Environmental Impact Assessment of the Use of Industrial Construction Materials in Hydro-engineering on German Federal Waterways

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2 Materials and methods

3 Emissions into the aquatic phase

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1.1 Use of construction materials in German Federal Waterways in 2006

- Copper slag: 600,000 t
- Linz-Donawitz slag: 400-500,000 t
- Natural armourstones: 2.7 Mill. t

1.2 Topics of this study

- Water quality;
- Predicted impacts on water quality;
- Predicted impacts on sediment quality;
- Target values;
- Protected areas;
- Exclusion criteria with regard to industrial armourstone materials;
- Water management.

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2.1 Investigated material

Material		Grain size mm		
Slags				
Copper slag	CUS	0 - 2;	8 - 11;	100
Steel slag	Linz-Donawitz (LDS)	0 - 2;	8 - 11;	100
	Electo furnace (EOS)	0 - 2;	8 - 11;	100
Natural stones				
	Basalt	0 - 2;	8 - 11;	100
	Graywacke	0 - 2;	8 - 11;	100

2.2 Applied methods

Standard	Title	Issue	W / s	Duration [h]	Grain size [mm]	Reference
DIN 38414-4	Determination of leachability by water	Oct. 84	10	24		BfG -1522
DIN 1744-3	Preparation of eluates by leaching of aggregates	Nov 02	10	24	< 32	BfG -1314
DIN EN 12457-1	One-stage batch test at a liquid to solid ratio of 2 l/kg	Jan 03	2	24	< 4	BfG -1522

2.3 Elution apparatus: Forgenta 1200

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3.1 Copper slag

Mobilisation of selected elements according to DIN 38414-4

Parameter	Ave.	Ave.	Ave.	± CB	Ave.	± CB	Ave.	± CB	Ave.	± CB	060222-01	060222-02
Grain size (mm)	0/2;8/11;100	mg/kg	0/2		0/2		8 / 11		8 / 11		100 *	100 *
Number of sampl.	22		5		5		5		5		27.04.06	29.05.06
pH	7.4		7.5	0.3	7.9	0.3	6.7	0.2	6.6	0.1	6.8	9.0
As [µg/l]	nd	nd	nd		nd		nd		nd		nd	nd
Cd [µg/L]	nd	nd	nd		nd		nd		nd		nd	nd
Cr [µg/L]	nr	nr	16	2.1	nd		nd		nd		nd	nd
Cu [µg/L]	31	0.31	16	5.3	13	3.8	39	7.0	54	10	nd	nd
Ni [µg/L]	nr	nr	23	6.5	22	6.2	nn		nn		nd	nd
Pb [µg/L]	nr	nr	nd		nd		nd		112	11	57	22
Zn [µg/L]	41	0.41	13	6.8	9.6	4.8	101	12	91	7,9	12	19
o-PO4-P [mg/L]	0.02	0.15	0.022	0.013	0.02	0.009	0.003	0.0005	nd		nd	nd
DOC [mg/L]	0.20	2.04	0.21	0.19	0.15	0.10	0.10	0.000	0.122	0.07	0.44	nd
TN [mg/L]	0.16	1.62	0.21	0.06	0.16	0.05	0.13	0.035	0.174	0.18	0.14	nd
SO4 [mg/L]	2.7	27	4.4	0.5	3.9	0.3	1.2	0.4	1.4	0.7	nd	nd

nd: < detection limit nr: > 50% of values nd CB: confidence band * approximated

3.2 Copper slag

Mobilisation with water from the Rhine River

Parameter	DL	Blanc	CUS	± CB	CUS	± CB	Basalt	± CB	Basalt	± CB
			ave.		ave.		ave.		ave.	
Grain size (mm)		Rhine	0 / 2		8 / 11		0 / 2		8 / 11	
Number of sampl.			3		3		3		3	
As [µg/l]	0.5	nd	8.6		8.5	1.7	0.22		0.16	0.006
Cd [µg/L]	0.05	nd	0.16		nd		nd		nd	
Cr [µg/L]	0.5	nd	nd		7.2		nd		nd	
Cu [µg/L]	0.5	nd	107	4.2	9.6	0.70	2.1	0.70	0.45	0.35
Ni [µg/L]	0.5	nd	5.2	0.25	3.2	1.2	nd		nd	
Pb [µg/L]	0.5	nd	4.3	0.70	nd		nd		nd	
Zn [µg/L]	5	43	nd		nd		nd		nd	

DL: detection limit nd: < DL nr: > 50% of values nd CB: confidence band

3.3 Steelwork slag LDS

Mobilisation of selected elements according to DIN 38414-4

Parameter	Ave.	Ave.	Ave.	± CB	Ave.	± CB	060220-01	060220-02
Grain size (mm)	0/2;8/11;100	mg/kg	0 / 2		8 / 11		100 *	100 *
Number of sampl.	12		5		5		24.04.06	22.05.06
pH	11.5		12.5	0.1	11.6	0.1	10.5	10.4
As [µg/l]	nd	nd	nd		nd		nd	nd
Ca [mg/L]	227	2.270	768	75	106	13	17	18
Cd [µg/L]	nd	nd	nd		nd		nd	nd
Cr [µg/L]	nd	nd	nd		nd		nd	nd
Cu [µg/L]	nd	nd	nd		nd		nd	nd
Ni [µg/L]	nd	nd	nd		nd		nd	nd
Pb [µg/L]	nd	nd	nd		nd		nd	nd
V [µg/L]	63	0.63	nd		49	19	78	62
Zn [µg/L]	7.1	0.07	5.5	1.5	nd		8.7	nd
o-PO4-P [mg/L]	nr	nr	nd		nd		0.039	-
TN [mg/L]	0.22	2.2	0.21	0.05	0.20	0.17	0.19	0.23

nd: < detection limit nr: > 50% of values nd CB: confidence band * approximated

3.4 Natural stones: Basalt

Mobilisation of elements according to DIN 38414-4

Parameter	Ave.	Ave.	Ave.	± CB	Ave.	± CB	060241-01	060241-02
Grain size (mm)	0/2;8/11;100	mg/kg	0 / 2		8 / 11		100*	100*
Number of samp	12		5		5		11.05.06	27.06.06
pH	7.9		8.6	0.2	7.8	0.1	8.2	7.1
As [µg/l]	nd	nd	nd		nd		nd	nd
Ca [mg/L]	3.1	31	8.1	0.8	-		0.52	0.63
Cd [µg/L]	nd	nd	nd		nd		nd	nd
Cr [µg/L]	nr	nr	nd		nd		nd	nd
Cu [µg/L]	nd	nd	nd		nd		nd	nd
Ni [µg/L]	nr	nr	nd		nd		30	-
Pb [µg/L]	nd	nd	nd		nd		nd	nd
Zn [µg/L]	nr	nr	nd		nd		17	nd
o-PO4-P [mg/L]	0.04	0.405	0.04	0.04	0.015	0,009	0.06	-
DOC [mg/L]	0.37	3.67	0.14	0.14	0.28	0.37	0.68	nd
TN [mg/L]	0.22	2.2	0.18	0.02	0.16	0.04	0.33	0.19

nd: < detection limit nr: > 50% of values nd CB: confidence band * approximated

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4.1 Construction materials
Solid-matter content of selected elements in copper slag (CUS), steel slags (LDS, EOS) and natural stones

Elements mg/kg	CUS NA	LDS	EOS	Basalt Westerwald	Diabas Harz	LAWA 2003
As	**300**	**0.8**	**0.6**	**0.5**	**0.6**	**40**
Cr	**500**	**954**	**228**	**107**	**18**	**640**
Cu	**10,000**	**6.4**	**8.5**	**33**	**73**	**160**
Zn	**50,000**	**14**	**7.4**	**70**	**77**	**800**
Reference	Merkel & Motz FG EHS Heft 6 Duisburg 2000	Bertsch 1997 FG EHS Heft 4 Duisburg 1997	Bertsch 1997	Bertsch 1997	Bertsch 1997	LAWA 2003 Append II, V of EU WFD 02.07.2003

4.2 Construction materials

Use of 2000 t CUS: Emissions of selected elements into the sediment – an example

Element	Emission of 0.5 wt. %	Initial sediment concentration	Enrichment
	mg/kg dry mat.	mg/kg dry mat.	wt.-%
Cd	0.02	0.3	6.9
Cu	14	19	72
Ni	1.4	8.2	17
Pb	6.9	39	18
Zn	69	150	46

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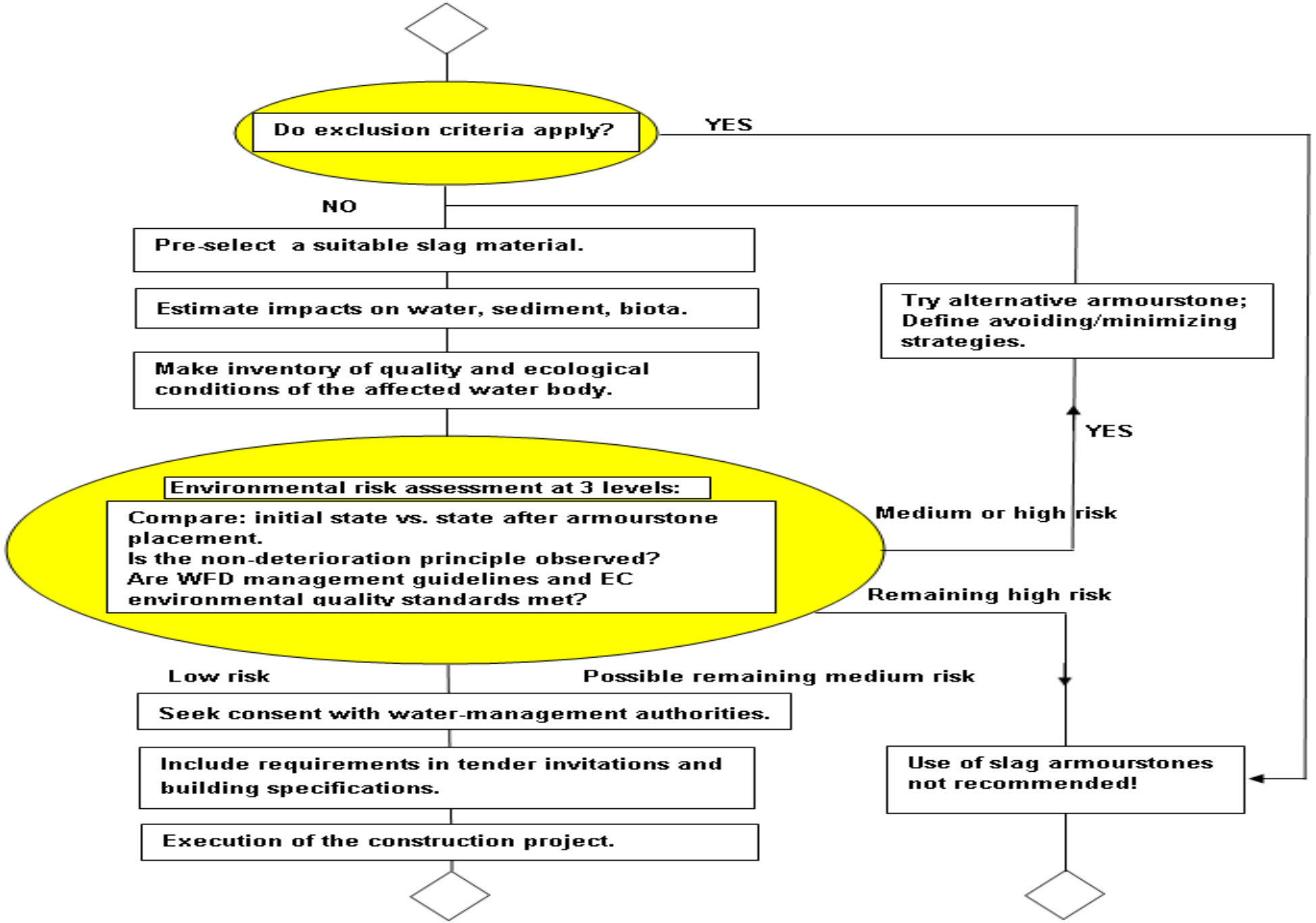
Do exclusion criteria apply?
YES
NO
Pre-select a suitable slag material.
Estimate impacts on water, sediment, biota.
Make inventory of quality and ecological conditions of the affected water body.
Try alternative armourstone; Define avoiding/minimizing strategies.
YES
Environmental risk assessment at 3 levels:
Compare: initial state vs. state after armourstone placement.
Is the non-deterioration principle observed?
Are WFD management guidelines and EC environmental quality standards met?
Medium or high risk
Remaining high risk
Low risk
Possible remaining medium risk
Seek consent with water-management authorities.
Include requirements in tender invitations and building specifications.
Execution of the construction project.
Use of slag armourstones not recommended!

5.2 Criteria for the exclusion of slag material in waterway engineering

- Application in protected areas (e.g. drinking water, FFH);

- Use of steel slags in stagnant waters with the water / solid relation < 20;

- Use of slag material as filter material and artificial bed load;

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6.1 Further necessary investigations

- Long-term stability of the construction material;
- Weathering of the armourstone materials;
- Abrasion due to transport processes;
- Identification of the abrasion material in existing embankments against waterborne suspended material;
- Bioaccumulation of selected elements in the food chain;
- Evaluation of the model for the calculation of the element-mobilisation.

Many thanks to my co-workers for their contributions

Mr Harald Schmid G2,
Mr Thomas Krämer G1,
Dr. Werner Manz G3 and
Dr. Jürgen Pelzer G2.

Many thanks for your kind attention!

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Surface of a 5 mm copper slag particle