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Investigation on Harmful Substances in Pharmaceutical Wastewater and Their Influencing Factors on Residents' Health and Living Environment

Ting Huang, Guochao Liu, Lelin Sun

Wuhan Huaxia Insititute of Technology, Department of Biological and Pharmaceutical Engineering, Wuhan, Hubei, 430023, China

ABSTRACT
With the rapid development of the pharmaceutical industry, the pharmaceutical wastewater it generates has become an increasingly severe environmental issue, seriously threatening the quality of life and physical health of surrounding residents. The World Health Organization's definition of health emphasizes that health is not merely the absence of disease but also includes the impact of social and environmental factors to achieve holistic physical and mental well-being. This paper reviews relevant literature and, combined with practical cases from pharmaceutical factories in China, elucidates three main pathways of pollution impact: direct exposure, food chain transmission, and environmental migration and transformation mechanisms. It analyzes the multidimensional effects of pharmaceutical wastewater on residents' health, including respiratory and digestive diseases, heavy metal poisoning, and risks of antibiotic resistance; explores its damage to living environments such as air, water, and soil pollution as well as noise disturbance; and reveals its adverse impacts on residents' psychological status, including anxiety and reduced life satisfaction. Meanwhile, this study calls for strengthened regulation, enhanced public awareness, and advanced pollution control measures to achieve coordinated progress in environmental protection and industry development.

KEYWORDS
Pharmaceutical industry; Pharmaceutical wastewater; physical health; Environmental health

1 Introduction

With the rapid development of the pharmaceutical industry, while promoting economic growth and medical progress, it has also brought severe environmental pollution problems. The wastewater discharged during the production process is rich in various organic pollutants, heavy metals, and antibiotic residues, with complex components, difficult degradation, and significant toxicity and bioaccumulation. Relevant pollutants can enter the living environment of residents through various channels such as air, water bodies, and soil, causing health threats to the respiratory system, digestive system, and other aspects, seriously affecting the quality of life of residents, and even inducing psychological problems such as anxiety. For example, due to improper control of exhaust gas emissions by the General Pharmaceutical Factory of Harbin Pharmaceutical Group in Heilongjiang, the concentrations of hydrogen sulfide and ammonia exceeded the standards by 1150 times and 20 times respectively, and surrounding residents have long suffered from respiratory diseases. Therefore, in-depth analysis of the impact mechanism of pharmaceutical wastewater on residents' health and the environment is of great practical significance for formulating scientific and effective pollution prevention and control strategies and improving the level of public health protection.

2 Impact of pharmaceutical wastewater on residents' physical health

2.1 Increased risk of respiratory diseases

Pharmaceutical wastewater and the volatile organic compounds (VOCs) [1]and malodorous gases (such as hydrogen sulfide and ammonia) released during its treatment can diffuse through the air, posing significant threats to the respiratory health of surrounding residents. Long-term exposure to such pollutants easily induces respiratory diseases such as cough, asthma, bronchitis, and allergic asthma. Studies and field surveys have shown that residents around a pharmaceutical factory in Heilongjiang Province developed symptoms of tracheitis and pulmonary emphysema due to long-term inhalation of exhaust gases. In 2023, a pharmaceutical park in Jiangsu Province experienced an 8-fold 超标 (exceedance) of benzene series concentrations in the air due to a malfunction in VOCs treatment facilities, leading to collective cough and chest tightness among residents for three consecutive months, with the number of visits to the respiratory department of regional hospitals increasing by 40% compared to the same period. These pollutants can irritate the respiratory mucosa, trigger chronic inflammatory responses, and further damage respiratory system functions, significantly increasing the risk of respiratory diseases among residents.

* **Corresponding Author:** Guiyan Liu, 158895805@qq.com

2.2 Frequent occurrence of digestive system problems

Pharmaceutical wastewater contains heavy metals (such as lead, mercury, cadmium), antibiotic residues, and refractory organic compounds, which can pose a serious threat to the digestive system health of residents by contaminating drinking water sources and food chains. After oral intake, these pollutants may cause acute symptoms such as nausea, vomiting, and abdominal pain. Long-term exposure may lead to gastric ulcers, intestinal flora disorders, and even induce digestive system tumors. Take Taizhou, Zhejiang as an example. In 2021, an API factory was exposed to directly discharging antibiotic-containing wastewater into farmland irrigation canals, resulting in widespread intestinal flora disorders among residents in surrounding villages. Physical examination data showed that 60% of adults had intestinal flora disorders, and the infection rate of Helicobacter pylori in children was 27% higher than that in the control area. Relevant studies have also shown that the incidence of digestive system diseases among residents drinking contaminated water is significantly higher than that in uncontaminated areas. It can be seen that long-term exposure to such wastewater will significantly increase the risk of digestive system diseases among residents.

2.3 Hazards of heavy metal poisoning

Pharmaceutical wastewater often contains heavy metals such as mercury, lead, and cadmium. These substances are highly toxic, difficult to degrade in the natural environment, and prone to gradual accumulation in the human body through water or the food chain, posing long-term and hidden threats to residents' health. Different types of heavy metals can cause various systemic diseases: mercury poisoning often manifests as memory loss, insomnia, and limb tremors; lead poisoning is particularly harmful to children, potentially causing intellectual developmental delay and attention deficits; cadmium poisoning can lead to renal failure and osteoporosis. These health hazards are highly covert, with initial symptoms difficult to detect, but once onset, they often result in irreversible damage. Therefore, long-term exposure to wastewater containing heavy metals significantly increases the risk of poisoning among residents, severely threatening public health and safety.

2.4 Risk of Antibiotic Resistance[4]

The persistent release of residual antibiotics in pharmaceutical wastewater into the environment easily leads to the development of drug resistance in microbial populations, thereby exacerbating public health risks. Such antibiotic pollution not only alters the structure of environmental microecology but also promotes the transmission of resistance genes among bacteria, posing challenges to conventional anti-infective treatment methods[5]. Monitoring data have shown that in areas with concentrated pharmaceutical enterprises, the level of antibiotic resistance in microorganisms in water bodies and soils has significantly increased, far exceeding that in non-polluted areas. This trend indicates that antibiotic residues in pharmaceutical wastewater are becoming an important driving factor inducing the spread of environmental drug resistance, posing a potential threat to population health.

3 Impact of pharmaceutical wastewater on residents' living environment

The impact of pharmaceutical wastewater on residents' living environment is not only reflected in the destruction of physical environments such as air, water bodies, and soil, but also profoundly disrupts the stability of the human microecosystem. Once residual antibiotics and their metabolites in the wastewater are ingested by residents through drinking water or the food chain, they may disrupt the balance of intestinal flora, inhibit the growth of beneficial bacteria, and promote the reproduction of drug-resistant bacteria. Such flora disorders not only weaken the body's immune defense function but may also reduce or even invalidate the efficacy of antibiotics during treatment, increasing the difficulty and complexity of treating infectious diseases. In the long term, the superposition of environment-induced microecological imbalance and antimicrobial resistance transmission constitutes a new public health hazard.

3.1 Air pollution

Volatile organic compounds (such as benzene, toluene, xylene) and inorganic malodorous gases (such as hydrogen sulfide, ammonia) released during pharmaceutical wastewater treatment are the main pollutants affecting ambient air quality. These gases are more volatile at high temperatures, causing strong odors in local areas, which makes it difficult for residents to open windows for ventilation, significantly restricts outdoor activities, and remarkably reduces the quality of life. For example, residents near a pharmaceutical factory reported that pungent odors could be continuously smelled even indoors, severely interfering with daily life and rest in such an environment for a long time. In addition, these volatile substances also pose potential hazards to human health. Besides causing olfactory discomfort, they may also induce

symptoms such as dizziness, nausea, and chest tightness.

In the summer of 2022, a malfunctions in the ammonia treatment tower of an antibiotic production enterprise in Shandong caused a large-scale ammonia leakage, with the pollution spanning a 3-kilometer radius. "White fog" phenomena appeared in some areas, and even clothes dried outdoors by residents carried a strong pungent odor. Post-incident testing showed that the ammonia concentration in the air exceeded the standard by 128 times. The incident triggered collective complaints from more than 200 households, highlighting the dual impact of air pollution on residents' physical health and environmental perception.

3.2 Water pollution

Once high-concentration organic matters, heavy metals[7] and antibiotic components in pharmaceutical wastewater enter water bodies, they will not only damage water quality, but also may induce a series of ecological and economic chain reactions. Such pollutants can significantly aggravate the eutrophication process of water bodies, leading to abnormal algae reproduction and the decrease of dissolved oxygen content in water bodies, thus causing a large number of aquatic organisms to die and destroying the original ecological balance.

For example, in 2020, a biopharmaceutical company in Sichuan illegally discharged high-concentration organic wastewater into a tributary of the Yangtze River through privately constructed hidden pipes, causing a severe cyanobacterial bloom in about 20 kilometers of the downstream river section. This not only gave the drinking water of 50,000 沿岸 (coastal) residents an obvious peculiar smell, but also caused large-scale fishery resource losses, with economic losses exceeding 20 million yuan. Water pollution may also affect agricultural irrigation systems, influencing crop yield and quality, thereby having a far-reaching impact on residents' livelihoods. It can be seen that water pollution is not only an environmental issue, but also concerns the foundation of regional public health and economic sustainable development.

3.3 Soil pollution

When harmful substances such as heavy metals and organic pollutants in pharmaceutical wastewater enter the soil environment, they easily accumulate in the surface or deep layers of the soil, altering the physical and chemical properties of the soil, weakening its buffering capacity and ecological functions, and thus affecting the activity of soil microorganisms and the nutrient cycle necessary for crop growth.

Long-term retention of pollutants may also be absorbed by plant roots and accumulated in edible parts, leading to a decline in agricultural product quality, thus threatening residents' food safety and physical health. Heavy metal pollution is particularly 隐蔽 (covert) and difficult to reverse, which can accumulate in the human body through the food chain, triggering the risk of chronic poisoning. Typical cases show that ten years after a pesticide factory in Shijiazhuang, Hebei stopped production, the residual amount of DDT in the local soil still exceeded the standard by 15 times, and the lead content in wheat grown in surrounding farmland exceeded the safety limit by 2.3 times, eventually forcing all of it to be destroyed. Soil pollution also inhibits vegetation growth, causing green space degradation and ecological landscape deterioration, bringing long-term negative impacts on the quality of residents' living environment, which urgently needs to attract the attention of environmental governance departments.

3.4 Noise pollution

The continuous noise generated by equipment such as water pumps, cooling towers, and fans in pharmaceutical plants during operation has become a significant environmental factor affecting the quality of life of surrounding residents. Especially at night, the noise interferes with residents' normal rest, leading to decreased sleep quality and in turn causing psychological and physiological problems such as irritability, anxiety, and insomnia. Multiple resident complaint cases show that the noise intensity generated by night-time production in some pharmaceutical factories exceeds the reasonable range, seriously affecting the living environment of the community and highlighting the urgent need for industrial noise control.

4 Impact of pharmaceutical wastewater on residents' psychological state

4.1 Anxiety and fear emotions

Residents living in surrounding areas face significant psychological stress due to concerns about drinking contaminated water, inhaling polluted air, or consuming contaminated food[9]. This persistent uncertainty and perception of health risks can easily lead to the accumulation of long-term anxiety and fear, thereby increasing the incidence of mental health problems such as anxiety disorders and depression, which seriously affect residents' mental well-being and quality of life.

4.2 Decline in life satisfaction caused by environmental pollution

The continuous deterioration of environmental quality, manifested as air pollution, water pollution, and noise disturbance, makes it difficult for residents to enjoy fresh air and quiet living spaces, significantly reducing their life satisfaction. Meanwhile, the accumulation of negative emotions triggered by environmental issues easily leads to residents' dissatisfaction and trust crises towards relevant enterprises and regulatory agencies, thereby intensifying community conflicts and social disputes, and hindering the harmonious and stable development of the region.

5 Mechanisms of pharmaceutical wastewater impact on residents

Residents are directly exposed to harmful substances in the wastewater through breathing contaminated air, drinking polluted water, and consuming contaminated food. These toxic substances continuously accumulate in the body, potentially damaging the normal functions of multiple organs and systems and posing health risks[10].

Pollutants in pharmaceutical wastewater are absorbed by aquatic organisms and crops, and gradually enriched through the food chain, eventually entering the human body. For example, the concentration of pollutants in the bodies of people who eat fish from contaminated waters increases significantly, leading to potential chronic toxic effects.

Volatile organic compounds diffuse through the air, and heavy metals undergo chemical speciation transformation in the soil. These processes may enhance the toxicity of pollutants or improve their bioavailability, indirectly exacerbating the threat to residents' health.

6 Conclusions and prospects

Pharmaceutical wastewater has had severe negative impacts on the physical health, living environment, and psychological state of surrounding residents. Through mechanisms such as direct contact, food chain transmission, and environmental migration and transformation, harmful substances in pharmaceutical wastewater threaten residents' health, damage the quality of the living environment, and trigger negative psychological emotions among residents. To address these issues, joint efforts from the government, enterprises, and all sectors of society are needed. This includes strengthening regulatory measures, upgrading treatment technologies, enhancing public awareness, and implementing rational planning and layout. These actions aim to reduce the harm of pharmaceutical wastewater to surrounding residents, protect their living environment and health rights, and achieve coordinated progress between the sustainable development of the pharmaceutical industry and environmental protection. Future research can further explore the long-term impacts of pharmaceutical wastewater pollution and comprehensive prevention and control strategies, providing more scientific basis and practical guidance for solving this environmental problem.

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