

Letter to the editor

Comment on: Vidgren, H., Helland, A., and Lepland, A. 2015. Stability of Capped Dredged Sediments in a Confined Disposal Facility at Malmøykalven, Oslofjord, SE Norway. *Soil and Sediment Contamination: An International Journal*, v. 24, n. 6, pp. 675-693. DOI: 10.1080/15320383.2015.998167

Gijs D. Breedveld^{1,2} and Arne Pettersen¹

¹Department of Environmental Engineering, Norwegian Geotechnical Institute, P.O. Box 3930 Ullevaal Stadion, N-0806 Oslo, Norway

²Department of Geosciences, University of Oslo, P.O. Box 1047 Blindern, N-0316 Oslo, Norway

Key words

sediment capping, trace metals, cap efficiency, consolidation, Oslofjord

Introduction

The topic of the recent paper by Vidgren and colleagues is concerned with the cap stability of a confined aqueous disposal facility (CAD) located in the inner part of the Oslofjord, Norway. Increasing our understanding of cap behavior is a very relevant topic in sediment remediation since this method is widely used and relies on the assumption of intrinsic safety through an increase in cap stability with time (Fredette, 2006). The authors have collected a set of six gravity core samples to study the physical and chemical status of the cap, 2 years after placement. The samples have been thoroughly analyzed for particle size distribution, trace element composition and total organic carbon (TOC). This data set is quite valuable for long-term monitoring of the CAD in question. However, since we have been closely involved in the control and monitoring of this project, we feel obliged to correct some of the conclusions drawn by the authors from this dataset. We would like to point out two, in our opinion, serious omissions in the data interpretation: 1) reference data on characterization of the capping material delivered on site have not be included in the data interpretation, 2) the physical basis for the hypothesized particle transport in the cap is lacking given the time frame of consolidation and the resulting porewater flow velocity that can be generated during consolidation.

Characterization of capping material

Based on differences in the characterization of the sampled sediments and cap material the authors conclude that: *“The results provided evidence that consolidation-induced pore water advection was able to transport fine particles (<63 μm) and organic material into the cap layer. Metal transport in the particulate phase was suggested to be the main transport process into the*

cap layer.” Unfortunately the authors based their conclusion on characterization data of one sample of the material that was planned to be used for capping referred to as Multiconsult (2008). Surprisingly they have not used the weekly data collected on site when the barges were actually loaded with the capping material in 2009, and during supplemental capping in 2010 and 2011. A total of 38 samples have been collected on a weekly basis and characterization data are freely available on-line at www.renoslofjord.no. Table 1 compiles the characterization data of the capping material used for the data interpretation by the authors, reported by Multiconsult (2008) and actually delivered on site (NGI, 2009a; 2010; 2011). An initial comparison shows that the origin of the data used by the authors is not clear since none of their data coincide with any of the 4 datasets reported by Multiconsult (2008). Data of the material delivered on-site for capping show that there is a considerable variation in the chemical composition of the capping material that has been used.

As part of the monitoring and control program, the initial capping layer was sampled *in-situ* in 2009 using grab sampling. Results from these samples are presented in table 2. Comparison with the data from Vidgren et al (2015) shows that the data from 2009 and 2013 are in the same range, with the exception of cadmium and mercury. Unfortunately the lowest detected levels for these elements are reported as “0” which is not very informative and makes interpretation of the significance of the data with respect to the limit of detection impossible.

The authors did not supply the full data set that would allow a more rigorous statistical analysis of their data. This in combination with the observed variation in the capping material delivered

on site should lead to the conclusion that the reported chemical data show no evidence of any transport of fines (<63 μm) or organic material into the cap layer.

Particle transport through a cap

The authors show that the particle size distribution of the material they sampled is not consistent with the cap material design criteria formulated by Reible (2008). The coarser texture should raise the potential for transport of fine particles in the cap. At the same time the authors note that available mathematical models (Lampert and Reible, 2009; Go et al.,

2009; Alshawabkeh et al., 2005) only consider pore water induced transport of contaminants in the dissolved form. The reason these models do not include consolidation induced advective particle transport is that relative high porewater velocities are required to mobilize a particle. Stoke's law allows us to estimate the settling rate of ideal non-cohesive particles as a function of particle size, particle density and fluid viscosity under the viscous drag of laminar flow (Reynolds number below 1). Rapid settling of large particles is governed by turbulent drag (Ferguson and Church, 2004). A porewater velocity greater than the settling rate would be required to move a single particle from the sediment surface up into the free water column, excluding any hindrance from the capping material on top. Table 3 shows the settling rate of mineral particles, with a density of 2.68 kg/dm^3 (submerged in seawater 1.65 kg/dm^3), in the size range 1-63 μm in seawater at 10°C . The required velocity ranges from 6 cm to 200 m per day. These water velocities can be found in groundwater and surface water systems. However, at the CAD site the dredged material was allowed to consolidate during 6 months to 1 year before the cap was put in place in several consecutive rounds. Therefore it is unrealistic to assume

consolidation rates that could induce porewater velocities of this magnitude. This leads to the conclusion that there is no physical basis for the authors hypothesized transport of fines (<63 μm) or particulate organic material into the cap layer.

We consider the dataset that has been collected to be a valuable source of information to study the long-term behavior of the CAD. However, the data require proper statistical interpretation and should not be misused for unsupported conclusions.

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Table 1. Chemical characterization data of capping material used at the CAD before placement

Parameter	Vidgren et al. 2015		Multiconsult 2008		NGI 2009a; 2010; 2011	
	cap material(n = 1)		cap material(n = 4)		cap material(n = 38)	
Range	min	max	min	max	min	max
TOC (% TS)	<0.1		0.008	0.145	0.03	0.98
Arsenic (As)			1.2	1.7	0.1	9.1
Lead (Pb)	3.3		3.4	4	3.3	12
Cadmium (Cd)	<0.05		<0.05	<0.05	0.02	0.35
Copper (Cu)	9.1		4.3	13	6.9	45
Chromium (Cr)			11	19	10	110
Mercury (Hg)	<0.01		<0.01	<0.01	0.04	0.09
Nickel (Ni)			6	12	0.11	22.6
Zinc (Zn)	32.7		26	41	28	106
< 63um %	2	7	9	11		

Table 2. Chemical characterization data of capping material sampled *in-situ* after placement.

	Vidgren et al. 2015		NGI 2009b	
	core samples (n = 7-12)		grab samples (n = 9)	
	min	max	min	max
TOC (% TS)	0.04	0.67		
Arsenic (As)			0.18	1.44
Lead (Pb)	2	13	2.76	10.4
Cadmium (Cd)	0	0.50	0.005	0.177
Copper (Cu)	3	15	7.66	19.6
Chromium (Cr)			11.1	19
Mercury (Hg)	0	0.40	0.02	0.09
Nickel (Ni)			8.45	14.3
Zinc (Zn)	14	65	31.7	72.5
< 63um %	3	21		

Table 3. Vertical porewater velocity required to mobilize non-cohesive mineral particles from the sediment surface as a function of particle size (based on Stoke's law).

Particle size	water velocity (m/s)	water velocity(per day)
63 μm	2.66E-03	229 m/d
10 μm	6.69E-05	5.8 m/d
6 μm	2.41E-05	2.1 m/d
2 μm	2.68E-06	23 cm/d
1 μm	6.69E-07	5.8 cm/d