Changes in Acoustic Impedance of Marine Sediment Covered with Liquid Pollutants

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Abstract: Acoustic properties of porous material are slightly changed by a coating layer, which is thin compared to the acoustic wavelength. These changes affect mainly the spherical-wave reflection coefficient at grazing incidence. The phase change of a surface wave component is observed and enables to detect easily the thin layer by measuring the interference of direct and guided surface wave. This method is investigated for screening observations in order to monitor liquid pollutants on marine sediments. Since sediment is usually not plain but more or less irregular grooved, the coating by liquid pollutants will occur in patches. Laboratory experiments are carried out with plain and rough surfaces of sediment to investigate the sensitivity of detecting an average change in impedance. The results are compared with a numerical model incorporating Biot theory. Experimental results are presented and the possibility to use this method for monitoring purposes is discussed. [Work supported by German Ministry of Technology BMBF]

EXPERIMENTAL SETUP

Scaled measurements were done in a water tank with a sand sediment layer on the ground. Two spherical hydrophones located in variable positions close to the ground were used as transmitter and receiver. To prevent reflections from the tank walls and the water surface, chirp signals in the 2 - 200 kHz range with 0.5 ms duration were applied. Normalization of the acoustic transfer function between the hydrophones in the presence of the sediment to the spectrum of a formerly recorded free field measurement yields the EAF (excess attenuation function).

MEASUREMENTS AND COMPARISON WITH THEORY

The theoretical description of sound propagation above and in a sediment is based on the model of homogeneous stratified media. The influence of sediment properties as for example porosity is included in Biot theory (1) which predicts, in addition to the compressional wave in water, a shear wave and two compressional waves in the sediment. Numerical modelling is done with program FFLAGS (Fast Field Program for Layered Air Ground Systems) (2), which solves the Helmholtz equation for layered media.

![Figure 1.](image)

Figure 1. Top: Measured EAF for small (left) and large (right) amounts of poured 1-bromopentane (solid line) compared to those measured over plain sand (dashed line). The sound incidence angle is 8°.
Bottom: Results of the numerical simulation of the experiment.
Measurements of the excess attenuation function above plain sand layers reveal that the presence of liquid chemicals on the ground causes a frequency shift of the interference pattern (fig. 1). This shift depends on the angle of sound incidence, the acoustic impedance of the poured chemical and its layer thickness. Because the chemical does not form a connected layer when poured in small amounts, the simulations were carried out with the assumption of an effective layer thickness calculated from the amount and the sediment surface covered by the chemical.

The relative frequency shift of the EAF caused by the poured substances was investigated systematically for various chemicals (tab. 1) with different densities and sound speeds as a function of grazing angle. The measurements clearly show that the magnitude of the shift of the dips increases with decreasing grazing angle and increasing quantity of the liquid.

### TABLE 1

<table>
<thead>
<tr>
<th>Substance</th>
<th>c [m/s]</th>
<th>ρ [g/cm³]</th>
<th>Z = ρ + c</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-bromopentane</td>
<td>1042.8</td>
<td>1.22</td>
<td>1272.2</td>
</tr>
<tr>
<td>1,3-dichlorobenzene</td>
<td>1259.3</td>
<td>1.29</td>
<td>1624.5</td>
</tr>
<tr>
<td>1,6-dichlorohexane</td>
<td>1327.5</td>
<td>1.07</td>
<td>1415.1</td>
</tr>
<tr>
<td>2,4-dichlorotoluene</td>
<td>1289.7</td>
<td>1.25</td>
<td>1612.2</td>
</tr>
<tr>
<td>propiophenone</td>
<td>1520.0</td>
<td>1.01</td>
<td>1535.2</td>
</tr>
<tr>
<td>1,1,2-trichlorotrifluoroethane</td>
<td>719.3</td>
<td>1.58</td>
<td>1136.6</td>
</tr>
<tr>
<td>water</td>
<td>1485.0</td>
<td>1.00</td>
<td>1485.0</td>
</tr>
</tbody>
</table>

Results of the measurements and simulations for propiophenone and 1,6-dichlorohexane are shown in fig. 2. The interference pattern is shifted towards lower frequencies for chemicals with sound velocity lower than water. In case of higher sound velocity the pattern is shifted towards higher frequencies, as can be seen in the propiophenone measurement.

![Graphs](image1.png)

**Figure 2.** Relative frequency shift of the interference minima normalized to an EAF for sand as a function of grazing angle for different chemicals.

Top: Measurement. The parameter is the amount, varied as 0.1, 0.5, 1.0 and 2.0 liters.

Bottom: Simulation with a layer thickness of 0.2, 2.2, 3.3 and 4.3 mm corresponding to the amounts used in the experiments.

### REFERENCES
