Revising Sediment Quality Guidelines to Reflect Current Scientific Understanding of Chemical Interactions in Sediment with Ecosystems

Sediment Assessment for the 21st Century – Sediment Quality Goals (SQGs) and other mythical creatures

13th International SedNet Conference
Faculty of Sciences of the University of Lisbon, Lisbon, Portugal

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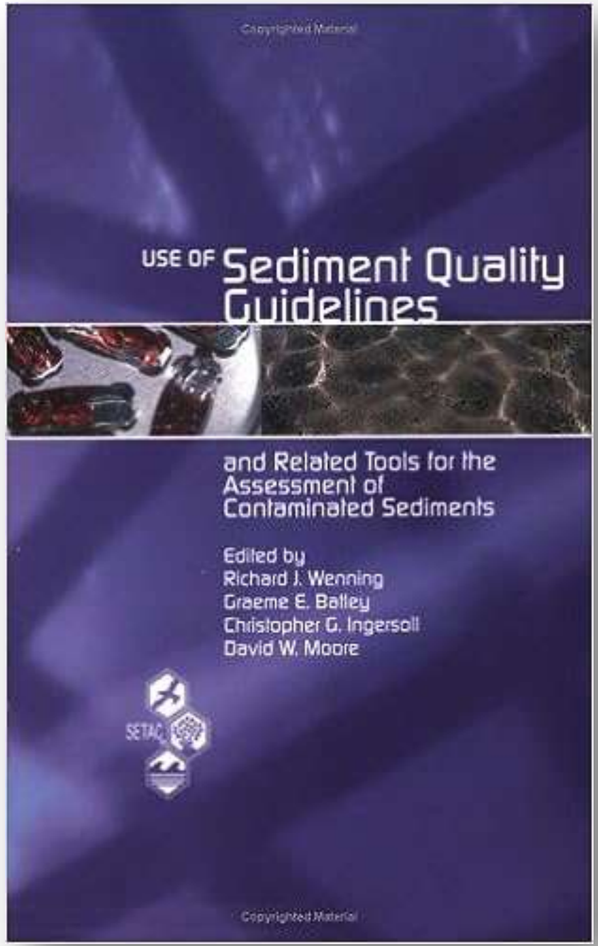
Talking Points

- SQGs for most substances rest on 40^{+}-year-old science and reflect conditions that may no longer be environmentally relevant.
- And yet, there is a strong preference to use "SQG look-up tables" (*particularly in the U.S.*) for monitoring, management, and regulatory purposes.
- New assessment tools and a reframing "sediment quality" are needed to support a future focused on sustainable sediment management.

What do we need to manage sediments in the 21st Century?

That is to say….we're overdue for an update

2001 - 2005



Assessing and Managing Sediment Quality in the 21st Century

Edited by
Richard J. Wenning
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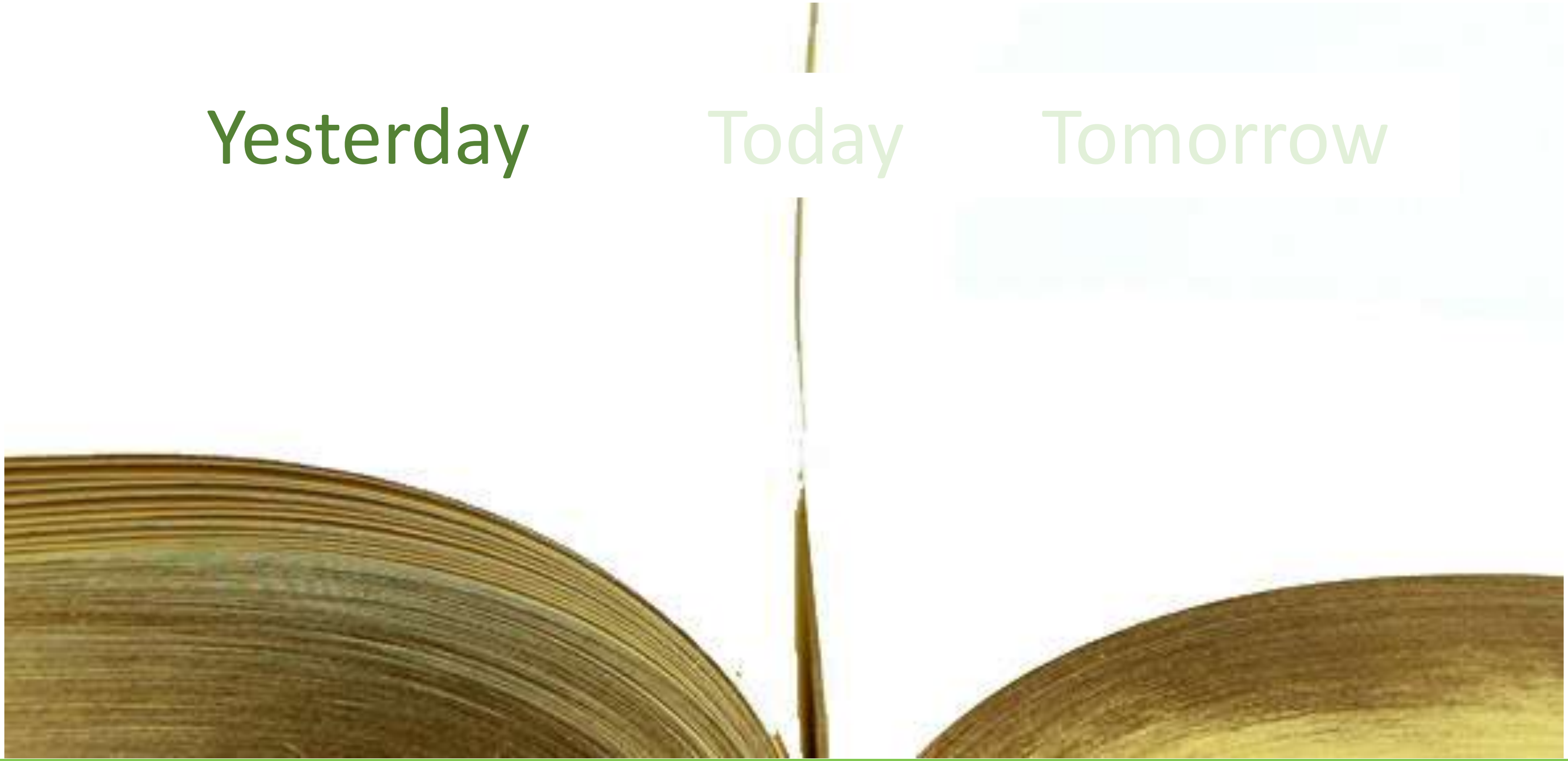
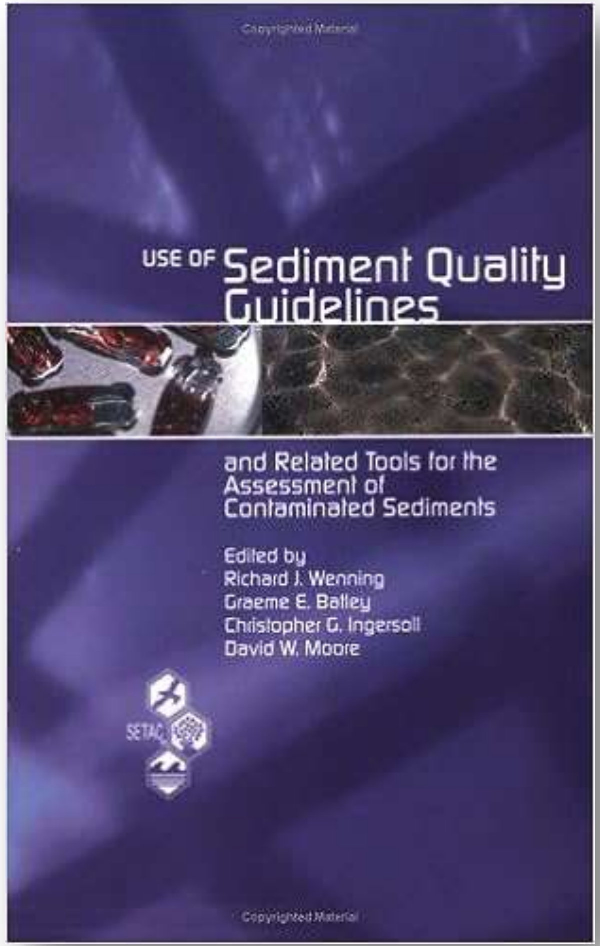
SETAC

Yesterday Today Tomorrow



Where were we in 2005?

2005 SQG Book – Assessing the science behind the tools



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SQG Look-up Tables

SQG	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	Reference
PEL[1]	17	3.53	90	197	91.3	0.486	36	315	a
ERM	85	9	145	390	110	1.3	50	270	a
EC-PEL[2]	41.6	4.21	160	108	112	0.7	42.8	271	b
NOAA ERM[3]	70	9.6	370	270	218	0.71	51.6	410	c
SQAV PEL-HA28[4]	48	3.2	120	100	82	–	33	540	d
SQO Netherlands Limit	55	2	–	36	530	0.5	–	480	e
Hong Kong ISQV-high[5]	70	9.6	370	270	218	1	–	410	f
Norwegian Moderate	80	1	300	150	120	0.6	130	700	g
Flanders RV Y[6]	69	2	107	50	0.3	88	69	422	h
Elevated Stream Sediments[7]	11	1	23	60	38	0.1	–	100	i
Highly Elevated Stream sediments[7]	17	2	38	100	60	0.17	–	170	i

SQG, Sediment quality guideline; PEL, probable effects level; ERM, effect range median; EC, Environment Canada; NOAA, National Oceanic and Atmospheric Administration; SQAV, Sediment Quality Advisory Value; SQO, Sediment Quality Objective; ISQV, Interim Sediment Quality Value; RV, Reference Value; FDEP, Florida Department of Environmental Protection; ANZECC, Australian and New Zealand Environment and Conservation Council; ISQG, Interim Sediment Quality Guidelines

[1] Same as Canadian Freshwater Sediment Quality Guidelines[e]
[2] Same as FDEP Guidelines[e] and Canadian Marine Sediment Quality Guidelines[e]
[3] Same as ANZECC ERM[e], ANZECC ISQG-high[e], ERM[j], and ERM/PEL[j]
[4] All other SQAVs are the same as SQGs[a]
[5] Same as Hong Kong ISQG-high values[e]
[6] Reference values and class limits for rivers in Flanders; <X class 1, <Y class 2, <Z class 4, >Z class 5
[7] Classification of Illinois Stream Sediments
[a] MacDonald et al. 2000b
[b] Smith et al. 1996
[c] NOAA 1999
[d] Swartz 1999
[e] ANZECC 1997
[f] Chapman et al. 1999
[g] Helland et al. 1996
[h] De Cooman et al. 1999
[i] Classification of Illinois Stream Sediments
[j] Hyland et al. 1999

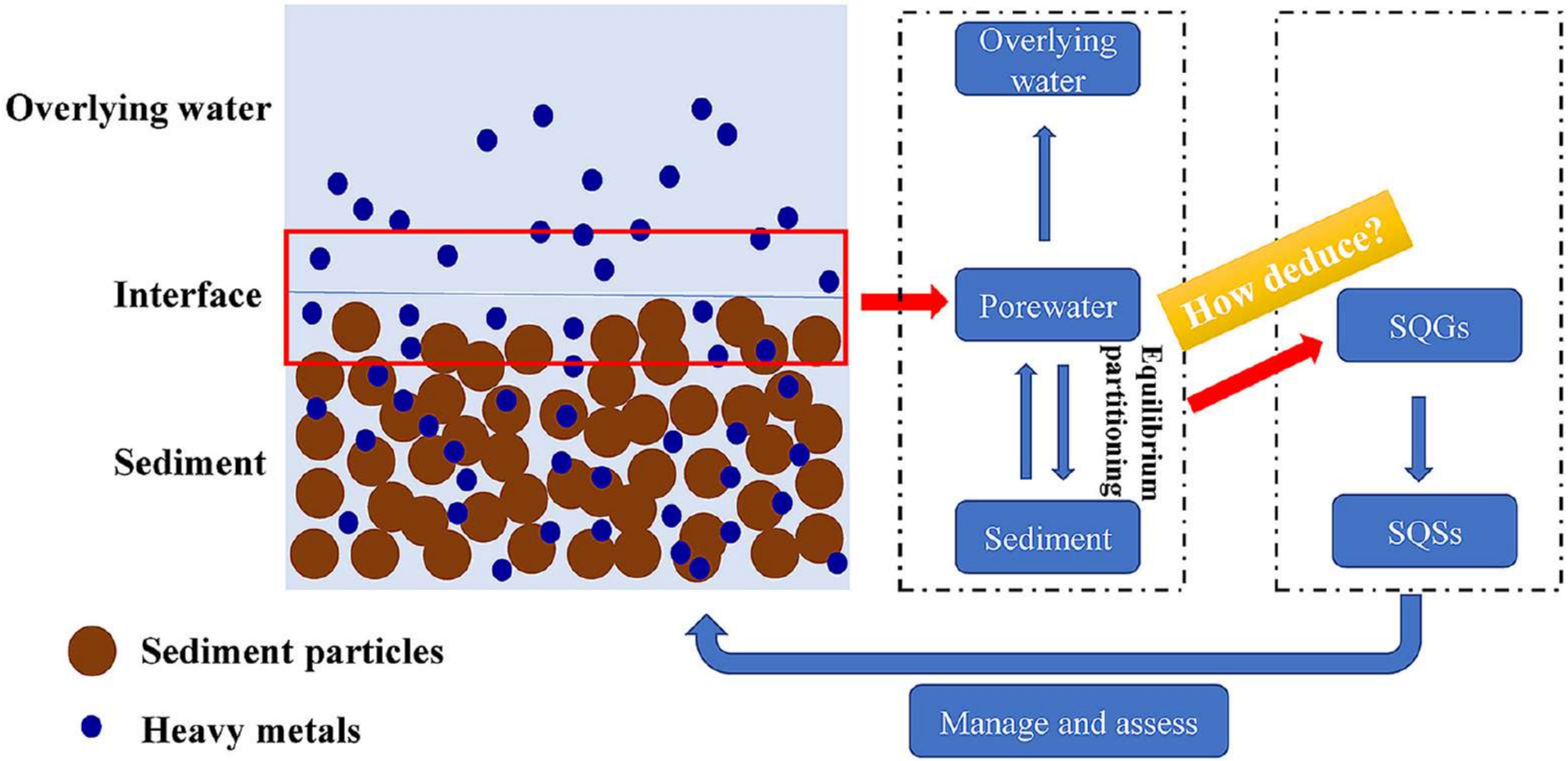
Substance	SLC	TEL[1]	ERL	LEL	MET	CB TEC 95% CI	Ontario Minimum Environmental Screening Level-low	NOAA freshwater TEL[3]	NOAA TEL marine[2]	NOAA ERL[1]
Acenaphthene	60	10	20						6.71	16
Acenaphthylene	50	10	40						5.87	44
Anthracene	160	50	90						46.85	85.3
Fluorene	100	20	20						21.17	19
Naphthalene	410	30	160						34.57	160
Phenanthrene	270	90	240					41.9	86.68	240
LMW PAHs									311.7	552
B(a)Anthracene	260	70	260					31.7	74.83	261
Benzo(b)fluor	320	70	320							
Benzo(k)fluor	280	60	280							
Benzo(a)pyrene	400	90	430					31.9	88.81	430
Dibenzo(a,h)anthracene									6.22	63.4
Chrysene	380	110	380					57.1	107.77	384
Fluoanthene	640	110	600					111	112.82	600
Pyrene	660	150	660					53	152.66	665
HMW PAHs									655.34	1700
Total PAHs	4090	870	3500			2900 1190–4610	2000		1684.06	4022
p,p'-DDD		3.54	2	8	10	4.88		3.54	1.22	2
p,p'-DDE		1.42	2	5	7	3.16		1.42	2.07	2.2
p,p'-DDT			1	8	9	4.16			1.19	1
Total DDT		7	3	7	9	5.28	7	6.98	3.89	1.58
Chlordane		4.5	0.5	7	7	3.24	7	4.5	2.26	0.5
Dieldrin		2.85	0.02	2	2	1.9	2	2.85	0.715	0.02
Endrin		2.67	0.02	3	8	2.22	3	2.67		0.02
Heptachlor epoxide		0.06		5	5	2.47	5	0.6		
Lindane		0.09		3	3	2.37	3	0.94	0.32	0.32
Total PCBs	3	34	50	70	200	35	70	34.1	21.55	22.7
Reference	a	a	a	a	a	a	b	c	c	b,c

SLC, screening level contamination; TEL, threshold effect level; ERL, effects range low; LEL, lowest effect level; MET, minimal effect threshold; CB, Consensus Based; TEC, threshold effect concentration; CI, confidence interval; NOAA, National Oceanic and Atmospheric Administration; LMW, low-molecular-weight; PAHs, polycyclic aromatic hydrocarbons; HMW, high-molecular-weight; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCBs, polychlorinated biphenyls; ISQG, Interim Sediment Quality Guidelines; ISQV, Interim Sediment Quality Value; ANZECC, Australian and New Zealand Environment and Conservation Council; FDEP, Florida Department of Environmental Protection

[1] Same as Hong Kong ISQG-low[b], does not include DDT, DDE, DDT, chlordane, dieldrin, endrin, heptachlor epoxide, and lindane
Same as Hong Kong ISQV-low[d], does not include DDT, DDE, DDT, chlordane, dieldrin, endrin, heptachlor epoxide, and lindane
Same as ANZECC ISQG-low[b], does not include heptachlor epoxide
Same as ANZECC guidelines for sediments sea disposal[b], screening level effects range low, except Chlordane and Dieldrin
[2] Same as Canadian sediment quality criteria[e]
Same as FDEP Guidelines[b]
Same as Canadian Marine Sediment Quality Guidelines[b]
[3] Same as Canadian Freshwater Sediment Quality Guidelines[b]
[a] Swartz 1999
[b] ANZECC 1997
[c] NOAA 1999
[d] Chapman et al. 1999a
[e] Smith et al. 1996

https://link.springer.com/article/10.1007/s102010200008

Using Porewater to Set Sediment Quality Standards for Metals



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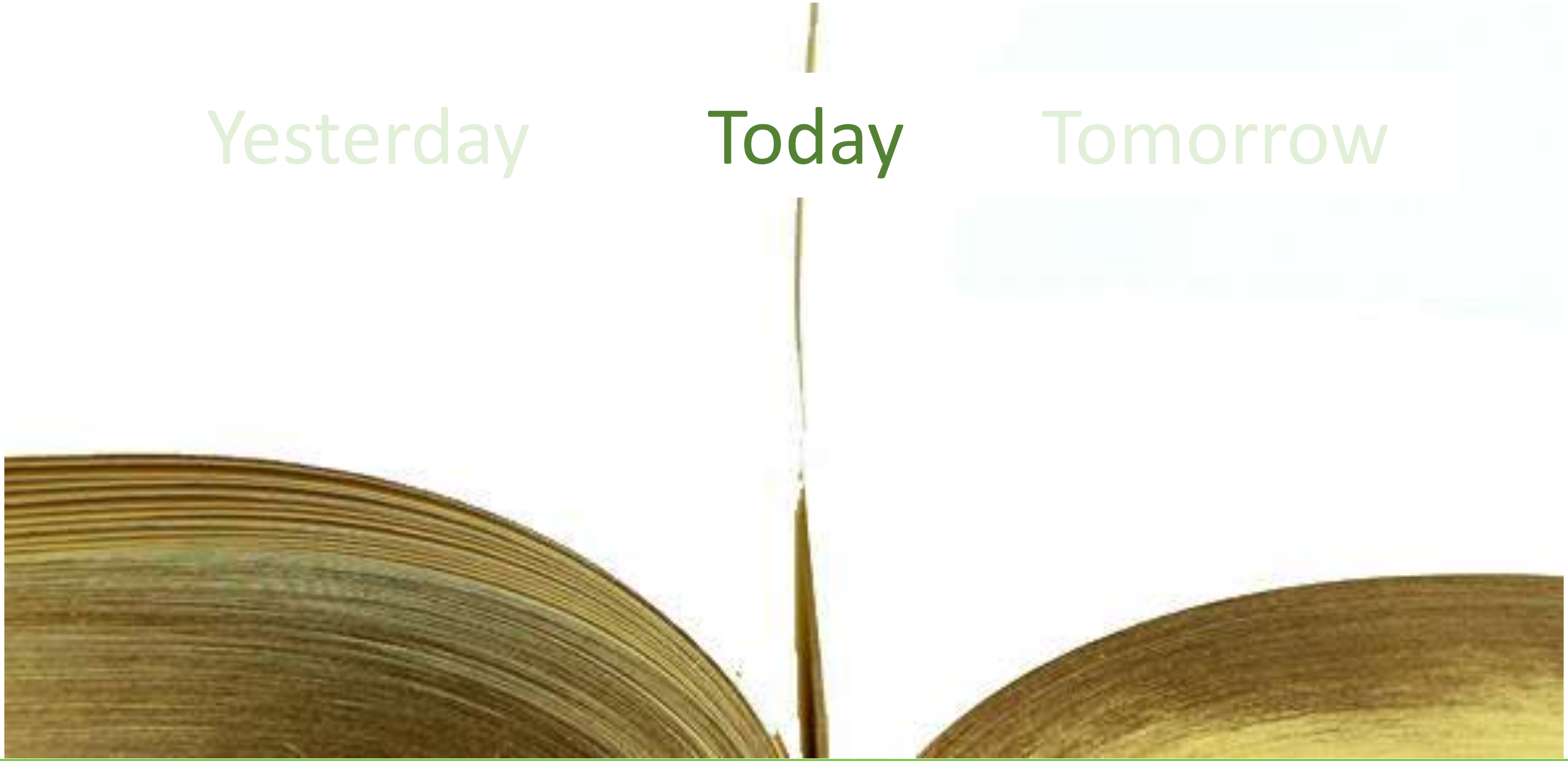


Where are we now?

SQGs in Use Today – not a lot of change

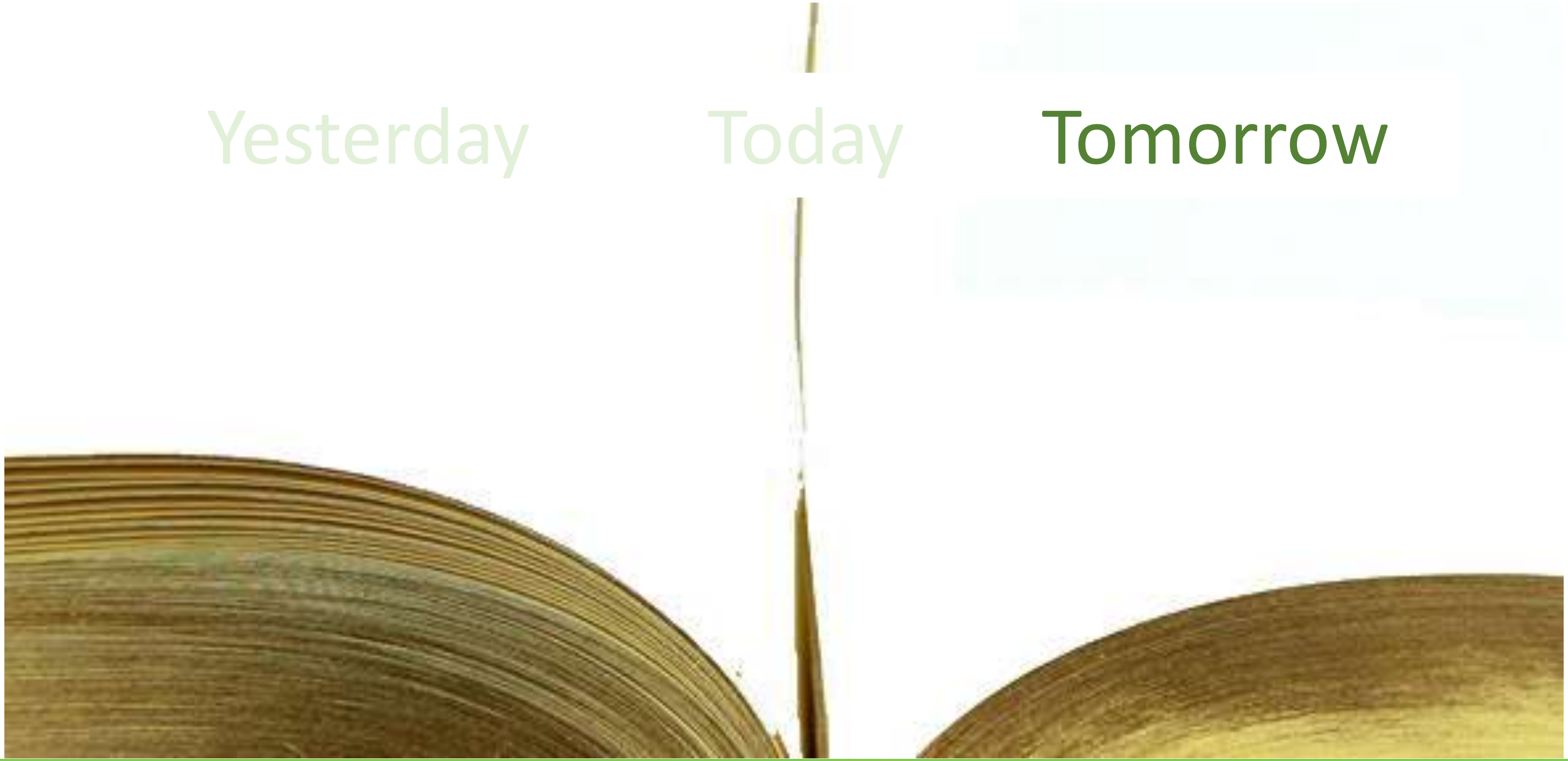
SQG Category	Approach	Developers
Theoretical	Equilibrium Partitioning	Di Toro, Mahony et al. (1991) Di Toro, Zarba et al. (1991) Ankley et al. (1996) NYSDEC (1998) Di Toro and McGrath (2000)
Empirical	Screening-Level Concentration	Persaud et al. (1993) Von Stackelberg and Menzie (2002)
Empirical	Effects Range-Low (ERL) and Effects Range-Median (ERM)	Long et al. (1995) USEPA (1996)
Empirical	Threshold-Effects Level (TEL) and Probable-Effects Level (PEL)	MacDonald et al. (1996) Smith et al. (1996) USEPA (1996)
Empirical	Apparent-Effects Threshold (AET)	Barrick et al. (1988) Ginn and Pastorok (1992) Cubbage et al. (1997)
Empirical	Consensus-Based Evaluation	Swartz (1999) MacDonald, DiPinto et al. (2000) MacDonald, Ingersoll et al. (2000)
Empirical	Logistic Regression Modeling (LRM)	Field et al. (1999, 2002)

Role of SQGs in Sediment Management

Reason for Sediment Assessment	Role for SQGs	Specific Role
Mapping spatial patterns	Primary	Relative patterns of contamination
Measuring temporal trends	Primary	Relative patterns of contamination
Remediation / restoration objectives	Primary	In cases of simple contamination… where the costs of investigation outweigh the costs of remediation
Remediation / restoration objectives	Secondary	As part of an ecorisk assessment and/or tiered assessment scheme involving other tools
Determining condition of populations and communities	Secondary	As part of an ecorisk assessment and/or tiered assessment scheme involving other tools
Estimating ecological risks, including bioaccumulation	Secondary	As part of an ecorisk assessment and/or tiered assessment scheme involving other tools
Screening suitability of proposed use or development	Secondary	As part of an ecorisk assessment and/or tiered assessment scheme involving other tools
Assessing impacts of sediment dredging and / or management	Secondary	As part of an ecorisk assessment and/or tiered assessment scheme involving other tools
Long-term monitoring of system status post-remediation	Secondary	As part of an ecorisk assessment and/or tiered assessment scheme involving other tools
Estimating human health risks / evaluation of biomagnification	None	Not designed for this purpose
Determining sediment stability / transport	None	Not relevant

Source: Wenning and Ingersoll (2002)
* "Primary" = can be used alone for management purposes; "Secondary" = should be used with other assessment tools.

Yesterday Today **Tomorrow**

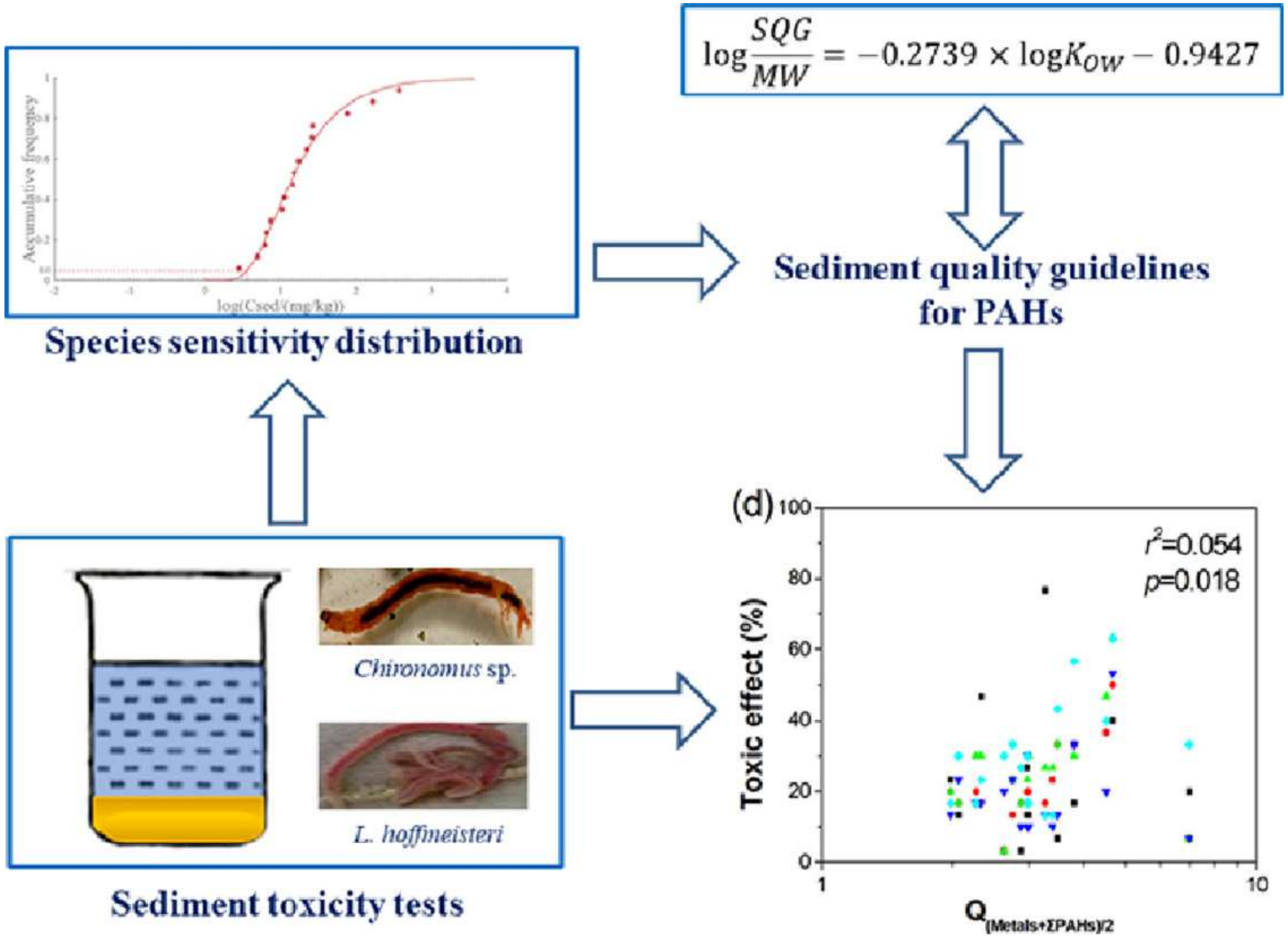


Where should we be going?

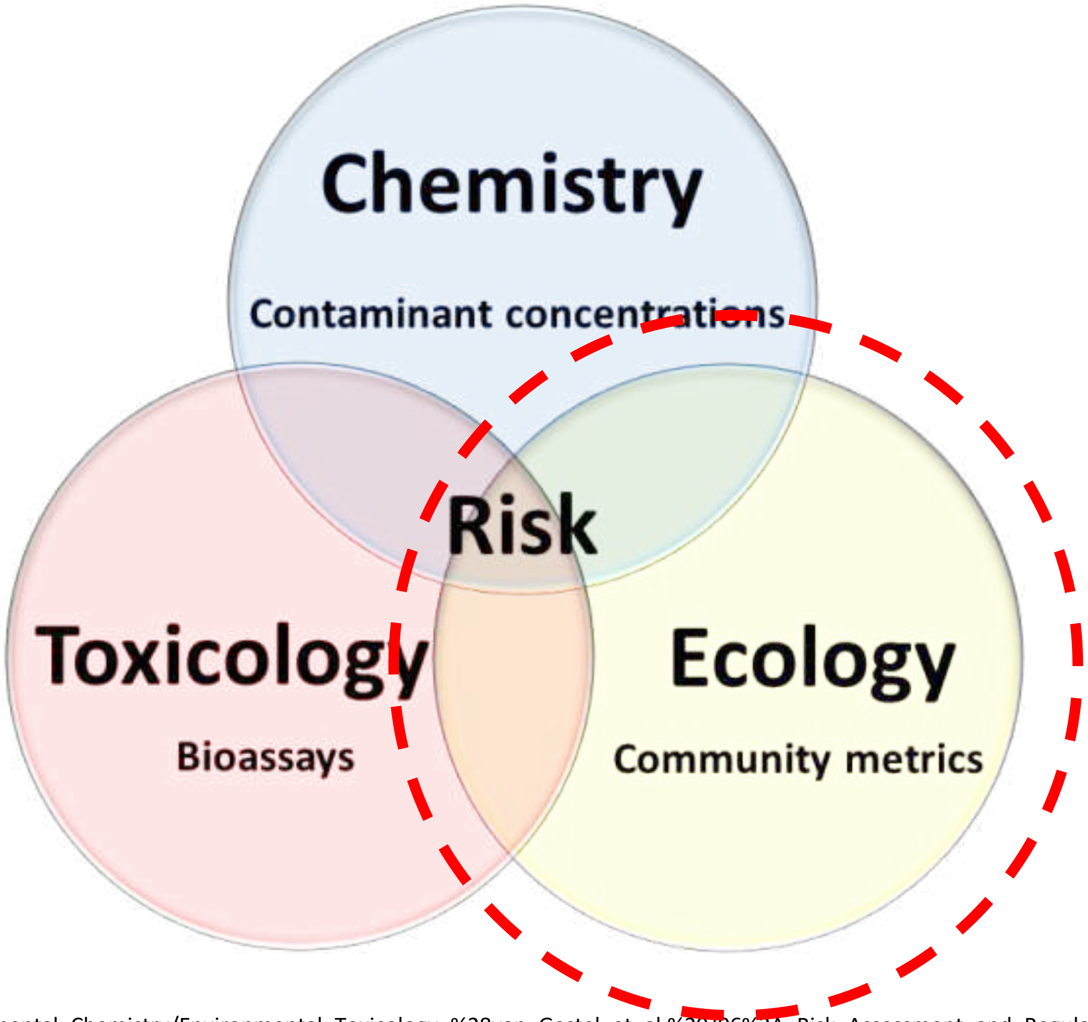
What has evolved to inform management?

- Methods for analyzing and interpreting biological, chemical, and physical sediment parameters have evolved considerably… tools such as passive samplers, bioanalytical tools, “omics”, and eDNA.
- Advanced statistical methods for interpreting ecotoxicological and environmental data sets.
- Better understanding of historical, pre-development, and regional environmental baseline values and natural variability.
- Relationships between sediment quality and aquatic life parameters important to assessing the consequences of contaminants on food chains, human health, and wildlife.
- Ecosystem- and region-specific sediment quality favored over generic numeric criteria when managing beneficial re-use of dredged materials and developing nature-based solutions.
- Improved understanding of habitat features indicative of changes to ecosystem structure and function.

Species Sensitivity Distributions (SSDs)

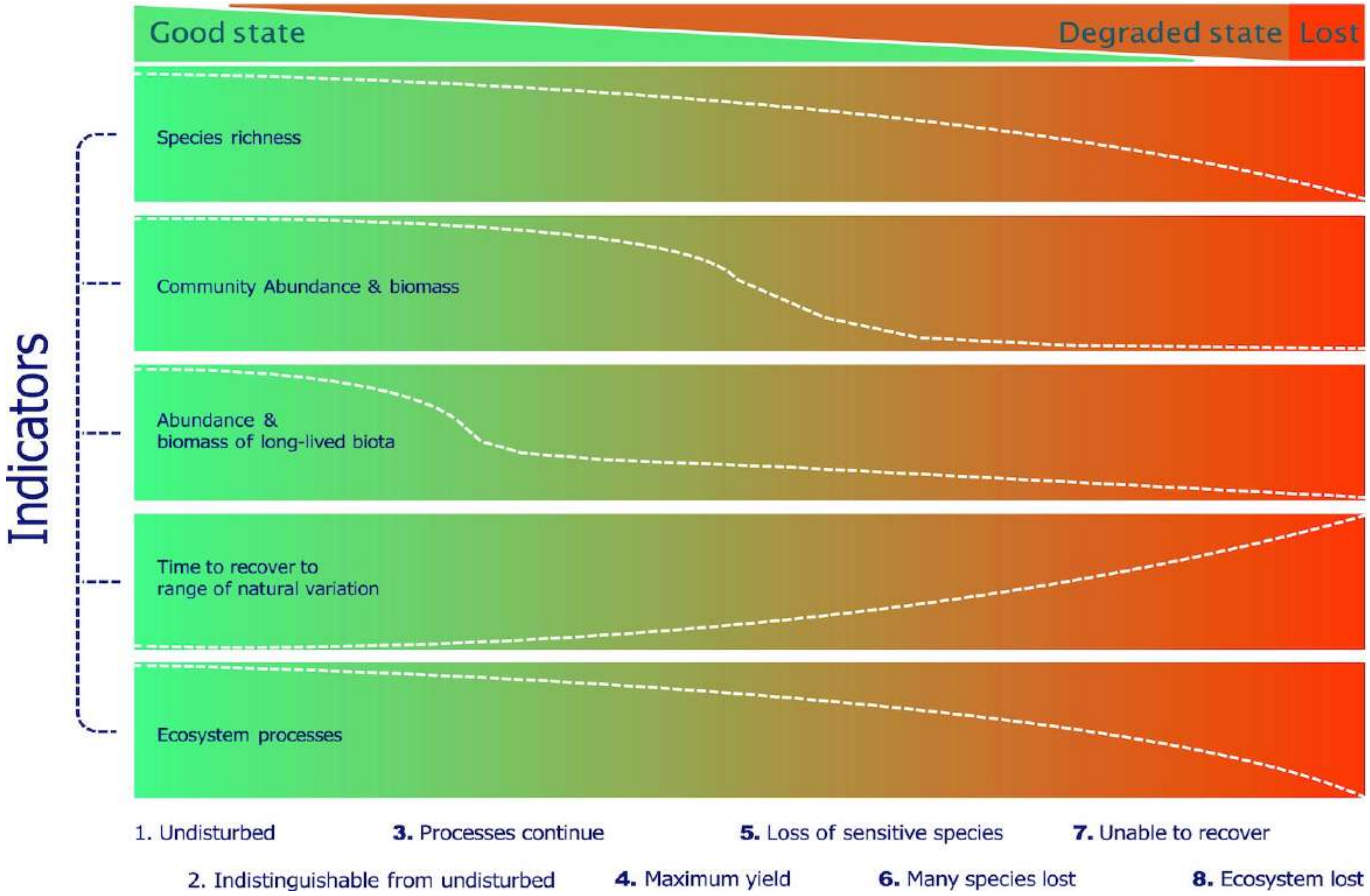


Let's not forget the third leg of the classic triad…



https://chem.libretexts.org/Bookshelves/Environmental_Chemistry/Environmental_Toxicology_%28van_Gestel_et_al.%29/06%3A_Risk_Assessment_and_Regulation/6.04%3A_Diagnostic_risk_assessment_approaches_and_tools

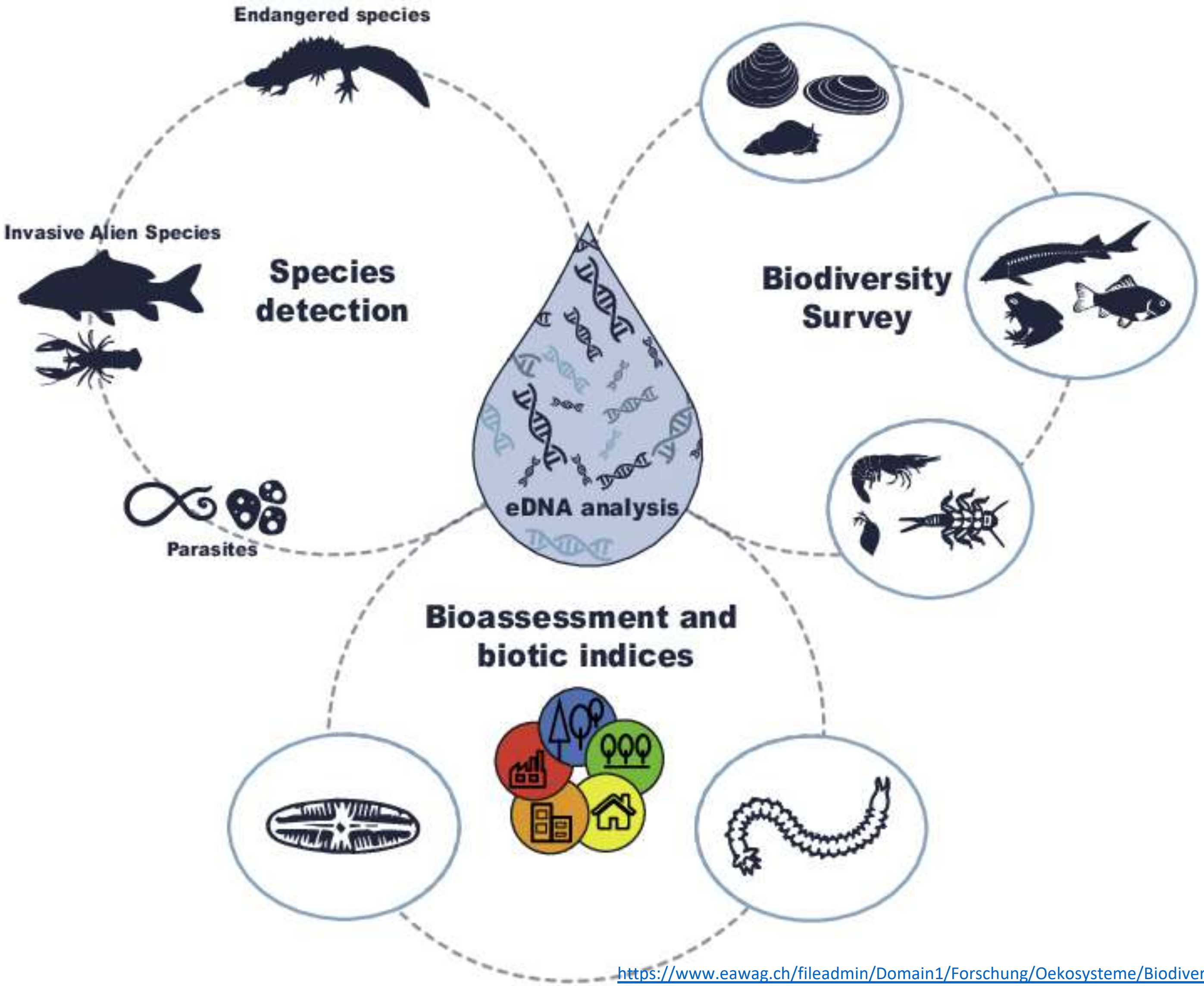
Ecosystem ("good-state") Threshold Guidelines
(Hiddink et al. 2023)



"If the management objective is to have (some of) the ecosystem in a good ecological state, it appears logical to define good state on a local scale (quality)"

https://doi.org/10.1093/icesjms/fsad035

Potential Applications of eDNA for Biomonitoring and Sediment Quality Assessment (Pawlowski et al. 2020)



https://www.eawag.ch/fileadmin/Domain1/Forschung/Oekosysteme/Biodiversitaet/edna_bioassessment_ecosystems.pdf

Other Emerging Sediment Assessment Tools

- BioCriteria based on macroinvertebrate communities (*e.g.*, Arman et al. 2019)
- Ecological context-based guidelines (*e.g.*, Costello and Burton 2014)
- Tropics-based guidelines (Zhou et al. 2014)
- Assessing bioavailability using passive sediment samplers (Niu et al. 2020)
- Evolution of “omics” tools and data

https://online.ucpress.edu/elementa/article/doi/10.12952/journal.elementa.000030/112942/Response-of-stream-ecosystem-function-and
https://academic.oup.com/icesjms/article/80/4/698/7070114
https://link.springer.com/article/10.1007/s11356-016-8338-x
https://pubs.acs.org/doi/abs/10.1021/acs.est.0c05124

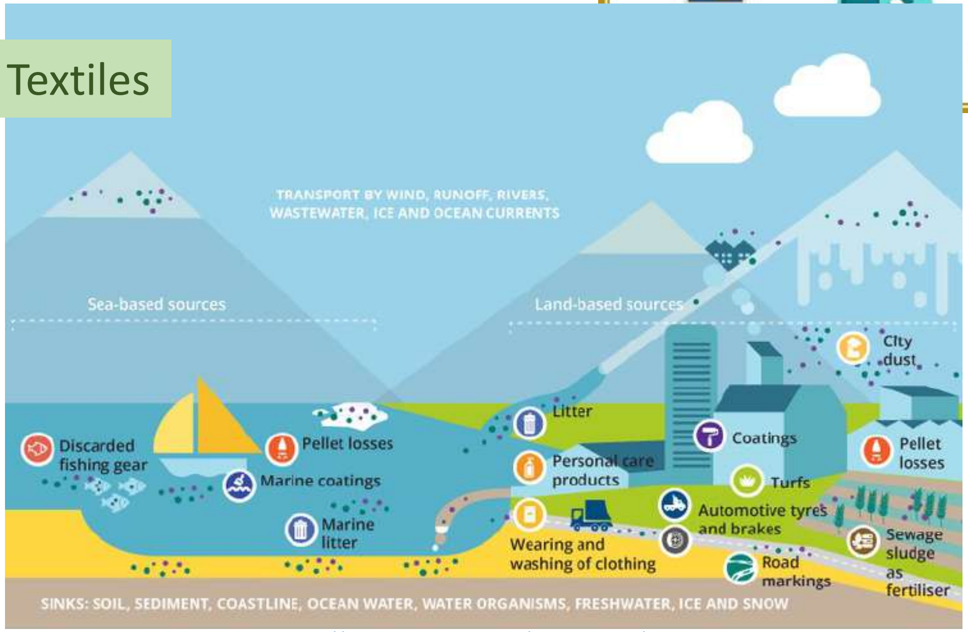
Circular Economies Everywhere and Anywhere

Water

https://www.mdpi.com/2073-4441/13/7/946

Cigarette butts

Textiles

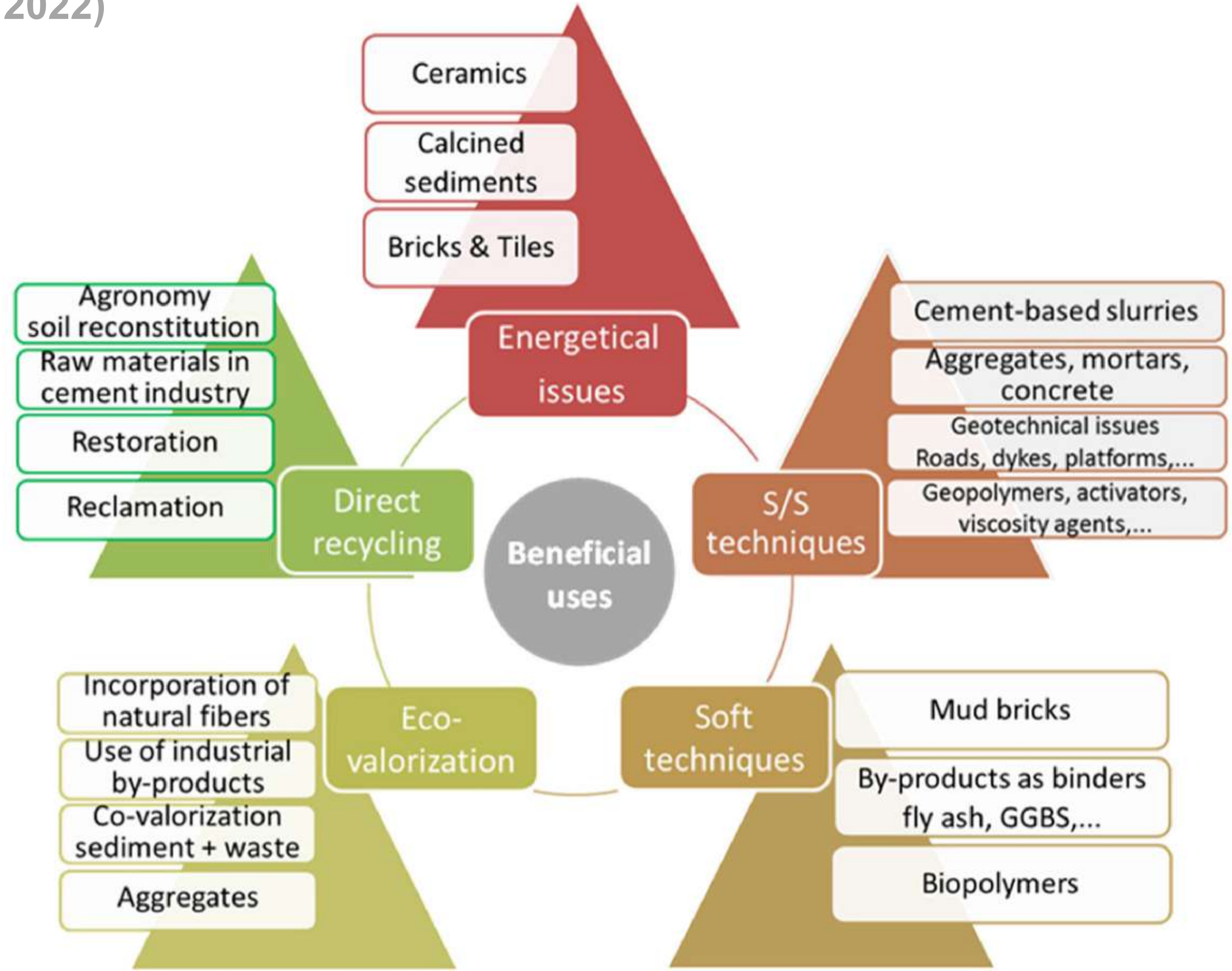


https://www.eea.europa.eu/publications/microplastics-from-textiles-towards-a

https://www.sciencedirect.com/science/article/pii/S0048969722047325

Valorization of Highly Organic Sediments

(Hussan et al. 2022)



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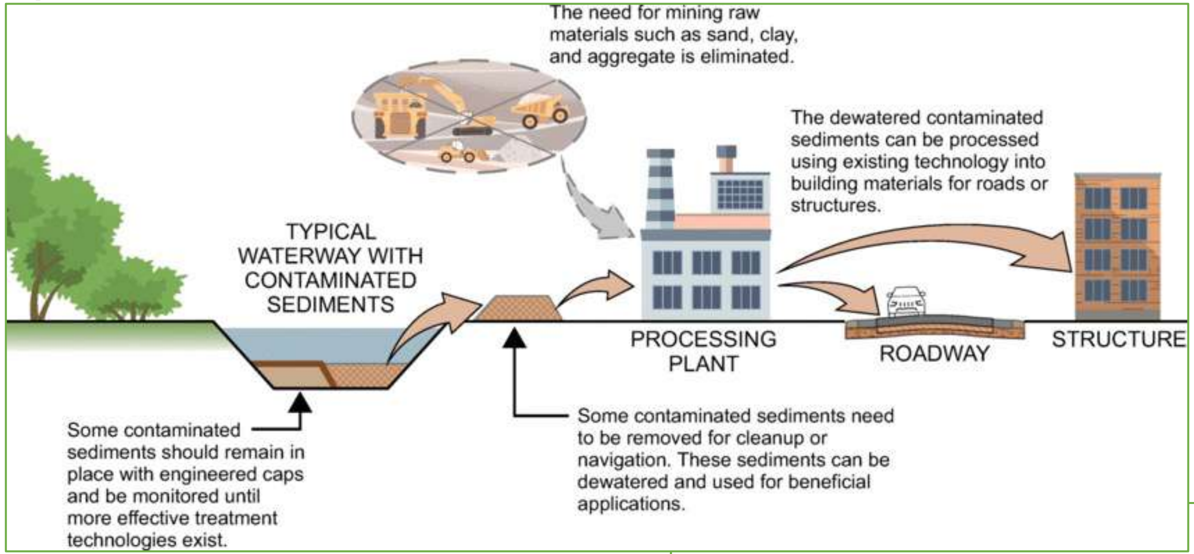
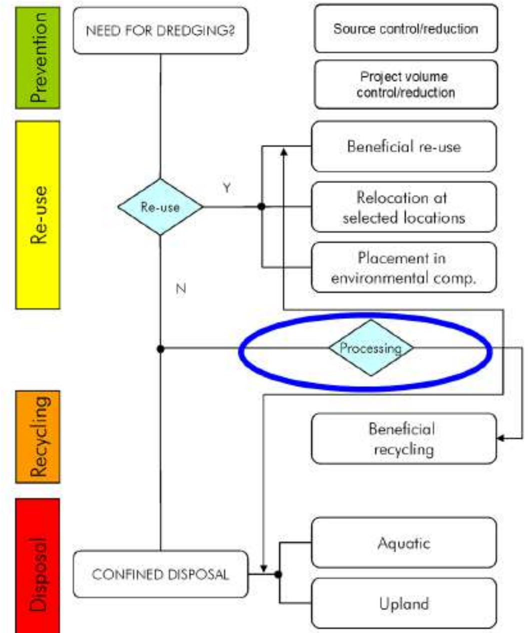
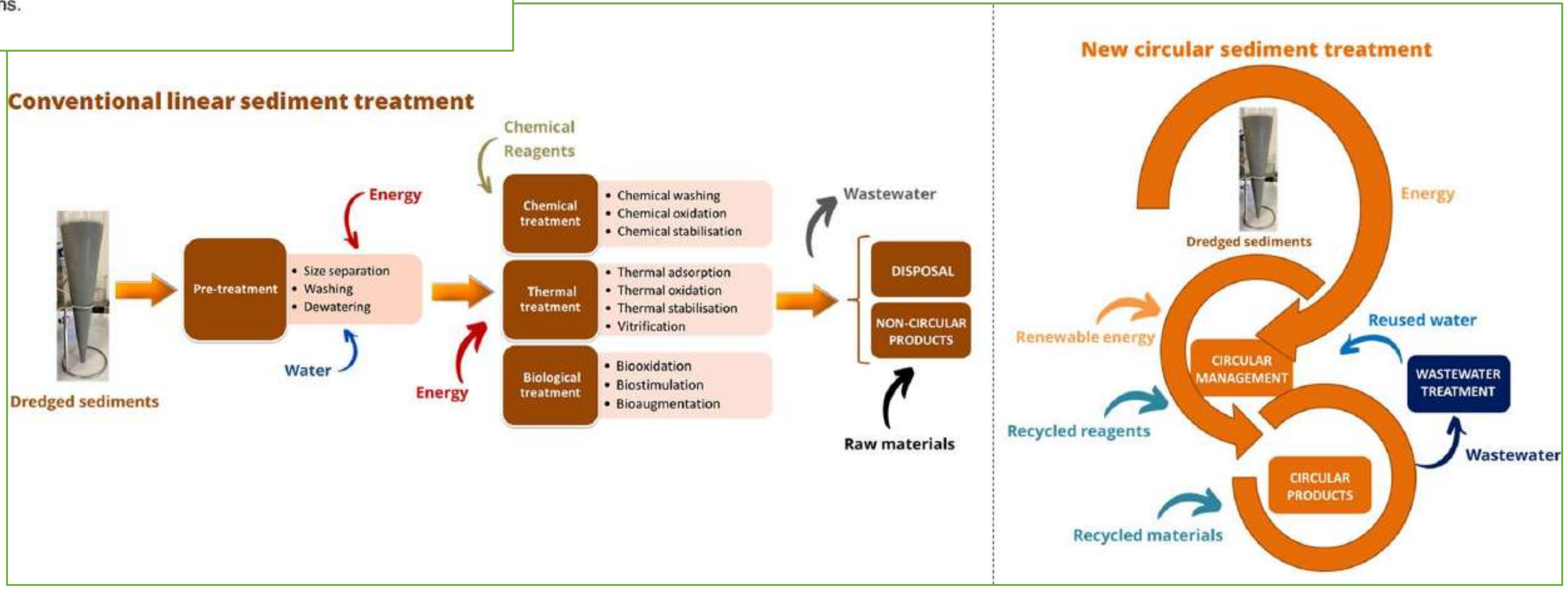
Sediments in a Circular Economy
(Apitz 2010; Spadaro and Rosenthal 2020; Crocetti et al, 2022)



Circularity may require that we re-think baseline and background contaminant levels; and the definition of waste

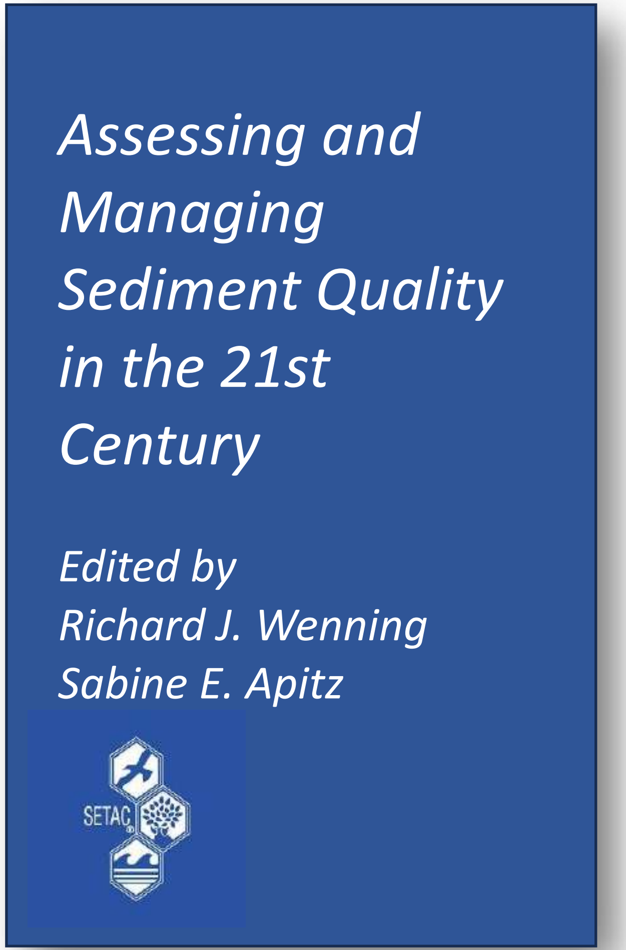


Apitz (2010) *JSS*, **10(8)**:1657-1668



https://www.mdpi.com/2504-477X/6/5/147
https://www.sciencedirect.com/science/article/abs/pii/S0956053X22002173
https://link.springer.com/article/10.1007/s11368-010-0300-9

Is "Sediment Quality" Informing Management Objectives?



The "so what" questions about sediment assessment

- Are we looking at sediment differently today?
- Are the sediment investigation tools and frameworks fit for purpose?
- Are we assessing sediments properly?
- Are SQGs even relevant anymore?
- What data do we need to manage sediments for the 21st century?
- Are new tools helpful for establishing sediment quality?

Proposed Scope of Content

Assessing and Managing Sediment Quality in the 21st Century

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I. Current Approaches for the Derivation of SQGs

- Empirical and theoretical methods
- Use of species sensitivity distributions
- Weight of evidence frameworks
- Screening approaches in different countries and regions

II. New and Emerging Tools for Sediment Quality Assessment

- Bioassessment and bio-criteria
- Ecological-context based guidelines
- eDNA and other molecular tools
- Use of passive samplers and other in situ devices

III. Managing Sediments in the 21st Century

- Beneficial re-use and valorization
- Health and ecological risk considerations in contaminated sediments
- Role of numeric SQGs in sediment quality assessment
- Sediments in the circular economy

Invitation to SedNet (and all) Experts

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September – October 2023

- Confirm contributors
- Instructions delivered to contributors

December 2023

- Online group conference call
- Chapter outlines due to editors

June 2024

- First complete draft manuscripts due to editors for peer-review
- Peer-review of draft manuscripts

October 2024

- Revised manuscripts addressing review comments due to editor

Publication by John Wiley & Sons in Spring 2025

Have a topic that fits the theme of the book?

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