

# Influence of Anaerobic Degradation of Organic Matter on the Rheological Properties of Cohesive Mud from Different European Ports

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## Supplementary information

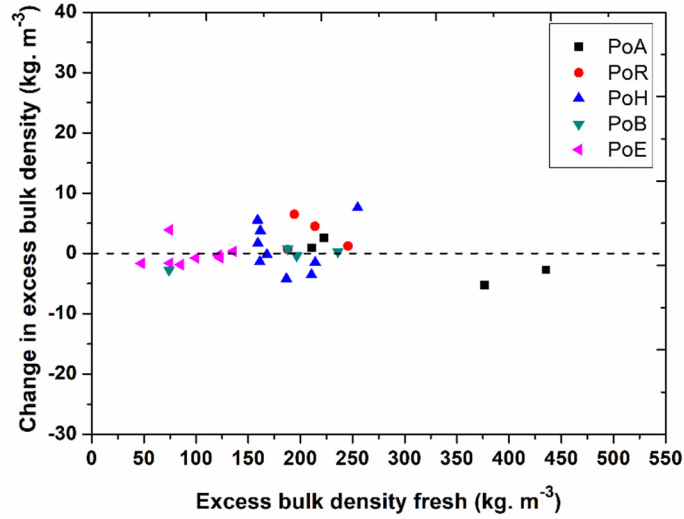
## 1. Experimental methods

**Table S1.** Details of the mud samples collected from different European ports.

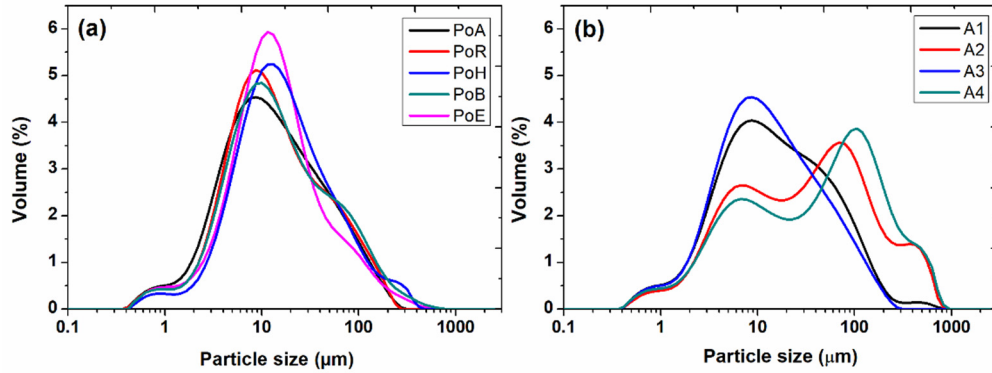
Locations ID	Electrical Conductivity (mS/cm)	pH	Wet Bulk Density (kg. m <sup>-3</sup> )	Total Organic Carbon (% TS)	Coordinates (WGS 84)	
					°N	°E
Port of Antwerp (PoA)						
A1	18.0	7.3	1211	3.2	51.264507	4.290137
A2	19.5	7.3	1377	2.8	51.278554	4.326887
A3	22.6	7.4	1223	3.3	51.264064	4.267839
A4	22.0	7.3	1435	2.0	51.344834	4.275627
Port of Rotterdam (PoR)						
R1	48.7	7.3	1214	2.4	51.964011	4.085257
R2	22.5	7.5	1194	3.5	51.897481	4.361255
R3	18.4	7.4	1246	3.8	51.898966	4.436281
R4	47.3	7.3	1188	2.3	51.972873	4.084746
Port of Emden (PoE)						
E1	32.8	7.6	1085	3.5	53.343819	7.187947
E2	30.6	7.4	1136	3.4	53.343819	7.187947
E3	28.8	7.3	1048	3.3	53.334588	7.178431
E4	30.2	7.4	1121	3.4	53.334588	7.178431
E5	28.5	7.2	1075	3.4	53.348712	7.197238
E6	24.9	7.1	1100	3.6	53.348712	7.197238
E7	31.0	7.3	1075	5.5	53.338239	7.192957
E8	27.2	7.4	1123	3.6	53.338239	7.192957
Port of Hamburg (PoH)						

<b>H1*</b>	1.24 – 2.19	6.9 – 7.9	1066 – 1255	3.5 – 4.1	53.538894	9.881215
<b>Port of Bremerhaven (PoB)</b>						
<b>B1</b>	32.0	7.2	1074	3.1	53.574246	8.553273
<b>B2</b>	32.3	7.3	1188	3.2	53.574246	8.553273
<b>B3</b>	29.4	7.4	1236	3.4	53.574246	8.553273
<b>B4</b>	30.1	7.3	1197	3.1	53.573482	8.548059

\*Several samples from the same location



**Figure S1.** Change in excess bulk density (degraded – fresh) as a function of excess bulk density ( $\rho - \rho_w$ ) of fresh mud sample from different ports. The dashed line represents the value where the degraded and fresh mud samples have the same bulk densities.



**Figure S2.** Particle size distribution of (a) mud samples from PoA, PoR, PoE, PoH and PoB; (b) mud samples from different locations of PoA obtained using static light scattering technique.

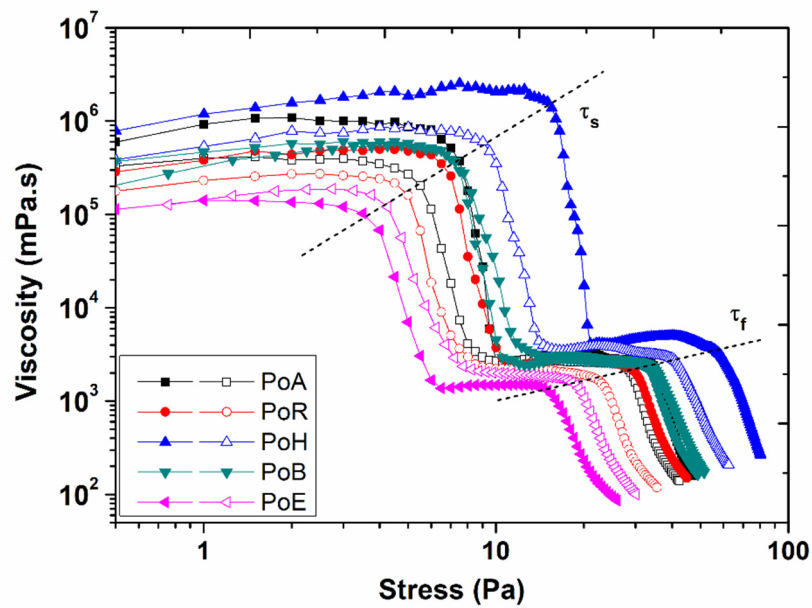
**Table S2.** Particle size distribution, obtained by static light scattering technique, of the mud samples collected from different European ports.

Sample ID	D <sub>10</sub> (μm)	D <sub>50</sub> (μm)	D <sub>90</sub> (μm)
PoA	2.70 ± 0.01	11.16 ± 0.07	61.33 ± 0.76
PoR	3.56 ± 0.34	13.49 ± 2.53	69.16 ± 3.51
PoE	3.31 ± 1.08	12.20 ± 3.14	62.21 ± 4.15
PoH	3.59 ± 0.03	14.71 ± 0.17	76.61 ± 3.17
PoB	3.37 ± 0.22	12.91 ± 0.73	79.97 ± 3.81
<b>Port of Antwerp (PoA)</b>			
A1	2.75 ± 0.04	13.29 ± 0.38	80.04 ± 6.33
A2	3.23 ± 0.04	29.14 ± 2.47	185.73 ± 41.09
A3	2.70 ± 0.01	11.16 ± 0.07	61.33 ± 0.76

A4	$3.18 \pm 0.06$	$40.89 \pm 2.81$	$219.28 \pm 31.04$
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**Table S3.** Particle size distribution, obtained by sieving technique (DIN ISO 11277 2009), of the mud samples collected from different European ports.

Locations ID	Clay, <2 $\mu\text{m}$ (%)	Silt, 2-63 $\mu\text{m}$ (%)	Sand, 63-2000 $\mu\text{m}$ (%)
<b>Port of Antwerp (PoA)</b>			
A1	48	47	4
A2	35	52	13
A3	57	41	2
A4	24	30	46
<b>Port of Rotterdam (PoR)</b>			
R1	50	45	4
R2	46	43	10
R3	44	42	14
<b>Port of Emden (PoE)</b>			
E1	60	38	1
E2	61	38	1
E3	61	38	1
E4	60	36	4
E5	48	47	5
E6	33	59	8
E7	58	40	2
E8	60	38	2
<b>Port of Hamburg (PoH)</b>			
H1*	30 – 52	44 – 59	3 – 9
<b>Port of Bremerhaven (PoB)</b>			
B1	48	43	9
B2	38	55	7
B3	39	51	10
B4	44	43	13



**Figure S3.** Apparent viscosity as a function of shear stress for fresh mud samples (filled symbol) and mud samples degraded for 250 days (empty symbols) collected from different ports. The dashed lines represent the static ( $\tau_s$ ) and fluidic ( $\tau_f$ ) yield stresses.

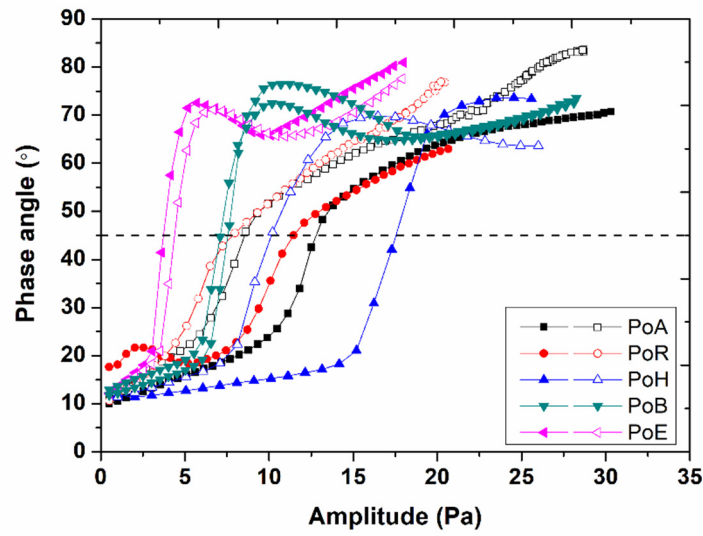
**Table S4.** The values of the fitting parameters of Eq. 1 for different ports.

Rheological property	a (Pa or Pa. s <sup>-1</sup> )	b (-)	a (Pa or Pa. s <sup>-1</sup> )	b (-)	a (Pa or Pa. s <sup>-1</sup> )	b (-)	a (Pa or Pa. s <sup>-1</sup> )	b (-)	a (Pa or Pa. s <sup>-1</sup> )	b (-)	a (Pa or Pa. s <sup>-1</sup> )	b (-)
	PoA		PoR		PoH <sup>a</sup>		PoE		PoB		PoH <sup>b</sup>	
SYS	3.86	-0.53	0.89	-0.22	2.35	-0.44	0.25	0.42	0.56	-0.05	-0.01	-0.35
FYS	8.59	-0.37	-1.83	-0.04	7.35	-0.36	0.31	0.39	3.22	-0.11	-0.41	-0.27
COA	3.33	-0.46	0.80	-0.25	1.76	-0.40	0.09	0.25	1.04	-0.11	-0.07	-0.35
G*	-423.4	-0.33	-178.9	0.08	-5.21	-0.39	8.14	0.42	-99.58	0.06	6.44	-0.45
HA	-67.5	-0.14	80.6	-0.46	119.3	-0.33	10.5	1.85	177.5	0.20	-5.97	-0.32

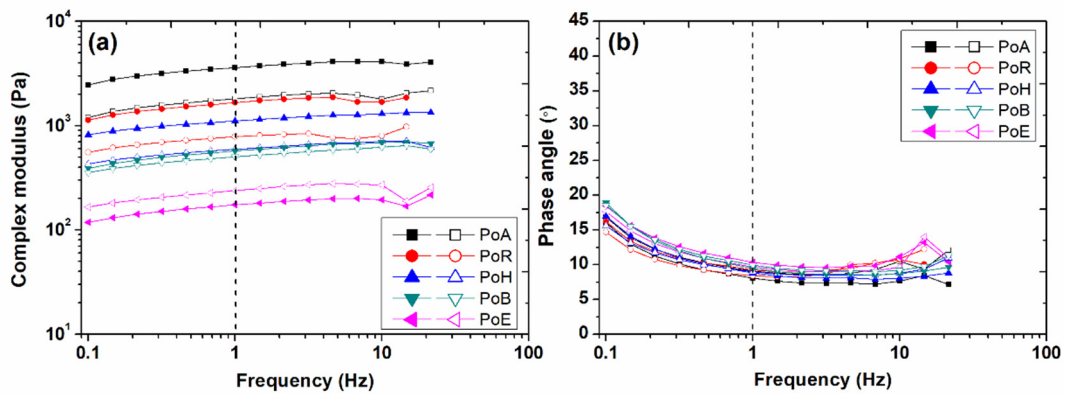
<sup>a</sup> Pre-consolidated mud samples from PoH

<sup>b</sup> Fluid mud samples from PoH

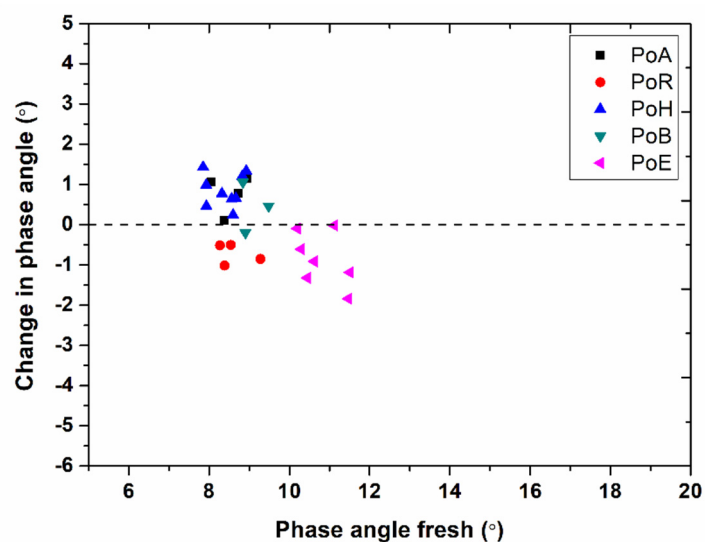
SYS = static yield stress; FYS = fluidic yield stress; COA = crossover amplitude; G\* = complex modulus at 1 Hz; HA = hysteresis area



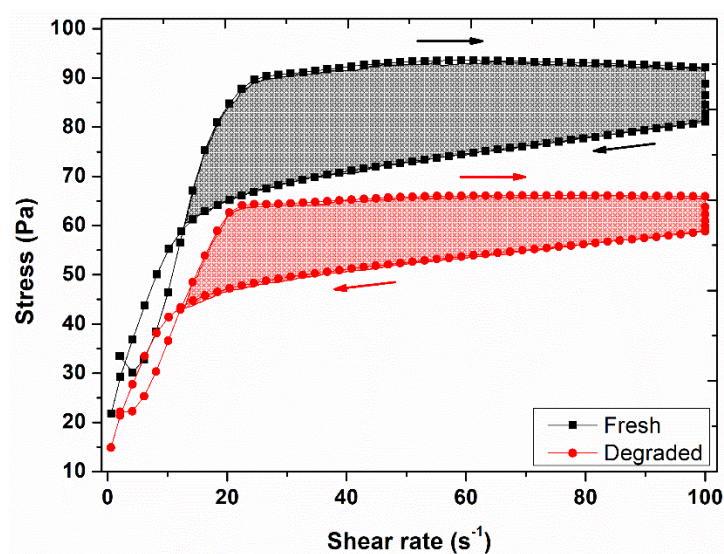
**Figure S4.** Phase angle as a function of oscillatory stress amplitude for fresh mud samples (filled symbol) and mud samples degraded for 250 days (empty symbols) collected from different ports. The dashed line represents the crossover amplitude (i.e.,  $G' = G''$  or phase angle = 45).



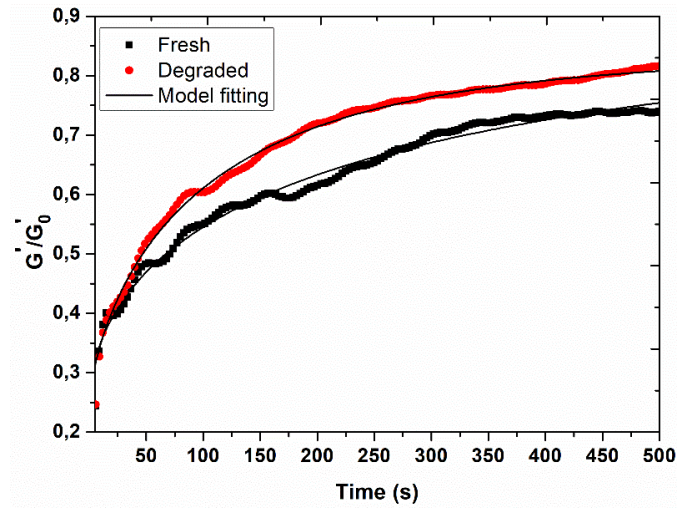
**Figure S5.** (a) Complex modulus and (b) phase angle as a function of frequency for fresh mud samples (filled symbol) and mud samples degraded for 250 days (empty symbols) collected from different ports. The dashed lines represent the complex modulus and phase angle at 1 Hz, which is typically used for comparative analysis of different samples.



**Figure S6.** Change in phase angle (degraded – fresh) at 1 Hz as a function of phase angle at 1 Hz of fresh mud samples from different ports. The dashed line represents the value where the degraded and fresh mud samples have same phase angle at 1 Hz.



**Figure S7.** Shear stress as a function of shear rate obtained by performing shear rate controlled ramp-up and ramp-down experiments for fresh mud sample and mud sample degraded for 250 days, collected from PoH. The direction of arrows represent the ramp-up or ramp-down curve. The filled region represents the hysteresis area.



**Figure S8.** Normalized time dependent storage modulus,  $G'/G'_0$  as a function of time obtained from the structural recovery step for fresh mud sample and mud sample degraded for 250 days, collected from PoH. The solid line represents the empirical fitting using Eq. 2.