Utilisation of Acoustics for Monitoring Local and Near-Field Mine Burial Processes: Proof-of-Concept

Peter D. Thorne
Proudman Oceanographic Laboratory,
Bidston Observatory,
Bidston, Merseyside CH43 7RA, UK
Phone: +44 (0)151 6538633 Fax: +44 (0)1521 6536269 e-mail pdt@pol.ac.uk

Award Number: N00014-01-1-0549
http://ocean.st.usm.edu/%7Ecwcurry/mineburial.html

LONG-TERM GOAL

The goal of the Proudman Oceanographic Laboratory's, POL, contribution to the Mine Countermeasures Programme, is to assess the applicability of recent developments in the application of acoustics, to the high resolution measurement of sediment processes, in the context of its utilisation for advancing our understanding of mine burial.

OBJECTIVES

The objectives of POL's research for 2002 has been to; (i) Provide continued guidance design criteria to OMNI Technologies for the development of acoustic suspended sediment and flow measuring instrumentation, which is to be mounted on the surface of a mine. (ii) The calibration of one of the systems developed by OMNI in the sediment tower at POL. (iii) The assessment of scattering models for sediments in suspension through a series of measurements.

APPROACH

To interact with OMNI technologies, via contact and publications, so as to provide an outline of the potential of acoustics to measure within the near-field of the mine, sediment processes and flow. The aim being to develop acoustically based systems that will improve our understanding of how mines become buried or not as the case may be. Underpinning this approach has been the study, through laboratory and marine experiments, of the application of acoustics to the measurement of small-scale sediment processes.

WORK COMPLETED

Specifications of a system design have been completed. This has included frequencies to be used, calibrations required, the necessary sampling and online processing, and data validation schemes. In September one of the systems from the mines will be brought over to the UK and calibrated in the POL sediment tower. A series of laboratory studies have been completed to assess the interaction of underwater sound with suspensions of uniformed size marine sediments, this work is required for the interpretation of the acoustic data to obtain suspension parameters.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE **Utilisation of Acoustics for Monitoring Local and Near-Field Mine Burial Processes: Proof-of-Concept**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Proudman Oceanographic Laboratory,,Bidston Observatory,Bidston, Merseyside CH43 7RA, UK, , ,**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The goal of the Proudman Oceanographic Laboratory???s, POL, contribution to the Mine Countermeasures Programme, is to assess the applicability of recent developments in the application of acoustics, to the high resolution measurement of sediment processes, in the context of its utilisation for advancing our understanding of mine burial.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

RESULTS

To date the data published on the backscattering characteristics of suspensions of irregularly shaped sand particles have been limited to the works of Hay [1, 2]. This work forms the basis of our current description of the backscattering properties of suspensions of marine sands. A further work has supported the present description [3]. However, a comprehensive study of the attenuation characteristics of sand suspensions showed significantly higher attenuation values than predicted by the commonly employed sphere based scattering models [4]. This result led to the present series of experiments on the backscattering characteristics of suspensions of sand

The backscattered root-mean-square voltage, V, from a suspension of sediments insonified with a piston source transducer can be expressed as

$$V = \frac{K_s K_t M^{1/2}}{r\psi} e^{-2r\alpha} \qquad (1)$$

where

$$K_s = \frac{f}{(\rho a_s)^{1/2}}, \quad K_t = RT_V P_o r_o \left\{\frac{3\tau c}{16}\right\}^{1/2} \frac{0.96}{ka_t} \quad \alpha = \alpha_\omega + \frac{1}{r}\int_o^r \zeta M dr \qquad (2)$$

The term K_s represent the sediment backscattering properties, ρ is the sand grain density, a_s is the particle radius, and f is known as the form function and describes the backscattering characteristics of the scatterer. For fixed settings K_t is a system constant comprising of: R the transducer receiver sensitivity, T_V the voltage transfer function, P_o is the reference pressure normally defined at r_o=1 m, τc is the pulse length, where τ is the pulse duration and c is the velocity of sound in water, k is the wavenumber of the sound in water and a_t is the radius of the transducer. The term α_ω is the sound attenuation due to water absorption, ζ is the sediment attenuation constant, M is the concentration of sediment in suspension, r is the range from the transducer, and ψ accounts for the departure from spherical spreading within the transducer nearfield.

In the present study the backscatter form function was required and therefore this can be expressed as

$$f = \frac{Vr\psi}{K_t}\left\{\frac{\rho a_s}{M}\right\}^{1/2} e^{2r\alpha} \qquad (3)$$

All the parameters on the RHS of equation (3) were measured or could be calculated and the form function obtained. To evaluate equation (3) the commonly employed high pass sphere model [1] was used to calculate the sediment attenuation. However, Ref 4 shows that this description may underestimate the attenuation. Therefore in the present study concentrations were kept reasonably low (0.3-0.6 kgm^{-3}) to reduce the impact any error in ζ may have had on the form function measurements.

The experimental set-up is shown in Figure 1. The sediment tower consisted of a re-circulating water flow with extraction at the bottom of the tower, and re-injection at the top through a mixing chamber designed to homogenise the suspended sediments in the tower. To further assist suspension homogeneity a triple unit near the base of the tower consisting of a turbulence grid, impeller and a propeller were rotated to generate a turbulent flow directed upwards. This combination generated a homogeneous suspension over the central section of the tower. To insonify the suspension a triple frequency acoustic system was used and the backscattered signal recorded.

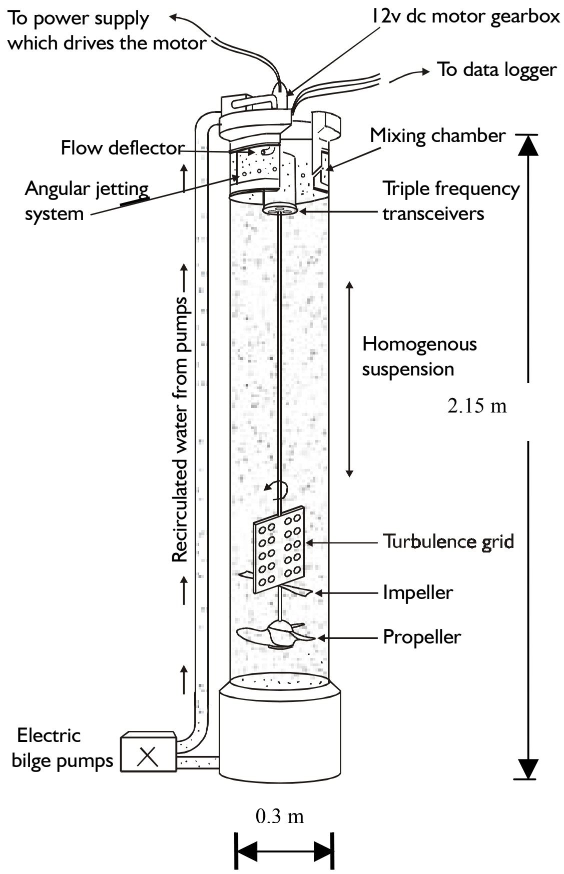

Figure 1. The sediment tower used for the measurements.

Measurements of the backscattering characteristics of suspension of marine sands are shown in figure 2. This shows the variation in the form function with $x=ka_s$, where k is the wave number of the sound in water, for four different suspensions of marine sands. Essentially the observations show an increase in the backscattering characteristic up a value of x=2, with a relatively constant value for the form function above this value of x. To model the behaviour of the backscattering from suspensions of sand, a modified mobile rigid sphere model has been used. This utilises an enhanced sphere scattering description, to obtain matching of the sphere based model with the data. Typically this enhancing factor is of the order of 1.6, indicating that the backscattering characteristics for irregularly shaped sand grains is around 60% higher than for the 'sphere equivalent' particle size. The results from this study provide the most accurate description of sediment scattering available to date.

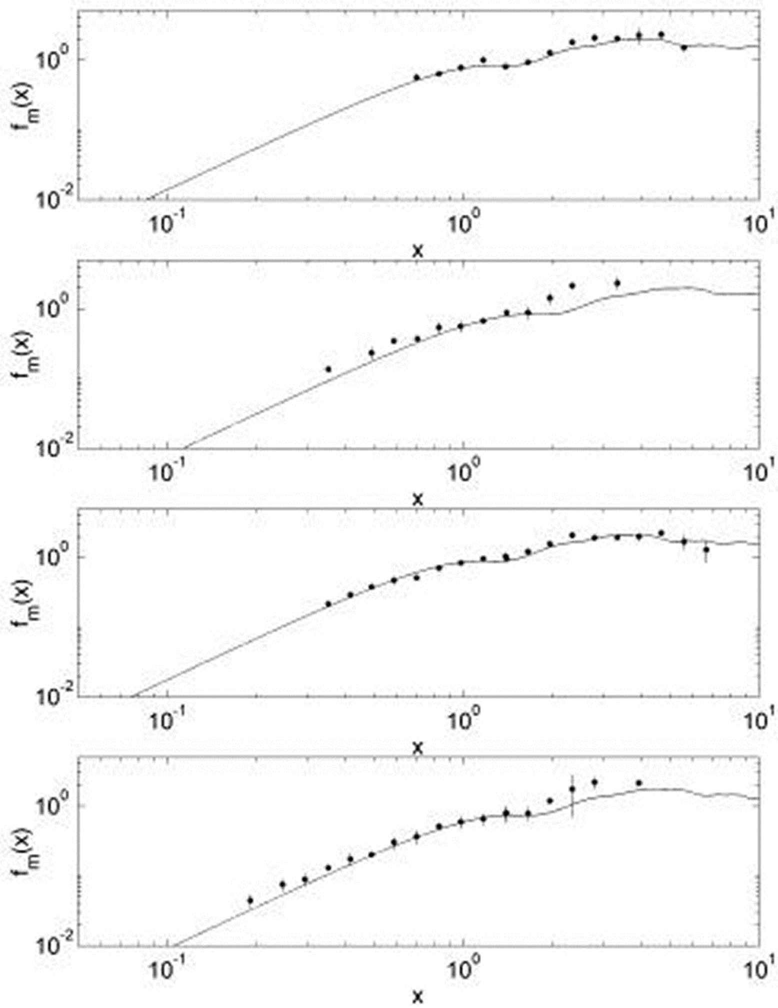

Figure 2. Variation of the backscatter form function with x for four different sediments

IMPACT/APLICATION

The work reported here will be used to interpret the data collected by the acoustic systems on the OMNI mine. It will be used to provide a framework for assessing the relationship between the presence of the mine, sediment mobility, and mine burial. The scattering results will also be made available to the general community through publication of these observations.

TRANSITIONS

The results from the present study will be incorporated into inversion algorithms, which will be used to extract suspended sediment parameters from the acoustic systems deployed on the OMNI mine.

RELATED PROJECTS

European funded access to large-scale facilities. http://www.pol.ac.uk/home/research/p2t2-532.html

REFERENCES

1. Sheng J and Hay AE. An examination of the spherical scatterer approximation in aqueous suspensions of sand. *J. Acoust. Soc. Am*.1998; **83**: 598-610.

2. Hay AE. Sound scattering from a particle-laden turbulent jet, J. Acoust. Soc. Am., 1991; **90**: 2055-2074.

3. Thorne PD, Sun S Zhang J Bjorno I and Mazoyer T. Measurements and analysis of acoustic backscattering by elastic cubes and irregular polyhedra. *J. Acoust. Soc. Am.* 1997; **102 (5)**: Pt. 1, 2705-2713.

4. Schaafsma AS and Hay AE. Attenuation in suspensions of irregularly shaped sediment particles: A two-parameter equivalent spherical scatterer model. *J. Acoust. Soc. Am*. 1997; **102 (3)**: 1485-1502.

PUBLICATIONS

Thorne, P. D. and Hanes D. M., 2002. A review of the application of acoustics to small scale sediment processes. *Continental Shelf Research*. Vol (22) N° 4 603-632.

Williams J. J., Rose C. P. and Thorne P.D. 2002 Role of wave groups in resuspension of sandy sediments *Marine Geology* 183 17-29

Betteridge K. F. E., Thorne P. D. and Bell P. S. 2002. Assessment of acoustic coherent Doppler and cross-correlation techniques for measuring near-bed velocity and suspended sediment profiles in the marine environment. Journal of Atmospheric and Oceanic Technology. Vol 19 No 3 March. 367-380.

Thorne, P. D., Williams J. J. and Davies A. G. 2002. Suspended sediments under waves measured in a large scale flume facility. *Journal of Geophysical Research*. In Press.

Williams J. J., Bell P. S. and Thorne P. D. 2002. Field measurements of flow fields and sediment transport above mobile bedforms. *Journal of Geophysical Research*. In Press.