DONG A/S

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Vindeby offshore wind farm

Mapping of environmentally harmful substances in regards to decommissioning

PROJECT

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APPENDIXES

1 INTRODUCTION

NIRAS has been assigned to map environmentally harmful substances in the construction materials in the structures at Vindeby offshore wind farm in regard to the planned decommissioning.

2 THE OFFSHORE WIND FARM

The offshore wind farm is located at Smålandsfarvandet near shore from the coastal village Vindeby on the southern Danish island Lolland. The Wind farm layout can be seen in Appendix 2.

2.1 Scope of decommissioning

The decommissioning includes removal of 11 wind turbines, their gravity based foundations and the recovery of the inter array and export cables. The mapping includes the offshore part of the wind farm which are planned for decommissioning.

2.2 Description of the offshore wind farm

General:

Capacity, total:	4.95 MW
Distance to shore:	1.5 - 3 km
Water depths:	2.1 – 5.1 m
Commissioned:	1991
Distance between turbines:	300 m (two rows of respectively 5 and 6 turbines)

Turbines:

Turbine Model:	Bonus 450 kW/37
Number of turbines:	11
Rotor weight:	4.9 tons
Hub height:	37.5 m
Blade manufacturer:	LM Wind Power
Blade model:	LM17
Nacelle, weight:	27.6 tons
Tower weight:	20 tons

Inter array and export cables:

Inter array cable	3 km
Export cable:	1.3 km
Cable type:	12 kV, 3x150 mm², Cobber
Buried:	1 m
Protection:	Flagstones, rock stones and sandbags

Foundation:

Concrete strength:	77,9 MPa (5 concrete core DS/EN 12390-3[1])

[1] See separate test report P1380-01 of April 24, 2016

Concrete bottom slap:	Diameter 14 m, height 0.6m
Concrete top slap:	Diameter 5.0 m
Weight incl. ballast:	710 – 1105 tons
Weight excl. ballast	366 – 559 tons

3 MAPPING BASIS

It is assumed that materials and waste are loaded in and processed in Denmark.

Based on the year of commission it is estimated that the structures potentially could contain environmentally harmful substances in the structures such as chlorinated paraffin's, heavy metals and asbestos.

The legislation within this field includes among other requirements as explained below (unofficial translation):

Working environment – Statutory Order regarding the builders obligations[2]

- Work with major hazards or risks must be mapped (includes work with environmentally harmful substances and risk drowning)
- Plan for occupational health & safety must be prepared for work classified as dangerous

Waste management – Statutory order regarding waste management[3] and Statutory order regarding residual products[4]

- Waste and materials must be sorted at source
- Recyclable materials must be reused and must be free of harmful substances (which therefore must be separated/cleaned)
- Waste must be reported (present report attached)

The survey and mapping of the structures containing environmentally harmful substances are based on:

- Forslag til undersøgelse af miljøfarlige stoffer (Proposal for survey of environmentally harmful substances), NIRAS note of March 9, 2016 prepared for DONG A/S
- Elsams report "Erfaringer fra Vindeby Havmøllepark" (Experience from Vindeby offshore wind farm) from 1991
- Service manual for BONUS 450 kW off shore turbines

[2] Statutory Order no. 117 of 05/02/2013 (Bekendtgørelse om bygherrens pligter)

[3] Statutory Order no. 1309 of 18/12/2012 (Bekendtgørelse om affald)

[4] Statutory Order no. 1414 of 30/11/2015 (Bekendtgørelse om anvendelse af restprodukter og jord til bygge- og anlægsarbejder og om anvendelse af sorteret, uforurenet bygge- og anlægsaffald)

- Drawings and other background material available from NIRAS project archive from the installation and following repair projects. The drawings material are not complete and concerns exclusively the foundations.
- Inspection of and sampling from turbines 4W and 5E

4 INSPECTION AND SAMPLING

Inspection and sampling where performed on April 18, 2016 by Johan Finsteen Gjødvad og Morten Dallov Ibsen, NIRAS A/S. Strong wind and required safety precautions made the inspection and sampling challenging and rather difficult. During the operation 4 samples were taken on the two turbines and structures. The location of the samples on the structures can be seen in Appendix 2.

5 RESULTS OF ANALYSIS AND WASTE CATEGORIZATION

The samples have been analysed by the external laboratory Dansk MiljøAnalyse ApS (DMA). The samples have been analysed for PCB and/or heavy metals. The results can be found in the DMA analysis report in Appendix 5.

The analysis shows occurrences of heavy metals of different concentrations in the paint on the tower structure and by the flange. No environmentally harmful substances has been detected in the concrete of the foundation.

The analysis results are furthermore summarised in Appendix 3. Each analysis result of the respective sample are stated in ppm (mg/kg). In addition the results are coloured dependent on the waste category which they fall under:

Red: Hazardous waste.

Yellow: Contaminated, not hazardous waste.

Green: Not contaminated.

The waste categorization must comply with the threshold values for waste management in the municipality of the receiving port. However at the time of writing the receiving port is not known, hence the waste categorisation stated in Table 1 this is the threshold values from the Municipality of Copenhagen, which is normative for waste threshold values:

	Not contaminated (mg/kg)	Contaminated, not hazardous (mg/kg)	Hazardous waste (mg/kg)
PCB_{total}	< 0,1	0,1 - 50	> 50
PAH_{total}	< 4	4 - 1.000	> 1.000
Benz(a)pyren	< 0,3	0,3 - 100	> 100
Dibenz(a,h)antrace	< 0,3	0,3 - 25	> 25
Heavy metal - Lead (Pb)	< 40	40 - 2.500	> 2.500
Heavy metal – Cadmium (Cd)	< 0,5	0,5 - 1.000	> 1.000

Heavy metal - Chrom $(Cr)_{Total}$	< 500	500 - 1.000	> 1.000
Heavy metal – Cobber (Cu)	< 500	500 - 2.500	> 2.500
Heavy metal – Nickel (Ni)	<30	30 - 1.000	> 1.000
Heavy metal Zinc (Zn)	< 500	500 – 2.500	> 2.500
Mercury, organic (Hg)	< 1	1 - 500	> 500
Asbestos	No asbestos fibers	-	Asbestos fibers
Chlorinated paraffins $_{\text{short chained}}$	-	-	> 10.000 (1%)

Table 1 Threshold values for waste categorisation

Waste which is not contaminated, sorted at source and recyclable should be sold for reuse or recycling with no restriction on the free market.

Recycling of contaminated materials requires a permit under the environmental protection law of Denmark (Miljøbeskyttelsesloven).

6 MAPPING

Based on the results of the survey NIRAS has mapped the structural components which contain contaminated or hazardous waste and materials in Table 1Table 2.

The table gives a short description of the structural component and states the respective waste categorization. In addition a proposed waste handling is given.

Description of structural component	Mapping			Håndtering
	PCB	Heavy metals	PVC	
Tower + nacelle		Paint, internal		Disposal for recycling at a licensed recycling site.
Concrete grout at flange		Paint		Removal and cleaning of paint and disposal at licensed e.g. Ekokem. Underlying concrete for recycling[1]
Top slap		Paint		Removal and cleaning of paint and disposal at licensed e.g. Ekokem. Underlying concrete for recycling[1]
Railing, machine parts etc.		Paint[2]		Disposal for recycling at a licensed recycling site.

[1] If offshore removal and cleaning is unfeasible without spreading of the hazardous paint removal of the concrete with the paint for disposal as contaminated waste could be considered as the safer method.

[2] It is assumed that the paint contain heavy metals in concentration equal to hazardous waste.

Table 2 NIRAS mapping of structural components

7 FURTHER SURVEYS

During the survey it was not possible to access all structural components which potentially contains environmentally harmful substances .

When the turbines and cables are loaded ashore it is therefore recommended to investigate the following components:

- **Inter array and export cables.** The cables contain asphalt. Asphalt can potentially contain PAH (tars), which might limit the possibilities for recycling of the materials.
- **Soft joints** potentially contains chlorinated paraffin'. Soft joints are registered in the service manual sealant (labyrinttætning) shown at a drawing on page 68 and a joint strip by the cable entry to the foundation and between the top slap and the floating caisson on the drawing 'Sænkekasser, beton- og armeringsplan'. 18/12-1989.
- There might be brake blocks in the yawing system and possibly other similar systems which contains asbestos. Asbestos-containing brake blocks have been excepted the prohibition of products containing asbestos until 2005. Furthermore practice has been to use old products containing asbestos from storages or from outside Denmark, where prohibition was not introduced until later. Hence the end year for the use of products containing asbestos cannot be precisely established.
- **Blades.** The foam might contains isocyanates, which can produce hazardous substances when cut.

8 WASTE QUANTITIES AND HANDLING PROPOSAL

Wherever possible the mapping of waste quantities and structural components is based on the accessible data. Besides structural components equipment and removable inventory is briefly included in the estimation.

Where no information have been accessible quantities and fractions are assessed on basis of information from other turbine models. Hence the stated waste quantities are guiding and should be used with caution.

Substances	Structural component	Tons	Handling proposal
Steel	Tower, machinery, concrete reinforcement	1020	If possible repaired for reuse otherwise recycled. Disposal only at licensed recycling sites due to heavy metals in paint.
Aluminium	Ladders and alloys	1	Recycling (remelting)
Cobber + epoxy	Windings on transformer	7	Recycling (remelting)
Fibre glass + polyester (resin, glue, gelcoat)[1]	Blades	20+23	If possible repaired for reuse as blades or other structures (e.g.

			noise barriers). Possible recycling of fibre glass and polyester. Alternatively incineration. (H.J. Hansen collect and store blades expecting future optimization of recycling)
PVC foam[1]	Shoring in blades	0.5	Separation and disposal for recycling
Lead[1]	Blade balancing	0.2	Recycling (remelting)
Cobber	Cables 3x150 mm^2	17	Recycling (remelting)
Asphalt	Cables	1	Recycling (remelting)
Steel wires	Cables	3	Recycling
PEX insulation	Cables	5	Recycling or incineration
Concrete	Foundation, grout and flagstone (cable protection)	4880	Recycling (e.g. as crushed concrete used in road construction)
Concrete	Grout with hazardous paint	4	Hazardous waste e.g.to Ekokem
Magnets	Nacelle	>1	Possible reuse or recycling otherwise for deposit
Electronics	Cables and boards	3	Recycling (remelting)
Rubber	Nacelle (hoses)	3	Recycling or incineration
Sand, gravel	Ballast, sandbags on cables	9980	Reuse on land or to dredging site (ballast is assumed to be marine materials)
Mineral oil and hydraulic oil	Transformer og hydraulic system	2	Recycling (refining) or incineration
Marine growth	(on foundation)	14	Possible use on crop field as fertilizer or in biogas facility. If contaminated with herbicides (anti-growth agent) it must be disposed.

[1] Information from LM Wind power

Tabel 3 Waste quantities and proposal for handling of 11 turbines including foundations and cables.

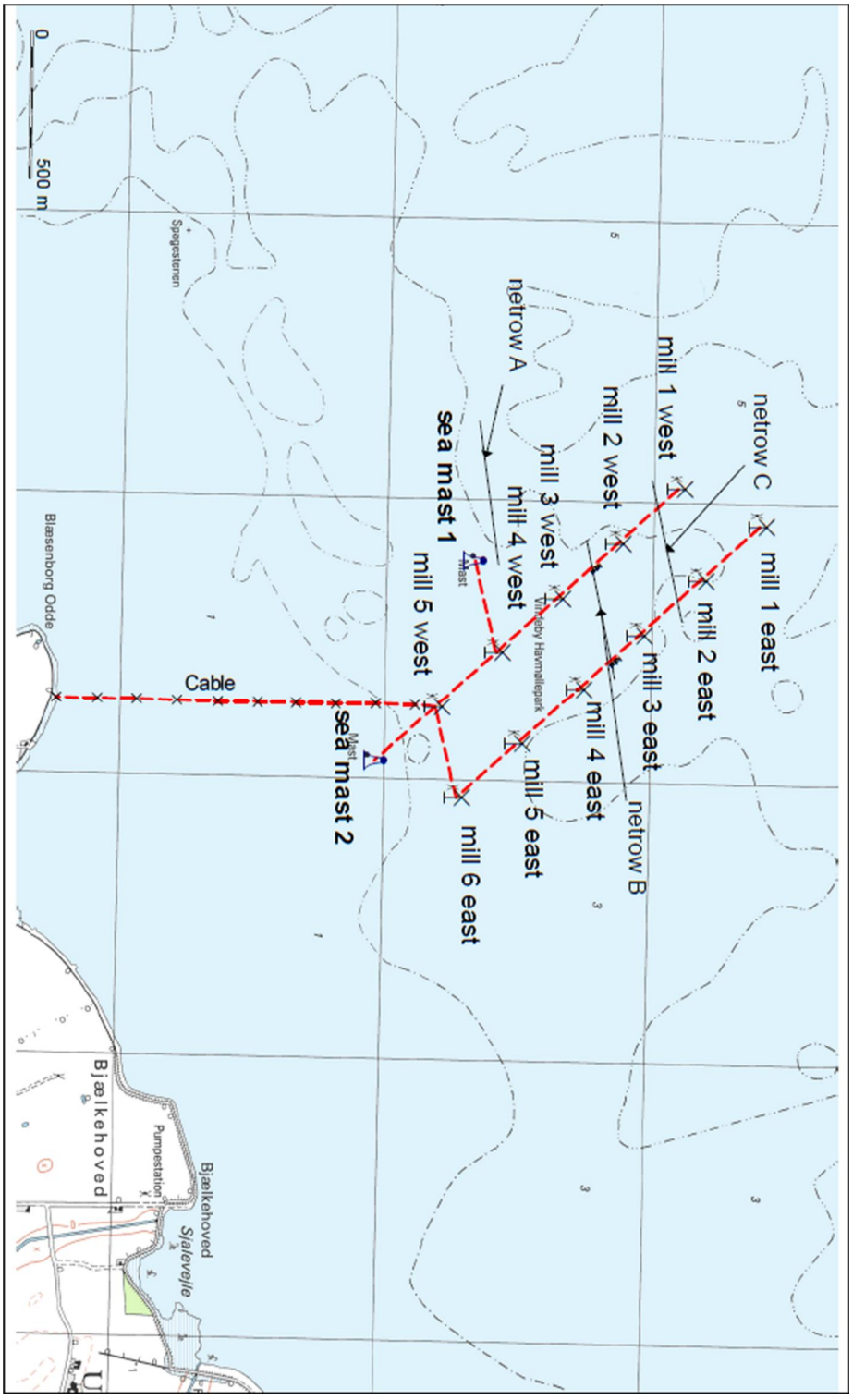
General comments:

Foamed materials must be handled according to instructions of receiving municipality (until known the rules of the Municipality of Copenhagen). The materials must be handled in as large pieces as practicable possible.

Electronic waste must be handled according to Statutory order no. 130 (elektronikaffaldsbekendtgørelsen) 06/02/2014 concerning electronic waste.

Equipment such as transmission system and removable inventory can be handed over to scrap dealers according to their standard cost.

Appendix 1 Layout offshore wind farm



Appendix 2 Photos marked with sampling positions

Sample 1, Turbine 4W

Paint on tower, inside facing south

Sampling 2, turbine 4W

Paint on tower, outside facing north

Sampling 3. Turbine 5E

Paint on grout at flange facing north.

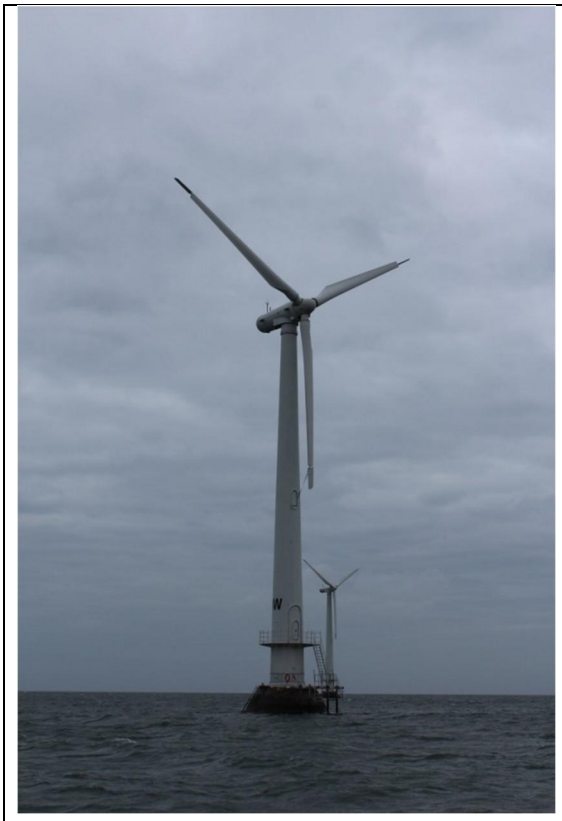
Sampling 4. Turbine 5E

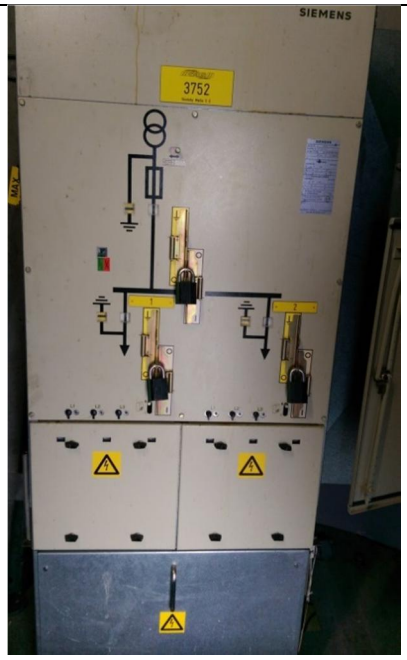
Concrete foundation. Sampled from drilling core for strength test.

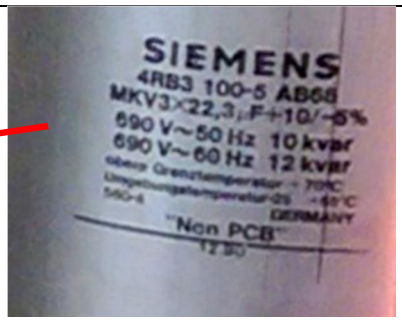
Appendix 3 Overview analysis results

					Heavy metals						
No.	Tower	Description	Dato	PCB	Cd	Cr	Cu	Ni	Pb	Zn	Hg
1	4W	Paint on tower, inside	18-Apr	I.D.	I.D.	84	30	37	19	256	I.D.
2	4W	Paint on tower, outside	18-Apr	I.D.	0.34	57	17	31	168	40800	I.D.
3	5E	Paint on grout at flange	18-Apr	I.D.	5.6	137	361	140	48	115000	I.D.
4	5E	Concrete foundation	18-Apr		0.06	11	15	9	9	54	I.D.
		Not contaminated		<0.1	<0.5	<20	<500	<30	<40	<500	<1
		Contaminated, not hazardous		0.1	0.5	500	500	30	40	500	1
		Hazardous		50	1000	1000	2500	1000	2500	2500	500

Appendix 4 Other photos






SIEMENS
4RB3 100-5 AB66
690 V~50 Hz 10 kvar
690 V~60 Hz 12 kvar
"Non PCB"

Appendix 5 Analysis report from Dansk Miljøanalyse, Journal no. 23252

dansk
MILJØANALYSE

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lab@dma.nu

ANALYSERAPPORT

Rekvirent	NIRAS A/S Sortemosevej 19 3450 Allerød Att.: Morten D. Ibsen			
Sagsnavn/ref.	Sag: 224148			
Vor Journal nr.	23252			
Antal prøver og typer	Type	Antal	Type	Antal
	PCB / 7 Metaller – fast stof (ikke jord) (DMA102/DMA101)	3 (Haste)	7 Metaller (6 met. + Hg) (DMA101)	1 (Haste)
Dato for modtagelse	2016-04-19			
Rapport version	Version 1.0			

Resultater – PCB i fast stof

Lab nr.	Prøve navn	PCB koncentration i mg/kg	Kommentar til prøvemateriale
1	1, 4 vest (4W), maling på tårn, udvendig	**I.D.**	
2	2, 4 vest (4W), maling på tørn, indvendig	**I.D.**	
3	3, 5 øst (5E), maling på understøbning	**I.D.**	
Metode	DMA102 (Udført akkrediteret, Akk. nr. 549)		

Bemærkning Normalt anvendes følgende grænseværdier:

- PCB indhold < 0,1 mg/kg betragtes som ikke PCB forurenet
- PCB indhold 0,1-50 mg/kg betragtes som forurenet, men ikke farligt affald
- PCB indhold > 50 mg/kg betragtes som farligt affald

I.D.: Ikke detekteret over detektionsgrænsen for den enkelte kongener

Detaljeret PCB resultatskema

	PCB Kongener (mg/kg)									
Lab nr.	28	52	101	118	138	153	180	∑7PCB	Faktor	Total PCB indhold
1	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	-	5,0	I.D.
2	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	-	5,0	I.D.
3	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	-	5,0	I.D.

Bemærkning
Der benyttes en omregningsfaktor på 5 ifølge MST-7543-00007, 5. juli 2011.
Detektionsgrænsen for den enkelte kongener: 0,01 mg/kg
Den ekspanderede usikkerhed på den enkelte kongener er 25 %.
Ved koncentrationer tæt på detektionsgrænsen kan den ekspanderede usikkerhed dog være op til 35 %
Den ekspanderede usikkerhed på den enkelte kongener er 35 % for beton
Ved koncentrationer tæt på detektionsgrænsen, kan den ekspanderede usikkerhed på den enkelte kongener være op til 55 % for beton

Resultater - 7 metaller (Cd, Cr, Cu, Ni, Pb, Zn, Hg) i fast stof									
Lab nr.	**Prøve navn**	**Koncentration mg/kg**							**Kommentar til prøvemateriale**
		Cd	**Cr**	**Cu**	**Ni**	**Pb**	**Zn**	**Hg**	
1	1, 4 vest (4W), maling på tårn, udvendig	**I.D.**	**84**	**30**	**37**	**19**	**256**	**I.D.**	
2	2, 4 vest (4W), maling på tørn, indvendig	**0,34**	**57**	**17**	**31**	**168**	**40800**	**I.D.**	
3	3, 5 øst (5E), maling på understøbning	**5,60**	**137**	**361**	**140**	**48**	**115000**	**I.D.**	
4	4, 5 øst (5E), beton på fundament	**0,06**	**11**	**15**	**9**	**9**	**54**	**I.D.**	
Metode	DMA101 (Udført akkrediteret, Akk. nr. 549)								

Bemærkning
Normalt anvendes følgende grænseværdier for deponi/forbrænding. Indhold over disse niveauer betragtes som farligt affald:
Cadmium (Cd): 0,5 - 1000 mg/kg, Krom (Cr): 500 - 1000 mg/kg, mg/kg, Kobber (Cu): 500 - 2500 mg/kg
Nikkel (Ni): 30 - 1000 mg/kg, Bly (Pb): 40 - 2500 mg/kg, Zink (Zn): 500 - 2500 mg/kg, Kviksølv (Hg): 1-500 mg/kg
Detektionsgrænsen for det enkelte metal:
Cadmium (Cd): 0,05 mg/kg, Krom (Cr): 5 mg/kg, Kobber (Cu): 5 mg/kg, Nikkel (Ni): 3 mg/kg, Bly (Pb): 4 mg/kg, Zink (Zn): 50 mg/kg, Kviksølv (Hg): 0,1 mg/kg
Den ekspanderede usikkerhed på analysen er 20 %. Ved koncentrationer tæt på detektionsgrænsen kan den ekspanderede usikkerhed dog være op til 50 %
I.D.: Ikke detekteret over detektionsgrænsen

Bemærkning til grænseværdier: Hvis ikke andet er nævnt er de oplyste grænseværdier de værdier der anvendes i Københavns kommune. Andre kommuner kan anvende andre grænseværdier.

2016-04-20
Venlig hilsen

Tobias Hansen

Ansvar: Ved indleverede prøver til analyse er DMA kun ansvarlig for selve laboratorieanalysen af den enkelte prøve. Således har DMA ikke ansvar for prøveudtagningen, dvs. om prøven er repræsentativ for det specifikke materiale den er udtaget af eller om prøveantallet er tilstrækkeligt til at kunne drage konklusioner om materialetyperne i det område hvor prøven/prøverne er udtaget. DMA er heller ikke ansvarlig for de praktiske handlinger på byggepladsen som modtageren af analyseresultatet udfører som konsekvens af resultatet.