Innovative Analysis of Rainfall-Driven Contaminant Patterns in Groundwater: A Path Toward Climate-Resilient Water Management

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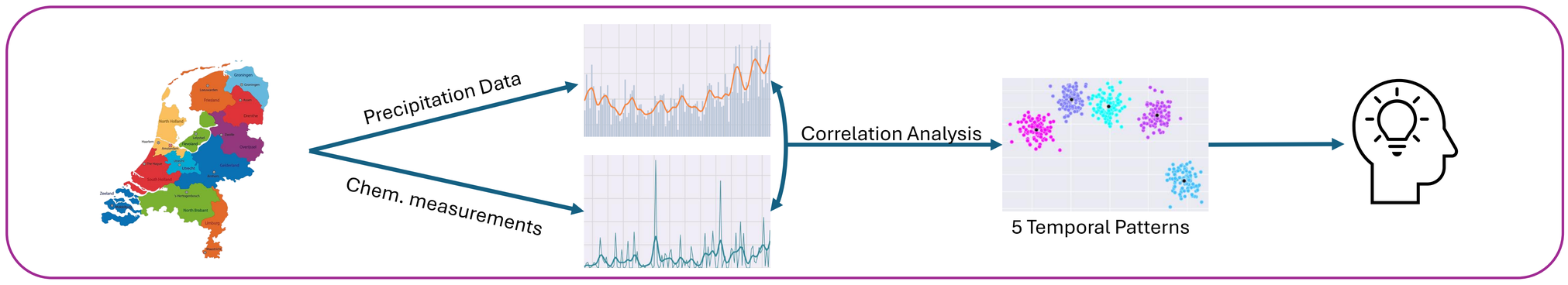
Abstract

This study investigates the influence of precipitation on groundwater contamination by analyzing the correlation patterns of various chemicals in the province of Zuid-Holland in the Netherlands. Through a comprehensive correlation analysis, five distinct temporal patterns were identified, highlighting the complexity of contaminant transport and the role of precipitation as a driver of temporal variations in groundwater quality.

These findings underscore the complexity of contaminant transport and the role of precipitation as a driver of temporal variations in groundwater quality. This research highlights the necessity of incorporating rainfall-driven contaminant behaviors into groundwater management, especially in regions facing climate change-induced droughts. The insights gained here are instrumental in informing climate-resilient water management practices to mitigate pollution risks and safeguard groundwater resources in drought-prone regions.



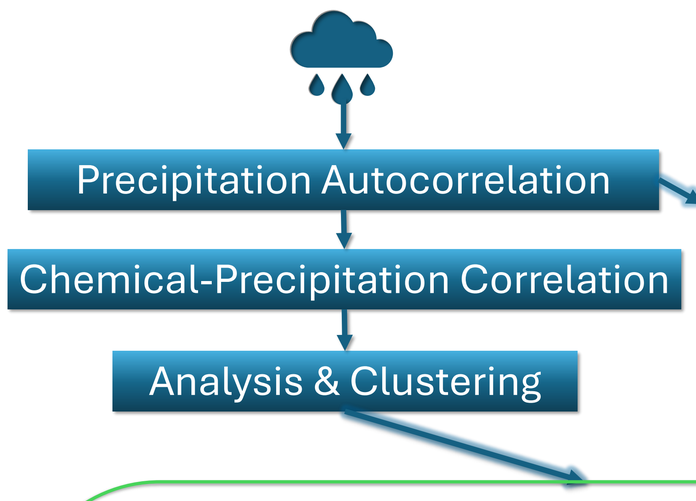
Introduction

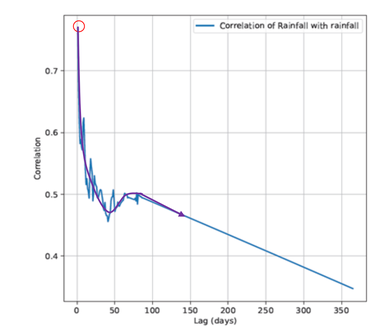
The Netherlands, including provinces like Zuid-Holland, faces increasing challenges due to prolonged droughts, exacerbating groundwater quality concerns. Understanding the interplay between precipitation patterns and chemical transport in groundwater is critical for climate resilience.

Methodology

A time-lagged correlation approach was used to analyze the influence of precipitation on chemical transport. Correlations with an absolute value above 0.5 were considered significant.

Focusing on the chemicals' response to precipitation over a 365-day window, chemicals were clustered based on the similarity in the shape and behavior of their correlation profiles to the rainfall autocorrelation, identifying five distinct patterns of response.

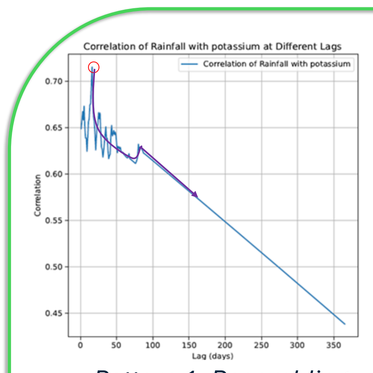




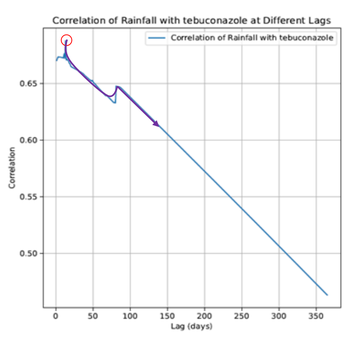
Precipitation autocorrelation pattern

Results

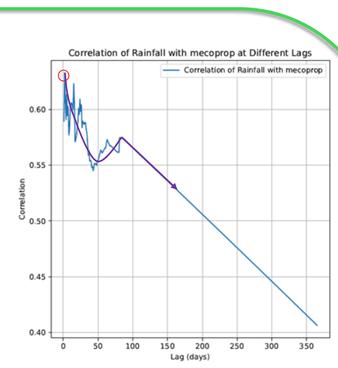
The distinct patterns cluster the chemicals into five groups: (1) Regular correlations resembling precipitation autocorrelation, (2) Smooth decline, (3) High peaks and lower valleys, (4) Inverse correlations, and (5) Irregular patterns with high correlation. These patterns reflect different chemical behaviors such as adsorption, hydrophobicity, and degradation.



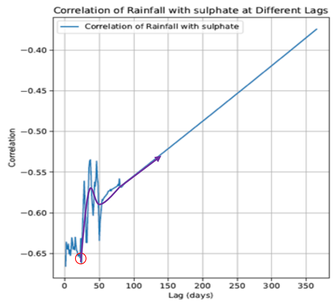
Pattern 1: Resembling Precipitation autocorrelation



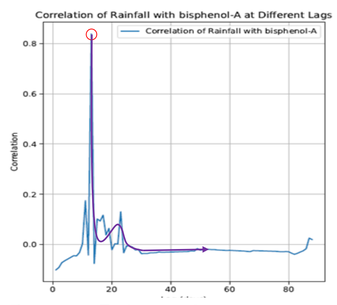
Pattern 2: Smooth Decline



Pattern 3: Higher Peaks and Lower Valleys



Pattern 4: Inverse Correlations



Pattern 5: Irregular patterns with high correlation | X-axis: 90 days

Conclusion

This study examines the influence of precipitation patterns on groundwater contamination, focusing on how climate-driven changes impact the transport dynamics of various chemical contaminants. By analyzing correlations between precipitation and contaminant behavior, five distinct temporal patterns emerged. These patterns reflect different mechanisms of chemical mobility and retention, such as soil adsorption and biodegradation, that affect contaminant persistence. This typology offers a basis for targeted monitoring and sustainable water management strategies, helping policymakers mitigate contamination risks. The findings enhance understanding of precipitation-driven contaminant transport, supporting adaptive groundwater management amid climate variability.

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