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Identification of Groundwater Aquifers Beneath Buildings with Cement-Cast Floors Using the Microtremor Method

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Abstract: The microtremor method is a passive geophysical technique that utilizes ambient ground vibrations to characterize subsurface structures. This study aims to identify groundwater aquifers beneath a building where the surface is completely covered by cement casting, making conventional geophysical methods difficult to apply. Microtremor measurements were conducted at 15 stations using tri-axial geophones. Data processing involved preprocessing, spectral analysis, and inversion to obtain shear wave velocity (Vs), compressional wave velocity (Vp), and Poisson's ratio. The results indicate the presence of aquifers at depths ranging from 70 m to more than 200 m. These aquifers are interpreted as confined systems with significant groundwater potential. The results demonstrate that the microtremor method provides an effective and non-invasive solution for groundwater exploration in constrained environments.

Keywords: microtremor; groundwater; aquifer; shear wave velocity; Poisson's ratio.

1. Introduction

Groundwater is one of the most important natural resources supporting domestic, industrial, and agricultural activities. The accurate identification of groundwater aquifers is therefore essential to ensure sustainable water resource management. Conventional geophysical methods such as electrical resistivity are commonly used for groundwater exploration due to their sensitivity to subsurface properties. However, these methods require direct contact with the ground surface, making them difficult to apply in areas where the surface is covered by infrastructure such as buildings or concrete flooring.

The microtremor method has emerged as an alternative passive geophysical technique that utilizes natural and anthropogenic ambient vibrations to characterize subsurface conditions. These vibrations propagate through the subsurface and contain information about its physical properties. The method is particularly useful in estimating shear wave velocity (Vs), which is closely related to the stiffness and lithology of subsurface materials [1-3]. In addition, the horizontal-to-vertical spectral ratio (HVSR) approach allows the identification of subsurface layering and resonance characteristics, which are strongly influenced by geological structures [2-4].

Through inversion analysis, microtremor data can be used to obtain compressional wave velocity (Vp), Vs, and density. These parameters can further be used to derive Poisson's ratio, which is sensitive to fluid content. High values of Poisson's ratio are generally associated with saturated materials, making it an effective parameter for identifying groundwater zones [5].

Compared to conventional geophysical techniques, the microtremor method offers several advantages, including its non-invasive nature, simplicity of deployment, and suitability for urban and constrained environments [4]. In this study, the microtremor

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method is applied to identify groundwater aquifers beneath a building with a cement-cast floor, where conventional methods are not feasible. This work presents a practical and novel approach for groundwater exploration in areas with limited accessibility.

2. Methodology

The passive seismic data acquisition campaign was conducted systematically inside the designated warehouse facility. The survey layout comprised 15 distinct measurement stations arranged in a grid format to ensure comprehensive spatial coverage beneath the concrete floor. The precise spatial coordinates (Easting, Northing, and Elevation) for all stations are structured and presented in Table 1.

Table 1 Location of data measurement points

Station	Easting (m)	Northing (m)	Elevation (m)	Station	Easting (m)	Northing (m)	Elevation (m)
A1	428766	9224097	186	D1	428806	9224085	186
A2	428763	9224091	186	D2	428804	9224080	186
A3	428762	9224085	186	D3	428801	9224073	186
A4	428760	9224079	186	D4	428798	9224066	186
A5	428758	9224073	186	D5	428796	9224060	186
B1	428779	9224092	186	E1	428819	9224081	186
B2	428776	9224086	186	E2	428817	9224075	186
B3	428775	9224081	186	E3	428815	9224068	186
B4	428771	9224074	186	E4	428812	9224061	186
B5	428770	9224069	186	E5	428811	9224055	186
C1	428793	9224089	186	F1	428834	9224078	186
C2	428790	9224083	186	F2	428830	9224071	186
C3	428788	9224078	186	F3	428829	9224065	186
C4	428785	9224071	186	F4	428826	9224057	186
C5	428783	9224064	186	F5	428825	9224051	186

The acquired signals were first subjected to preprocessing procedures, including detrending, mean removal, normalization, and filtering. These steps were performed to improve the signal-to-noise ratio (SNR) and ensure the quality of the data prior to analysis [2]. The processed data were then analyzed using the HVSR method to obtain spectral characteristics of the ambient vibrations.

To reduce the impact of transient disturbances such as human activity or environmental noise, an anti-triggering process was applied. Only stationary signal windows with low variance were selected for further analysis. This approach ensures that the inversion process is based on stable and reliable data, thereby improving the accuracy of the results [3].

The inversion process was then performed to derive key physical parameters, including compressional wave velocity (Vp), shear wave velocity (Vs), and density. From these parameters, Poisson's ratio was calculated using elastic wave relationships. Poisson's ratio is particularly sensitive to fluid content, with higher values indicating the presence of water-saturated materials [5].

To identify potential aquifer zones, a three-dimensional model of the subsurface was constructed using the derived parameters. Aquifer identification was based on the correlation between relatively low to moderate Vs values, which indicate permeable lithologies such as sandstone, and high Poisson's ratio values, which indicate fluid saturation. An overlay analysis between these parameters was performed to enhance the interpretation accuracy.

Fig. 1 Microtremor data acquisition inside a building with cement-cast flooring

3. Results and Discussion

The results of the analysis are presented in the form of three-dimensional models of shear wave velocity (Vs) are shown in Figure 2 left and Poisson's ratio are shown in figure 2 right. The Vs model reveals variations in subsurface stiffness and lithology. Zones with relatively low to moderate Vs values are interpreted as sedimentary layers, particularly sandstone formations that are favorable for groundwater storage.

The interpretation indicates that aquifer-bearing layers are present at depths between 70 and 140 m in the northeast part of the study area. In addition, deeper structures are identified at depths exceeding 170 m in the northwest area. These layers are interpreted as deeper aquifer systems that may represent confined aquifers.

The Poisson's ratio model provides complementary information regarding subsurface fluid content. High Poisson's ratio values are observed at depths ranging from 40 to 150 m in the northeastern zone and from approximately 120 m to more than 200 m in the northwestern zone. These values indicate the presence of saturated materials and support the identification of groundwater-bearing layers

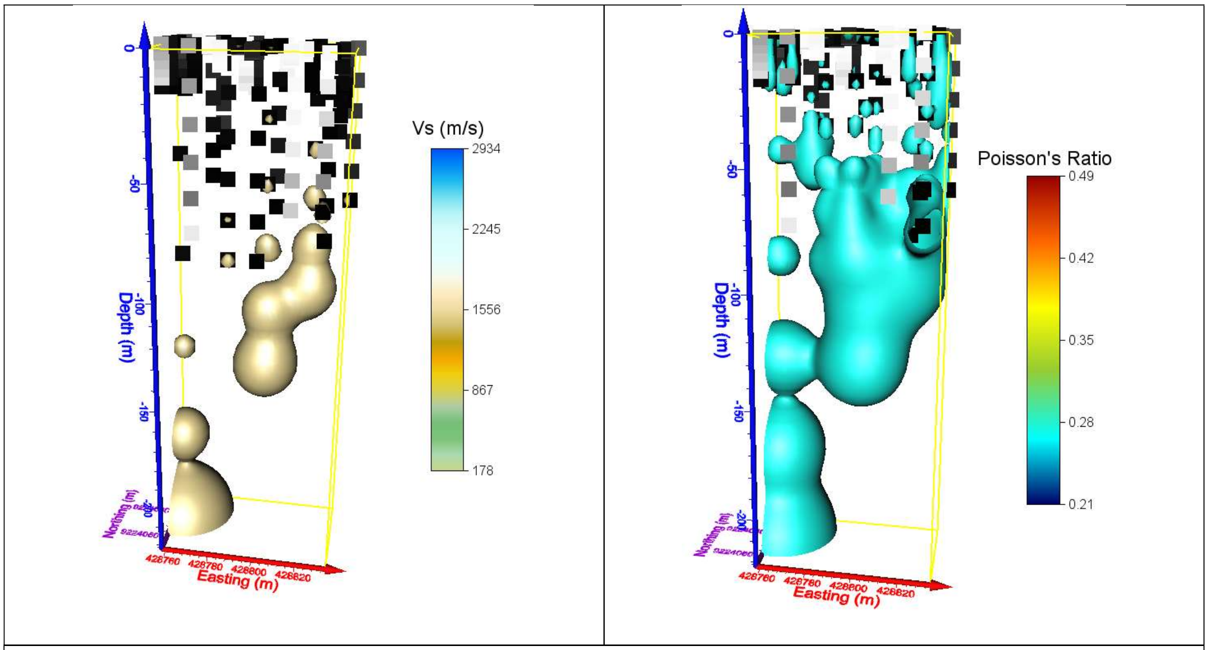

Fig. 2 Three Dimention subsurface physical models rendering the shear-wave velocity structure (left) and the calculated Poisson's ratio fluid saturation boundary (right).

To optimize the drilling accuracy for future water wells, 2D isosurface extraction maps were generated from the master 3D grid, highlighting structural conformity (Fig. 3). An advanced spatial overlay analysis of both the Vs lithofacies boundary and the Poisson's ratio fluid boundary was carried out (Fig. 4). The spatial zones where these two distinct isosurface konturs intersect at a relative depth value of 0 m represent the highly validated core zones of the active groundwater aquifer.

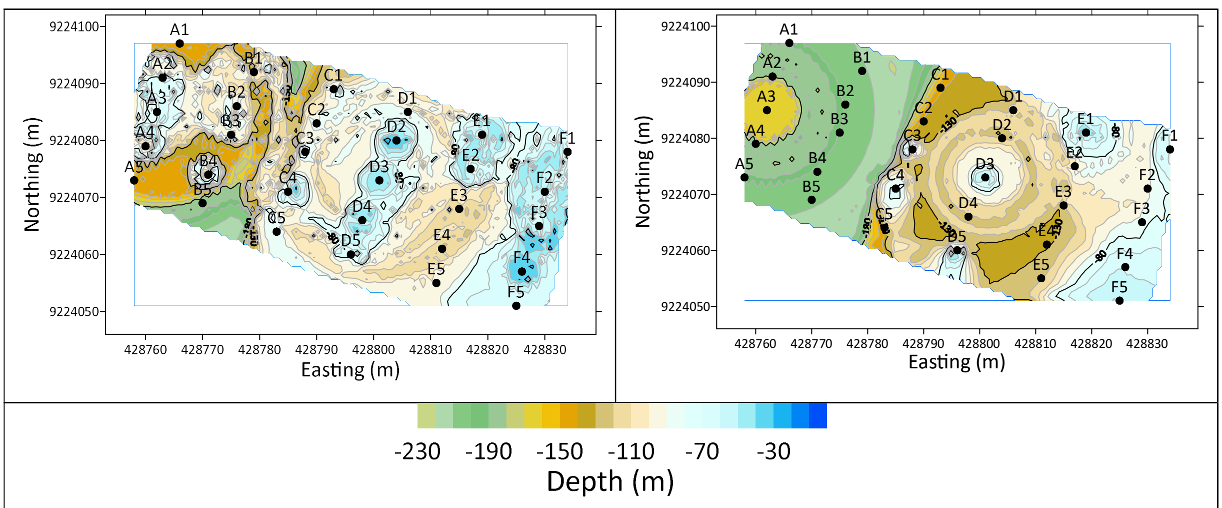

Fig. 3 2D Isosurface extractions highlighting the deep boundaries of the sandstone layers (left) and the fluid-saturated Poisson's ratio margins (right).

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The final interpretation identifies several main aquifer zones, including shallow aquifers at depths between 70 and 110 m, intermediate aquifers at depths around 100 to 140 m, and deeper aquifers at depths exceeding 160 m. These aquifers are interpreted as confined systems due to the presence of overlying low-permeability layers.

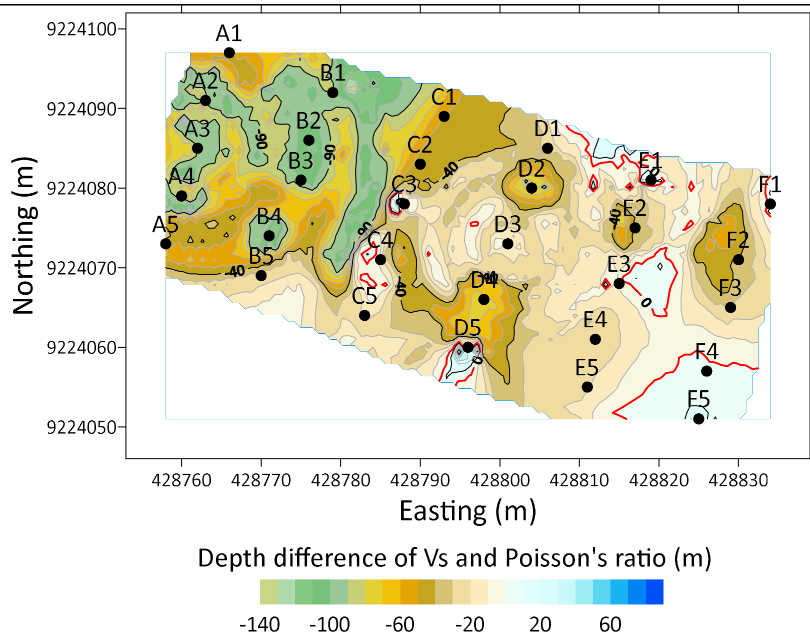

Fig. 4 Differential depth map generated by overlaying the Vs structure and Poisson's ratio fluid boundaries. The 0-meter intersection contours delineate optimum, risk-free aquifer drilling zones.

The results are consistent with previous studies, where Poisson's ratio values greater than 0.35 are typically associated with saturated materials [5,6], and Vs values within the observed range correspond to sedimentary aquifer formations [4,7]. Based on the spatial continuity and thickness of the identified layers, the aquifers are estimated to have discharge capacities exceeding 2 liters per second, indicating strong potential for groundwater exploitation.

Despite the promising results, several limitations should be considered. The interpretation is based solely on geophysical data without direct validation from borehole measurements. In addition, the resolution of the microtremor method decreases with depth, which may affect the accuracy of deeper interpretations. Future studies should integrate borehole data and complementary geophysical methods such as electrical resistivity to improve the reliability of the results.

4. Conclusion

This study demonstrates that the microtremor method is an effective tool for identifying groundwater aquifers in environments where conventional methods cannot be applied. The integration of shear wave velocity and Poisson's ratio provides a robust approach for detecting aquifer zones. The identified aquifers exhibit characteristics of confined systems with significant groundwater potential. The method offers a practical and non-invasive solution for groundwater exploration in urban and constrained environments. The indoor microtremor ambient noise framework successfully overcame the thick cement floor barrier, mapping a high-yield confined aquifer system without causing structural damage to the warehouse. Based on the integrated structural models, two primary hydrogeological zones are defined for development: Primary Drilling Vector (Stations E1–E2 to D3): A prolific, high-potential confined aquifer is situated directly along the northern periphery of the facility beneath

Station E1, extending laterally toward E2 at a secure depth of 70–110 m. This system connects directly to an expanded water-bearing zone beneath Station D3 at depths of 100–140 m, widening toward Stations D2 and D4. Given its geometric volume and high structural connectivity, this aquifer zone is estimated to deliver a sustainable discharge rate exceeding > 2 liter/second. Secondary Deep Vector (Stations A1–B1 to A3–B3): A deeper, secondary artesian aquifer sits beneath the western perimeter at a depth of 160 m to 200 m grading steadily toward the central axis of the warehouse facility.

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