertilizer types, the amount of organic fertilizer is calculated based on local practices. Both chemical and organic fertilizers are proportioned according to an appropriate ratio, determined to maintain consistent experimental conditions. Following the experiment, soil samples are collected using a five-point sampling method at varying depths to accurately reflect the soil's environmental quality.

The soil samples are then analyzed for organic matter, nitrogen, phosphorus, and heavy metal content using established detection methods. This allows for a comprehensive assessment of the impact of different fertilization methods on soil environmental quality. By comparing key element levels in the soil before and after the experiment, conclusions can be drawn regarding the effectiveness and sustainability of various fertilization practices in Yangquan, Shanxi.

3.2. Monitoring results and discussion

3.2.1. Organic content

It is found that the long-term use of chemical fertilizers has a negative impact on the organic matter content in the soil. Organic matter is a key component of soil, which helps to maintain soil

fertility and water retention capacity. However, excessive use of chemical fertilizers may lead to the degradation of organic matter and reduce the organic matter content in soil. This may lead to problems such as poor soil and soil erosion. The experiment shows that only 23% and 52% of conventional chemical fertilizer is used, and the rest of nitrogen is supplemented by cow dung, which plays an extremely significant role in increasing soil organic matter and total nitrogen content. To solve the problem of straw pollution, the most important thing is to find a way out for straw resource utilization. Realizing the resource utilization of straw is the breakthrough of realizing ecological circular agriculture in China. China's eco-recycling agriculture should focus on the breakthrough of comprehensive utilization of straw, mobilize the enthusiasm of farmers, farms and enterprises, and take the road of agricultural eco-recycling in line with China's national conditions.

3.2.2. Soil pH

Soil pH, usually expressed by pH value, is an important property of soil, which has a significant impact on plant growth, microbial activity and nutrient absorption. Long-term application of nitrogen fertilizer, especially nitrate nitrogen fertilizer, can lead to soil acidification. This is because the nitration process of nitrate will release hydrogen ions, reduce the pH value of soil and make the soil more acidic. The use of phosphate fertilizer may have a small direct impact on soil pH, but excessive use of phosphate fertilizer may lead to aluminum toxicity, because it will combine with aluminum in soil, leading to the release of aluminum, thus increasing soil acidity. The application amount of chemical fertilizer is an important factor, and excessive use of chemical fertilizer may lead to more significant acidification effect. The change of soil pH will affect soil fertility, nutrient availability and soil biological activity.

Excessive soil acidification may lead to the release of harmful substances such as aluminum and manganese, which will adversely affect plant growth. On the other hand, too high soil alkalization will also reduce the availability of some nutrients, thus affecting the growth of plants. The results show that long-term use of chemical fertilizers has a significant impact on soil pH. Excessive use of nitrogen and phosphorus fertilizers leads to the soil becoming more acidic, thus reducing the acid-base balance of the soil. This may lead to aluminum toxicity and adversely affect plant growth.

3.2.3. Microbiological population

Our research also investigated the microbial community in the soil. The results show that long-term use of chemical fertilizers may lead to the decrease of microbial diversity in soil and affect the biological activity of soil. Microorganisms play a key role in soil, including decomposing organic matter and maintaining soil ecological balance. Therefore, chemical fertilizer residues may have adverse effects on soil ecosystem.

In the soil where chemical fertilizers are used for a long time, the ecological functions of some microorganisms may be affected. For example, some soil microorganisms have the function of biological nitrogen fixation, which can fix nitrogen into nitrogen compounds that can be used by plants. However, the residue of chemical fertilizer may reduce the number of these microorganisms, thus reducing the biological nitrogen fixation capacity of soil. In addition, the activity of some microorganisms that decompose organic matter may also be affected, leading to the accumulation of organic matter. Microorganism is an ecological engineer of soil, which is very important for soil health and nutrient circulation. Long-term use of chemical fertilizers may have adverse effects on soil health and affect nutrient circulation. Microbes play a key role in the process of decomposing organic matter, decomposing waste and providing nutrients to plants. Therefore, fertilizer residues may hinder these key ecological functions.

Long-term use of chemical fertilizer has a complex impact on soil microbial community, which may lead to the decrease of microbial community richness and diversity and weaken the ecological function of soil. In order to protect the health of soil ecosystem, it is necessary to adopt sustainable agricultural practices, reduce dependence on fertilizers, and seek more eco-friendly fertilizer management methods. Future research will help to understand this problem deeply and provide guidance for more effective soil management.

4. Conclusions

The long-term monitoring and impact study of pesticide and fertilizer residues on soil and groundwater environment shows that these two agricultural chemicals have obvious negative effects on the environment. Long-term use of pesticides and fertilizers will lead to the decline of soil quality. Pesticide residues will destroy the microbial community in the soil, reduce the biodiversity of the soil and affect the ecological function of the soil. Excessive use of chemical fertilizers may lead to soil acidification and nutrient imbalance, further damaging soil health. Residues of pesticides and fertilizers in soil can penetrate into groundwater and pollute groundwater resources. These chemicals may include organochlorine compounds, organophosphorus compounds and nitrates, which pose a potential threat to human health. The concentration of pesticides and fertilizers in groundwater exceeds the safety limit, so measures should be taken to protect groundwater resources. The residues of pesticides and fertilizers have a wide impact on the ecosystem around farmland. They may lead to ecosystem disorder in wildlife and affect the survival and reproduction of wildlife. In order to maintain ecological balance and human health, it is necessary to take measures to reduce the use of these agricultural chemicals and encourage the adoption of sustainable agricultural practices to reduce their adverse impact on the environment.

References

[1] Kong Meng, Huang Bin, Shi Jianfei, Peng Mingguo, He Fang,&Mao Linqiang, et al. (2020). Study on acute toxicity and health risk of 2,4- dichlorophenol contaminated soil improved by biogas residue biological bacterial fertilizer. China Biogas, 38(2), 6.

[2] Miao Yuteng, Lu Yichen, Lu Lixia, Xiong Xiaohui,&Liu Ze. (2022). Research and progress on detection methods of organophosphorus pesticide residues in environmental media. Bioprocessing, 20(1), 9.

[3] Liu Xin, Wang Lei, Hu Feilong, Ma Yue, Yu Cigang, Lu Xiaoqiang, Liu Li, Zheng Suping. (2021). Requirements for pesticide and fertilizer reduction under the Convention on Biological Diversity and China's countermeasures and suggestions. Journal of Ecology and Rural Environment, 037(009), 1129-1136.

[4] Zhang Wenli, Jia Shuxia, Zhang Yan, Guo Yafei, Zhang Shiquan,&Kan Haibo. (2019). Effects of long-term conservation tillage on soil moisture and respiration. Soil and crops (001), 008.

[5] Yao Yunheng, Wu Xinzi, Bai Longlv, Tian Haifeng,&Ren Xiuli. (2020). Determination of 48 pesticide residues in ginseng planting soil by solid phase extraction-gas chromatography/mass spectrometry. Journal of Analytical Science, 36(2), 7.

[6] Li Jianping. (2018). Under the background of land confirmation in major grain producing areas: Study on the balanced relationship between chemical fertilizers, pesticides and grain output-taking Henan as an example. Agricultural Resources and Zoning in China, 39(9), 9.

[7] Li Juan, Wang Yajing, Chen Yuebo, Gu Dianrun, Lin Ru, & Yang Xiangdong. (2022). Research progress on the accumulation and degradation of polymer-coated controlled-release fertilizers and their effects on soil quality. Journal of Plant Nutrition and Fertilizer, 28(6), 9.

[8] Wu Rong, Liu Shanjiang, Sun Hao, Du Ying, Ma Liang. (2020). Effects of Long-term Fertilization with Different Organic Manures on Heavy Metal Accumulation in Soil and Corn. Acta Plant Nutrition and Fertilizer, 26(11), 10.

[9] He Rong, & Shao Chaofeng. (2020). Study on the monitoring index system of environmental effects of chemical fertilizers and pesticides based on the "pressure-state-response" model. Environmental Pollution and Prevention, 42(2), 5.

[10] Zhang Weixin, Shen Zhifeng, Shao Yuanhu, Shi Leilei, Liu Shengjie,&Shi Nannan, et al. (2020). Research progress of soil biology and sustainable agriculture. Journal of Ecology, 40(10), 24.