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# Identification of Subsurface Water Pipe Based on Horizontal to Vertical Spectral Ratio (HVSR)

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DOI: 10.47760/cognizance.2023.v03i12.003

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**Abstract**— Disruption of water distribution through underground pipe is a frequent case. As a handling, a method that can detect disturbances from subsurface pipe is needed. Microtremor is one of the geophysical methods that can provide an overview of the subsurface. Processing is done with the HVSR method with input in the form of seismic waves in the time domain which is then processed using Geopsy software to get output in the form of dominant frequency values, amplification, and H/V spectrum. The data used in this study are primary data obtained from data acquisition with a total of 60 measurement points. The distance between points is given 5 dm with a measurement time of 10 minutes for each point. The study was conducted on pipe with empty, partially filled with water, and fully filled with water with a pipe diameter of 0,9 dm. The pattern in each pipe condition from the modeling results appears at a frequency of 0-10 Hz. The difference in the range of amplification values in pipe anomalies is due to different levels of water content which can be concluded that pipe filled with water have higher amplification than empty pipe and be showed in 3D modelling.

**Keywords**— PVC, Microtremor, HVSR, pipe pattern, 3D modelling

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## I. INTRODUCTION

Pipe have an important role in water distribution. However, the process of distributing water through these underground pipe can in fact experience problems such as a lack of water flowing that occurs both due to natural conditions and due to human activity so that to detect the state of the distribution pipe a method is needed that can provide an overview of the subsurface layer in this study the microtremor method is used. Microtremors are very small ground vibrations that are constant<sup>1</sup>. The characteristics of the soil layer can be known based on the dominant period parameters and the wave amplification factor through the microtremor method<sup>2</sup>. This research data processing uses the HVSR (Horizontal to Vertical Spectral Ratio) method which can be used to analyze the characteristics of buried sites using only single station vibration recordings. The basic principle of this method is to compare the spectrum of the horizontal component with the spectrum of the vertical component<sup>3</sup>.

This study was conducted to detect a 0.9 dm diameter PVC pipe model with pipe conditions that are empty, partially filled with water, and fully filled with water as well as research soil conditions in the form of backfill soil (pipe excavation results) by analyzing the response of the subsurface water pipe model using the HVSR method based on its trajectory profile modeling. Previously, research has been conducted with the same media but using different methods, namely the GPR method<sup>4</sup>. The research was conducted to model subsurface pipe conditions by looking at the general characteristics of different pipe conditions. As a result, it is known that the characteristics in the condition of an empty pipe are hyperbola patterns with amplitude attenuation, in the condition of a partially filled pipe, it has the characteristics of a hyperbola pattern with image contrast between

water and air so that there is an amplitude attenuation pattern at the top and contrast at the bottom, while the characteristics in the condition of a pipe filled with full water are in the form of a hyperbola pattern with contrast in the part filled with full water. Meanwhile, similar research using the HVSR method has been conducted by<sup>5-7</sup>.

## II. METHODS

Microtremor data acquisition in this study was carried out west of the Diponegoro University Physics Department building on January 10-17, 2022. Soil excavation and pipe backfilling used as media in this study were carried out on January 3, 2022. The distance between points in each research track is 5 dm with a distance between tracks of 3.75 dm. Each track has 5 measurement points and the total research tracks are 4 tracks, namely tracks M, N, O, and P. Data collection was carried out using the VHL series land Ps-2B Axial Geophone 3 tool and DI710 Data Logger. The pipe as a research medium has a diameter of 0.9 dm with a vertical pipe length of 18 dm and a horizontal pipe (embedded below the surface) of 19 dm shown in Figure 1. The research trajectory and pipeline shown in Figure 2. Track M is marked in red near the vertical pipe, Track N is marked in light blue, Track O is marked in yellow, and Track P is marked in white. The buried pipeline crosses point 3 and is marked with a black line. Microtremor data processing begins with the first stage, namely opening the acquired data in the form of signals in time series with 3 components (Z, N-S, and E-W) using Windaq software and then converting the data into .txt form with Notepad++. After that, the raw data processing containing 3 signal components in the time domain was converted into the frequency domain using Geopsy software. This was done to obtain HVSR curves and spectra as well as amplification and frequency values. Sampling frequency was used to determine the frequency of 1-100 Hz and then using Konno & Ohmaci type smoothing to determine the frequency and amplification. As a final step, the area modeling, amplification contours, and frequency contours were processed using Surfer 13. Data processing used Geopsy software and 2D and 3D modeling was done with Surfer 13 software.



Figure 1 Pipe design

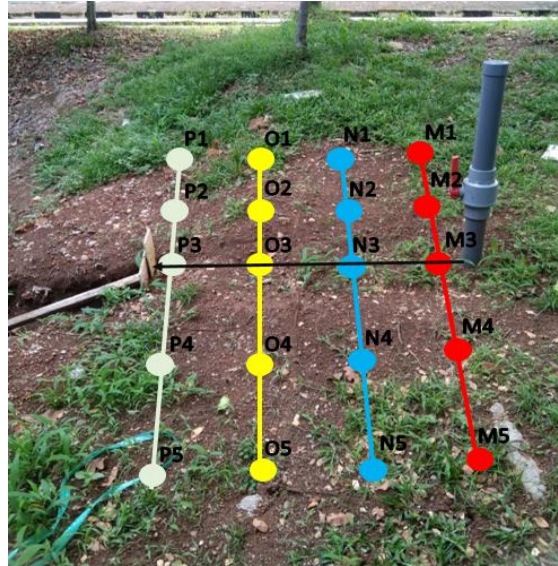


Figure 2 Research trajectory and pipeline

### III. RESULT AND DISCUSSION

After 2D modeling to create a trajectory profile, to identify the subsurface water pipe model is done by looking at the pipe pattern in each trajectory through 3D modeling. Figure 3 shows the trajectory profile in 3D for the pipe in an empty state. The outline of the buried pipeline at point 3 of the research track is marked with a red line. Meanwhile, for the partially filled pipe, the constant pattern in Figure 4 is seen at a frequency of 0-10 Hz and is marked in red. The pattern of the pipe with fully filled water is shown in Figure 5. There is a pipe pattern that constantly appears at a frequency of 0-10 Hz marked in red. The pattern forms an anomaly that is indicative of a subsurface pipeline. The amplification value shown in partially filled with water and fully filled with water is greater than when the pipe is empty, this is because the amplification factor value is inversely proportional to the shear wave movement speed ( $V_s$ ). When the pipe is filled with water, the shear modulus ( $\mu$ ) value is 0 so that  $V_s$  will be small (because the  $V_s$  value is directly proportional to the  $\mu$  value) or in other words, a pipe filled with water has a higher amplification than an empty pipe<sup>8</sup>.

The amplification value on track P is actually greater when compared to the other three tracks, this is because the soil on track P is not well compressed. In addition, the research location tends to be more sloping near track P which is intended to allow water to flow out through the water tap installed at the end of the pipe below point 3 of track P so that water will tend to be more in track P before finally going out through the water tap.

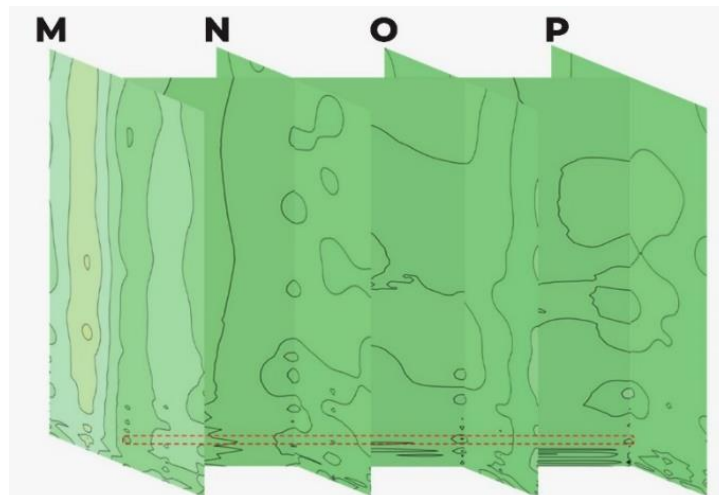


Figure 3 The pattern of empty pipe

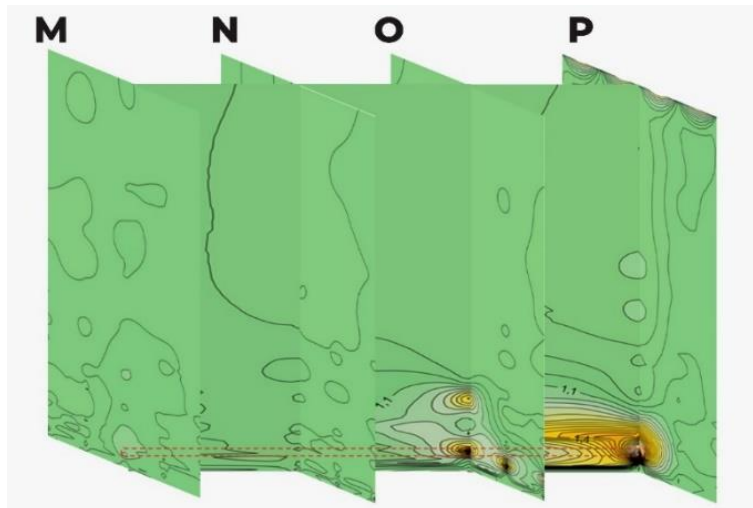


Figure 4 The pattern of pipe with partially filled water

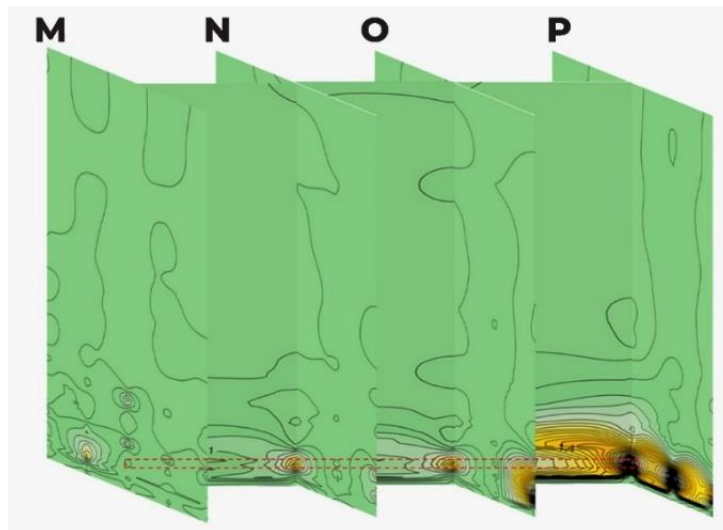


Figure 5 The pattern of pipe with fully filled water

#### IV. CONCLUSIONS

Based on this research, it can be concluded that the comparison is done in each pipe condition to see if there is a certain pattern in each track with the aim of knowing the response of the subsurface pipe model using the HVSR method. The pattern in each pipe condition appears at a frequency of 0-10 Hz which can be seen in the 2D track profile and in the pipe anomaly pattern in each track can be seen in 3D modeling. The difference in the range of amplification values in pipe anomalies is due to the level of water content, in other words, pipe filled with water have higher amplification than empty pipe. The more the pipe is filled with water, the lower the shear wave movement speed and the greater the amplification, and vice versa.

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