

Analysis of Chlorpyrifos in Surface Water, Samples of district Buner, KPK

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ABSTRACT

Chlorpyrifos is a commonly utilized organophosphorus pesticide, frequently applied in agriculture to manage pest populations and enhance crop production. Nevertheless, chlorpyrifos presents considerable risks to both human health and the environment due to its toxicity and persistence. This research examines the levels of chlorpyrifos contamination in surface water samples collected from agricultural regions in District Buner, Pakistan. Chlorpyrifos residues were measured in 25 surface water samples using gas chromatography with an electron capture detector (GC-ECD). The maximum concentration recorded was 0.143 µg/L. A health risk assessment based on US EPA criteria revealed that children may face potential cancer risks from chlorpyrifos exposure via surface water, while adults exhibited lower levels of risk. These results underscore the necessity for ongoing monitoring and regulation of chlorpyrifos application to safeguard environmental and public health.

Introduction

Pesticides are chemical agents utilized in farming to control pests and improve crop yields (Reis et al., 2014). Among the various pesticides, organophosphorus compounds like chlorpyrifos are favored for their efficiency and relatively brief environmental persistence compared to organochlorines (Kavlock, 2001). Chlorpyrifos is recognized for its neurotoxic effects, functioning by inhibiting acetylcholinesterase, which affects both humans and wildlife (Pope et al., 2005). Nonetheless, its extensive use results in environmental contamination, particularly in surface and groundwater, posing threats to ecosystems and human health (Giesy et al., 2014). This study examines the presence of chlorpyrifos residues in surface water from agricultural areas in District Buner and evaluates the health risks linked to exposure.

Literature Review

Organophosphorous pesticides (OPPs), such as chlorpyrifos, are widely utilized in farming to manage pest populations. These pesticides frequently enter surface water systems mainly via agricultural runoff and spray drift, as rain or irrigation can transport pesticide residues from treated fields into adjacent rivers, lakes, or ponds (Joshi et al., 2023; Moore et al., 2002). Chlorpyrifos, in particular, has a strong affinity for binding with soil particles and sediments, which can be washed away by soil erosion into water bodies, resulting in the contamination of aquatic environments

(Gebremariam et al., 2023). Due to its semi-volatile and persistent characteristics, chlorpyrifos can linger in the environment for weeks to months, although microbial degradation ultimately breaks down the substance into less harmful metabolites (Joshi et al., 2023).

Once it enters surface water, chlorpyrifos becomes a risk to non-target species, including aquatic life such as fish and invertebrates. Its harmful effects on these organisms have been thoroughly documented, leading to disturbances in aquatic ecosystems (Asselborn et al., 2015). It is critical to monitor and detect even trace amounts of chlorpyrifos in water for effective environmental risk evaluation. Analytical methods such as solid phase extraction (SPE) combined with gas chromatography-mass spectrometry (GC-MS) are frequently employed due to their sensitivity and precision in identifying very low pesticide levels in complex water samples (Bonansea et al., 2013).

Risk assessments associated with chlorpyrifos exposure utilize models that calculate chronic daily intake (CDI) based on identified concentrations, ingestion rates, exposure frequencies, and durations for various population groups (Phung, 2012). The hazard quotient (HQ) provides a measure of non-carcinogenic risk by comparing estimated exposure levels with reference doses, while estimates of cancer risk assess potential carcinogenic.

Methodology

The approach utilized in this research consists of several crucial steps to effectively evaluate chlorpyrifos contamination in surface water and examine associated health risks.

Initially, sampling took place in 2025 in District Buner, an agricultural area in Khyber Pakhtunkhwa, Pakistan, where pesticide application is common. A total of 25 surface water samples were gathered from various sites using sterilized containers to prevent any contamination. The samples were subsequently filtered to eliminate solid particles and debris that could hinder the analysis.

For the extraction of chlorpyrifos, the solid phase extraction (SPE) method was utilized. This technique employs a carbon-18 sorbent material that selectively captures chlorpyrifos molecules from the water samples. Once the pesticide is retained on this sorbent, methanol is used as an elution solvent to recover chlorpyrifos for subsequent analysis. SPE is preferred due to its efficiency, selectivity, and capacity to concentrate trace levels of pesticides in water.

Chlorpyrifos quantification was performed using gas chromatography combined with an electron capture detector (GC-ECD). Gas chromatography separates the chemical components of the extracted sample based on their volatility and interactions with the stationary phase of the column. The electron capture detector is extremely sensitive to halogenated compounds such as chlorpyrifos, enabling precise measurement even at very low levels. Specific instrument parameters, including injector and detector temperatures, carrier gas flow rates, and oven temperature programming, were optimized for dependable analysis.

Calibration curves were created by preparing standard solutions of chlorpyrifos at known concentrations. These curves establish the correlation between the detector response and pesticide concentration, facilitating the quantification of unknown

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sample concentrations based on their measured signals.

Finally, a health risk assessment was conducted following the models established by the U.S. Environmental Protection Agency (EPA). This assessment includes factors such as the frequency of exposure (exposure frequency) and the volume of water consumed (ingestion rate), average body weight of individuals, and toxicological reference doses. From this data, chronic daily intake (CDI) values were calculated, reflecting the estimated daily exposure per kilogram of body weight. Risk indices, including hazard quotients for non-cancer effects and estimates of cancer risk, were computed separately for adults and children, recognizing their differing exposure patterns and sensitivities.

In conclusion, this methodological framework integrates standardized water sampling, sensitive pesticide extraction and quantification methods, and comprehensive health risk modeling to deliver an accurate evaluation of chlorpyrifos contamination and its potential health effects.

Results

The findings from this research indicated that out of 25 collected surface water samples from District Buner, chlorpyrifos was identified in 3 of them. The concentration ranged from below detection limits to a peak level of 0.143 micrograms per liter ($\mu\text{g/L}$), with the highest concentration found in the sample taken from the Koga camp region. This suggests that while chlorpyrifos contamination is not widespread, certain areas show evidence of contamination likely due to nearby agricultural runoff or pesticide application.

The quantification method employed for analysis proved to be very dependable, as indicated by the outstanding linearity of the calibration curve, which had an R-squared value of 0.999. This value, which is close to 1, reflects a strong correlation between the detector response and the known concentrations of chlorpyrifos, reinforcing the reliability and accuracy of the measurement technique.

The health risk assessment highlighted that children may encounter a potential cancer risk that approaches the U.S. Environmental Protection Agency (EPA) acceptable threshold of 1×10^{-6} . This indicates that the likelihood of developing cancer from ingesting chlorpyrifos through surface water is roughly one in a million, a standard used in regulatory toxicology to ensure safety for the public. Conversely, the hazard quotients (HQ), which assess the risk of non-cancer health outcomes by comparing projected exposure to a reference dose, were determined to be below 1 for both children and adults. An HQ below 1 suggests that harmful non-carcinogenic effects are improbable at the levels of exposure detected.

In summary, these results indicate that while the risk of non-cancer health issues is low for the general population, there is a minor but noteworthy cancer risk for children, underscoring ongoing exposure concerns. These findings emphasize the necessity for continual monitoring and possible mitigation measures to decrease pesticide contamination in surface water, thereby safeguarding vulnerable populations and the broader ecosystem.

Discussion

The identification of chlorpyrifos in surface water samples within this study clearly indicates that agricultural runoff is the main cause of contamination. When pesticides such as chlorpyrifos are applied to crops, rainfall or irrigation can carry residues from fields into adjacent rivers, lakes, and streams, leading to the pollution of surface waters that are vital for the environment and drinking supply. This occurrence is well documented in farming regions, including certain areas of Pakistan where pesticide application is prevalent (Saad et al., 2017).

Even though the detected concentrations were relatively low, the presence of chlorpyrifos in surface water is concerning since chronic exposure—particularly among vulnerable populations like children—can pose health risks, including possible carcinogenic effects. Children are particularly sensitive to harmful substances due to their developing bodies and behaviors that heighten exposure, such as playing near water and their higher water intake relative to their body weight (Phung, 2012).

The observed low hazard quotient (HQ) suggests that, based on current concentration levels, non-cancer health impacts are unlikely for the general population. The HQ is a ratio that compares estimated pesticide exposure to a reference dose deemed safe by regulatory bodies. A value under 1 indicates that exposure is within acceptable limits. However, as pesticides can accumulate in the environment and people might be exposed through various pathways, ongoing monitoring is critical to identify any emerging trends or contamination hotspots.

Comparative analysis with international studies reveals similar contamination trends in other agricultural regions globally, where chlorpyrifos is commonly found in surface waters due to pesticide runoff. These studies also highlight the necessity for stringent regulations, improved pesticide application practices, increased public awareness, and alternative pest management techniques to decrease contamination and associated hazards (Moore et al., 2002; Asselborn et al., 2015).

In the context of Pakistan, the enforcement of pesticide regulations along with educational initiatives aimed at farmers and communities is vital. More effective management of pesticide usage can reduce runoff, thereby safeguarding water quality, aquatic ecosystems, and public health. The findings of this study underscore the pressing need for integrated pest and water resource management strategies customized to local agricultural practices.

Conclusion

This research presents clear indications of chlorpyrifos pollution in the surface waters of District Buner, Pakistan, revealing a serious environmental and public health issue. Chlorpyrifos, a widely utilized organophosphorous pesticide in farming, predominantly enters surface water via agricultural runoff, which this study confirmed by finding pesticide residues in collected water samples from the region.

The detection of chlorpyrifos residues at these concentrations has significant public health implications, especially for children, who are more susceptible due to their developing bodies and relatively higher water intake compared to adults. The health risk assessment in the study pointed out that children might face an increased likelihood of carcinogenic effects from exposure to these residues, highlighting the urgent need to focus on this group.

To mitigate these risks, it is crucial to enhance and enforce regulatory policies aimed at controlling and reducing pesticide application in farming practices. This should involve advocating for safer pesticide application methods and integrated pest management strategies that lessen the dependence on harmful chemicals like chlorpyrifos. Ensuring water quality not only protects ecosystems but also guarantees cleaner drinking water sources for local populations.

Moreover, the study suggests conducting further research to widen the focus by including other commonly used pesticides and extending the geographical scope beyond District Buner. Such extensive evaluations will provide a more comprehensive understanding of pesticide contamination trends and associated health risks in various agricultural areas of Pakistan, allowing for better-informed policymaking and risk mitigation approaches.

Collectively, these initiatives can aid in decreasing environmental pollution, safeguarding human health, and advancing sustainable agriculture in the area.

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