

List of abbreviations

AbfklärV	Ordinance on Sewage Sludge (<i>Klärschlammverordnung</i>)
ABWAG	Waste Water Charges Act (<i>Abwasserabgabengesetz</i>)
AEs	Assimilation Efficiencies
AHP	Analytic Hierarchy Process
ALARA	As Far As Reasonably Achievable
α -HCH	α -Hexachlorocyclohexan
AMPS	Analysis and monitoring of priority substances
a.o.c.	Areas of concern (this report)
a.o.r.	Areas of risk (this report)
AQC	Analytical quality control
ARGE Elbe	Working Group of the Elbe (<i>Arbeitsgemeinschaft zur Reinhaltung der Elbe</i>)
ATV	German Association for Water Pollution Control (<i>Abwassertechnische Vereinigung</i> ; see ATV-DVWK)
AVS/ Σ SEM	Acid Volatile Sulfide/Sum Simultaneously Extractable Metals
BBodSchG	Federal Soil Protection and Contaminated Site Act
BBodSchV	Federal Soil Protection and Contaminated Site Ordinance
BimSchG	Federal Immission Control Act (<i>Bundesimmissionsschutzgesetz</i>)
BCR	Community Bureau of References (EC)
BEBA	Biological effects-based sediment quality assessments
BAT	Best Available Techniques
BfG	Federal Institute of Hydrology (<i>Bundesanstalt für Gewässerkunde</i> , Koblenz)
BLAK QZ	German federal working group on quality targets
BNatSchG	Federal Nature Conservation Act (<i>Bundesnaturschutzgesetz</i>)
BRCs	Background Reference Concentrations
CBM	Conceptual river basin model
CDFs	Confined disposal facilities
CDM	Contaminated Dredged Material
CEDA	Central Dredging Association
CIS	Common Implementation Strategy
COSMOS	Contaminant and Sediment Transport Modelling System
CSS	Combined sewer system
CSTEE	Scientific committee on toxicity, ecotoxicity and the environment
CTM-SUBIEFF	Contamination Transport Module (French Transport Model)
CTT	Chemistry-Toxicity Test (The Netherlands)
CUWVO	Commission for the implementation of the Act on Pollution of surface waters (The Netherlands)
DGE-1	Dutch-German Exchange on Dredged Material, Part 1
DM	Dredged materials
DMAF	Dredged Material Assessment Framework
DOC	Dissolved organic carbon
DVWK	jetzt ATV-DVWK: German Association for Water, Wastewater and Waste
EAF	Expert Advirsoy Forum
ECJ	European Court of Justice
EDA	Effect Directed Analysis
EDTA	Ethylenediaminetetracetic acid

EPS	Extracellular polymer substances
EQSs	Environmental Quality Standards
ERA	Ecological risk assessment
EROMOB	mobiles Erosionstestgerät
FCV	Final Chronic Value
FIAM	Free-ion activity model
γ -HCH	γ -Hexachlorocyclohexan
HABAB-WSV	Directive for the Handling of Dredged Material on Federal Waterways (Inland)
HABA <u>K</u> -WSV	Directive for the Handling of Dredged Material on Federal Waterways (Coast)
HCB	Hexachlorobenzene
HC _C	Hazard Class of Compounds (this report)
HC _S	Hazard Class of Sites (this report)
HELCON	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)
ICES	International Council for the Exploration of the Sea
ICPR	International Commission for the Protection of the Rhine
IKSR	Internationale Kommission zum Schutz des Rheins
IMO	International Maritime Organization
IRMM	Institute for Reference Material and Measurements (EC)
IPPC	Integrated Pollution Prevention Control
IUPAC	International Union of Applied Chemistry
JAMP	Joint Assessment and Monitoring Programme
K _{ow}	Partitioning between n-octanol and water
KrW-/AbfG	Closed Substance Cycle and Waste Management Act (<i>Kreislaufwirtschafts- und Abfallgesetz</i>)
K _{TW}	Partitioning between water and triglycerides in organisms
LAWA	Länder Expert Group on Water (Germany)
LC	London Convention
LCA	Life cycle analysis
LfU	Landesanstalt für Umweltschutz Baden-Württemberg
LOE	Line of evidence
LUA	Landesumweltamt Nordrhein-Westfalen
MCA	Multi criteria analysis
METHA	Mechanical separation of harbour sediments
Metropolis	Metrology in Support of Precautionary Sciences and Sustainable Development Policies
NGO	Non Governmental Organisation
NOEC	No Observable Effect Concentration
NTA	Nitrolotriactic acid
NW4	Vierde Nota Waterhuishouding; Forth Policy Document on Water Management
OCP1s	Organo Chloro PesticidesDDT, Deldrins, HCB, lindane
OSPARCON	Convention for the Protection of the Marine Environment of the North-East Atlantic (Oslo and Paris Convention)
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PIANC	Permanent International Navigation Association
POSW	Dutch Development Program for Treatment Processes for Contaminated Sediments

QSAR	Quantitative structure-activity relationships
QsS	Quality Standards
RIKZ	Rijksinstituut voor Kust en Zee; National Institute for Coastal and Marine Management
RIZA	Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling; Institute for Inland Water Management and Waste Water Treatment
RM	Reference Material
RWS	Rijkswaterstaat; Directorate General for Public Works and Water
SAR	Structure-activity relationships
SEDCIA	Sediment Erosion Detection by Computer aided Image Analysis
SEDYMO	BMBF-Verbundprogramm: Feinsedimentdynamik und Schadstoffmobilität in Fließgewässern
SETEG	Pressure duct for the study of depth dependant erosion stability of aquatic sediments (<i>Strömungskanal zur Ermittlung der tiefenabhängigen Erosionsstabilität von Gewässersedimenten</i>)
s.o.c.	Substances of concern (this report)
SQGs	Sediment quality guidelines
SPM	Suspended particulate matter
SQC	Sediment quality criteria
ΣHC	Sum hydrocarbons
TA-Abfall	Technical Directive on Waste Disposal
TBT	Tributyltin
TIE	Toxicity Identity Evaluation
TRIAD	Combined Sediment analysis (Sediment chemistry, sediment toxicity, resident community alterations)
TU	Toxic units
UCT	Uniform content test
UBA	Umweltbundesamt; Federal Environmental Agency
UNEP	United Nations Environmental Programme
UNESCO	United Nations
UQC	Uniform Quality Criteria; Uniforme Gehalte Toets (UGT)
US-EPA	Environmental Protection Agency of the United States
VROM	Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer; Ministry of Housing, Spatial Planning and the Environment
WaStrG	Federal Waterway Act (<i>Bundeswasserstraßengesetz</i>)
WBB	Soil Protection Act
WFD	Water Framework Directive
WHG	Water Management Act (<i>Wasserhaushaltsgesetz</i>)
WHO	World Health Organization
WM	Environmental Management Act (NL)
WOE	Weight of evidence
WVO	Pollution of Surface Waters Act Freshwater (NL)
WVZ	Pollution of Surface Waters Act Seawater (NL)
WWTP	Wastewater treatment plant

List of boxes

Bioavailability – Limitations and Empirical Relationships (Dickson et al., 1994).....	14
Processes Controlling the Pollutants Mobility in Sub-Aquatic Depots of Dredged Material.....	23
Water Framework Directive (WFD) and Priority [Hazardous] Substances (PS/PHS).....	33
Analysis and Monitoring of Solid Matrices under the Water Framework Directive (Report of the Expert Group on Analysis and Monitoring of Priority Substances).....	36
Recommendations of the AMPS Drafting Group on Sediment Monitoring (06/2004).....	38
Opinion of the scientific committee on toxicity, ecotoxicity and the environment (CSTEE) on „The Setting of Environmental Quality Standards for the Priority Substances included in Annex X of Directive 2000/60/EC in Accordance with Article 16 thereof“, 28 May 2004.....	45
Differences between Dutch and German Regulations Concerning Sediment Quality.....	62
ICPR - Recommendation to the Criteria for the Relocation of Dredged Material into the Rhine and its Tributaries (Document Ssed 06-04=No. 89=PLEN 40/97).....	65
Priority Substances in Historical Contaminated Sediments as Possible Secondary Sources for Releases to the Aquatic Environment – WFD Article 16 “Measures”.....	87
Recommendations of SedNet WG 5 “Risk Management and Communication”.....	81
Die subaquatische Unterbringung von Baggergut in den Niederlanden (DEPOTEC 2002)	93

List of tables

ES1	Substances of concern and their ranking	II
1.1	Processes Affecting the Cycling of Pollutants in Aquatic Systems.....	5
1.2	Examples for Empirical Relationships in Bioavailability (Dickson et al., 1994).....	14
1.3	Demobilization of Pollutants in Solid Matrices by Natural Factors (Förstner 2003).....	17
1.4	Selected options for in-situ sediment remediation (after Joziasse and Van der Gun 2000; the original version comprises more than 20 technological concepts).....	19
1.5	Technology types for sediment remediation (Anonymous 1994).....	20
2.1	Objectives and aims of water quality assessment operations (Meybeck et al. 1992)....	28
2.2	increasing levels of monitoring sophistication (after Thomas and Meybeck, 1992).....	29
2.3	Some possible sources of errors in the water quality assessment process with special reference to chemical methods (Meybeck et al. 1992).....	32
2.4	for trend monitoring in sediment and or biota. P = preferred matrix over water phase, O= optional matrix).....	38
2.5	Overview on traceability aspects of chemical sediment analysis (Förstner 2004)	39
3.1	Criteria for the decision of relocation according to HABAB-WSV.....	71
3.2	NL-classification of effects in bioassays in the Triad approach 1).....	80
3.3	Ecotoxicological criteria for the CTT test for evaluation of dredged marine sediment....	82
3.4	Examples of Substances for further Assessment on Historically Contaminated Sediments.....	87
4.1	« substances of concern » with limit values according to CTT, and target values according to ICPR.....	109
4.2	Persistent organic pollutants (POPs), priority hazardous substances (WFD), priority substances (OSPAR) are depicted by grey cells. Substances of concern in this report are shown, assigned to different risk classes.	105
4.3	Organic substances of concern with the assigned hazard classes (Hazard Class Compound HC _c) due to their chemical properties.....	110
4.4	Potential industrial sources of heavy metals of concern in the Rhine area from 1985 to 1996.....	118
4.5	Potential industrial sources of organic substances of concern in the Rhine area.....	119
4.6	Estimations of likelihood of dioxin and furan releases to water from certain sources (Quass et al., 2000).....	133
4.7	Toxicity classes at different sampling locations in the Middle and Lower Rhine in 1996	148
4.8	Areas of concern and their main contaminating compounds in sediments	151
5.1	Hydrological data of gauging stations along the Rhine River and selected tributaries ...	162
5.2	Sediment stability in the headwaters of the Upper Rhine and major tributaries.....	168
5.3	Erosion risk in reservoirs along the Rhine.....	169
5.4	Flow rates of the Rhine and its tributaries at three different flood scenarios. Assigned are theoretical SPM concentrations in order to calculate the suspended matter load in the Rhine basin.....	173
5.5	Target concentrations above which a potential increase in the sediment concentration in PoR occurs under conditions of MQ.....	174
5.6	Target concentrations above which a potential increase in the sediment concentration in PoR occurs under conditions of MHQ.....	175
5.7	Target concentrations above which a potential increase in the sediment concentration in PoR occurs under conditions of HHQ.....	176

5.8	Comparison of the calculated concentration thresholds for exceedance of the CTT at the PoR at two high water scenarios A and B with the sediment surface concentrations that were measured at the Lippe.....	180
5.9	Estimations of concentration and load for the different flood return periods at the monitoring stations of the river Rhine and its tributaries.....	191
5.10	Areas of risk in the Rhine basin and its tributaries, concluded from evidence of hazard classes of areas of concern, theoretical possibility to exceed the CTT level, and indication of resuspension.	197
6.1	Substances of concern in this report.....	207
6.2	Areas of concern and their main contaminating compounds	209
6.3	Areas of risk in the Rhine basin and its tributaries.....	211

List of figures

ES.1	Pathways and processes for the transport of historic contamination downstream.	I
1.1	Scientific Disciplines and Study Objects in a Coordinated Research Programme of the German Federal Ministry of Education and Research, 2002-2006, on Fine Sediment Dynamics and Pollutant Mobility in Rivers (SEDYMO; Förstner 2001)	6
1.2	Implication of irreversible adsorption on sediment quality criteria (after Chen et al. 2000)	18
2.1	Sources of pollutants to sediments and the associated appropriate sampling operations for surveys of particulate pollutants (Thomas and Meybeck, 1992)	30
2.2	Sediment „Triad“ approach	46
2.3	Origin and transmission of uncertainties	50
2.4	Coping with uncertainties	51
2.5	Sampling site at the River Neckar	52
2.6	Sensitivity analysis	53
2.7	Calculated sediment mass eroded by historical flood events with variation of critical erosion shear stress from 2 to 10 N/m ²	54
2.8	Hydrograph of two selected historical flood events with different flood volume	55
2.9	Quantile of calculated sediment mass eroded during flood event 1998 with a peak flow rate of 1055 m ³ /s: (a) $\tau_{c,E}$ spatially constant and (b) $\tau_{c,E}$ spatially varied	55
2.10	HCB content of sediment from different sampling sites in the upper river Rhine reservoir Iffezheim (Witt 2004)	57
3.1	Overview over the interactions of national and international regulations (PORII, 2001)	62
3.2	Sources and Pathways of Contaminants in River Basins	95
3.3	Percentage of suspended solids flux discharged in 2% of time (Ms ²) vs log of basin area (km ²). (Meybeck et al. 2004b)	96
4.1	Schematic illustration of redistribution of certain organochlorine compounds based on their partitioning coefficients among air, water, and solids and the influence of temperature (Iwata, 1994)	109
4.2	Hazard classes for the areas of concern along the River Rhine	116
4.3	Cd in the clay fraction of sediments in the Rhine and its main tributaries in Germany (from Förstner & Müller, 1974)	120
4.4	Cadmium concentrations along the right Rhine side in the years 1980, 1985, 1988, and 1994 (LUA, 1997)	122
4.5	Cr in the clay fraction of sediments in the Rhine and its main tributaries in Germany (from Förstner & Müller, 1974)	123
4.6	Cu in the clay fraction of sediments in the Rhine and its main tributaries in Germany (from Förstner & Müller, 1974)	124
4.7	Hg in the clay fraction of sediments in the Rhine and its main tributaries in Germany (from Förstner & Müller, 1974)	125
4.8	Pb and Zn in the clay fraction of sediments in the Rhine and its main tributaries in Germany (from Förstner & Müller, 1974)	126
4.9	Ni in the clay fraction of sediments in the Rhine and its main tributaries in Germany (from Förstner & Müller, 1974)	127
4.10	Average PCB concentration in suspended matter (Busch & Büther, 2000)	129
4.11	Sum PCB (PCB 28, PCB 52, PCB 101, PCB 118, PCB 138, PCB 153) in the rhine	130

	between Königswinter and Rotterdam in 1995. (modified from ICPR, 1995)	
4.12	TBT concentrations in Lippe sediments between 1994 and 2003 in µg/kg (Data: LUA)	131
4.13	Balance of heavy metal load in the Ruhr River catchment area in 1980 (Imhoff et al. 1980) and in 1996 (Imhoff et al. 1996)	134
4.14	Ruhr catchment area	135
4.15	Heavy metal concentrations in sediments of the Harkortsee. Sediment depth is dated from 1945 to 1998 (Rosenbaum-Mertens, 2003)	136
4.16	Zn input/output balance of the Harkotsee 1965 and 1980	137
4.17	Progress lines and frequency distribution of discharges, Cd, and Pb concentrations for 2001	138
4.18	Upper Part of the River Rhine, beginning at Lake Constance	139
4.19	HCB in filtrated Rhne water taken at Rhine-km 163,9 which is very close to Basel	140
4.20	Contamination of eels in River rhine caught between Rhine-km 53 and 307 in the years 1979-2000	141
4.21	Flow chart for the production of chlorosilanes; the mass streams containing HCB are indicated	142
4.22	Treatment of the residue from the synthesis of chlorosilanes	142
4.23	Discharged HCB loads to River Rhine by a company in D-Rheinfelden from 1982 – 1993; from discharged water a flow proportional taken 24h-composite sample has been daily analysed for HCB	143
4.24	Frequency distribution of discharged HCB-loads from daily 24 h-composite samples which have been taken and analysed by a company in D-Rheinfelden	144
4.25	Results of sediment samples in River Rhine taken between Rhein-km 3 and 359 in the period 1982 - 1998	145
4.26	Sampling stations of the BfG survey along the High and Upper Rhine river in 2001	146
4.27	Toxicity in bacterial contact assay with Bacillus cereus measured in surface and core sediments along the High and Upper Rhine in 2001	147
4.28	Toxicity classes for sediments of the Middle and Lower Rhine, sampled in 1996, based on 5 bioassays and an integrated assessment of the response pattern	148
5.1	HCB concentrations of suspended matter at Koblenz / Rhine between 1991 and 1997 (BfG, 1997)	157
5.2	PCB concentrations of suspended matter at Koblenz / Rhine between 1991 and 1997 (BfG, 1997)	157
5.3	Suspended solids and copper concentrations on SPM at monitoring station Koblenz/Rhine in 1995, compared to the discharge at the time of sampling.	158
5.4	River Rhine discharges	159
5.5	Flood wave along the Rhine during the high water event in spring 1995 (BfG 1996)	160
5.6	change of discharge with time at the Lower Rhine in 1999 (gauging station Köln/Rhine), based on daily discharge measurements of the BfG	161
5.7	Hydrographs from the Rhine monitoring stations during the February flood in 1999	161
5.8	Flood event in May 1999: Discharges at different monitoring stations.	163
5.9	Suspended matter concentration 1994 to 2001 at the monitoring station Koblenz at the Rhine (right) and the Mosel (left) (Data: LUA)	164
5.10	Suspended matter concentration in mg/L in the Rhine and its lowland tributaries (Data: LUA)	165
5.11	Loads of suspended matter in rhine, Neckar, Main, Lahn and Mosel during high water between January 22 nd and February 12 th 1995 (BfG, 1996)	166

5.12	Suspended matter load along the Rhine during High Water in February 1999	166
5.13	Assumptions of the case study to assess the risk for the port that is represented by substances of concern.	171
5.14	Average annual concentration in mg/kg suspended matter at different monitoring stations and ICPR target value (1 mg/kg)	182
5.15	Cd load at monitoring stations along the river Rhine	182
5.16	Discharge and Cd concentration for the hydrological year 1999 (Ruhrverband 2000)	183
5.17	Cd concentrations and loads at the routine measuring stations Hattingen and Rees, depicted depending on the discharge. Vertically, the different flood return periods are indicated.	184
5.18	HCB concentrations in suspended matter of the Rhine near Iffezheim (90 percentile) (source: LUA 2003)	185
5.19	HCB Load at monitoring stations along the river Rhine during the spring flood event in 1999	186
5.20	HCB concentrations and loads at the routine measuring station Maxau depicted depending on the discharge. Vertically, the different flood return periods are indicated.	187
5.21	HCB concentrations at monitoring stations Lobith and Iffezheim after the flood event in May 1999.	188
5.22	HCB concentrations and loads in Koblenz (upper graph 1990-2001) and Kleve Bimmen (lower graph, 1990-1999) in relation to discharges measured at the nearest gauging stations	189
5.23	Map of Duisburg area with "Hafen Diergardt", "Parallelhafen" and "Aussenhafen" (bottom figure) and the borders of the flooded area during an HQ ₁₀₀ , purple lines, and an HQ ₁₀ , green lines (ICPR, 2001).	194
5.24	Map of Hitdorf harbour (right) and the borders of the flooded area during an HQ ₁₀₀ , purple lines, and an HQ ₁₀ , green lines (ICPR, 2001).	195
5.25	Waterways and Shipping Directions and Offices along the German Federal waterways	201
5.26	Functions and distributions of responsibilities between German institutions involved in sediment management	202

Acknowledgement:

We would like to thank the following people for discussions and the provision of data

Landesumweltamt Nordrhein-Westfalen, Dr. Vogt, Dr. Lowis, Frau Gabriel

Landesanstalt für Umweltschutz Baden-Württemberg, Dr. Lehmann, Dr. Zipperle

Staatliches Umweltamt Herten, Dr. Piegsa

Staatliches Umweltamt Düsseldorf, Dr. Lacombe

Staatliches Umweltamt Lippstadt, Dr. Buitkamp

Bundesanstalt für Gewässerkunde Koblenz, Dr. Martin Keller, Dr. Vera Breitung, Dr. Gölz

RIZA, The Netherlands, Dr. Dorien Ten Hulscher

Dr. Marc Braun, ICPR

