On the diversity of nutrient regulations found worldwide: How do they compare?

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modelEAU

Outline

- Principles
- Compliance testing
- Standards
- Discussion
- Conclusions

Principles

- A WWTP effluent standard reflects the requirements in terms of:
  - Quantity
  - Quality

  to meet the water quality objectives of a receiving water

B.N. Jacobsen & T. Warn (1999) European Water Management, 6, 25-39

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Principles

- Standards are expressed as:
  - Effluent concentrations (mg/L)
  - Effluent mass loads (kg/d)
  - Treatment efficiency (% reduction)
  - Treatment technology (primary/secondary/tertiary)

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Principles

- Standard setting is based on:
  - Environmental Impact Assessment
    - Specific location
    - Regional/National scale
  - Best available technologies not entailing excessive costs (BATNEEC)

    This is not (yet) considering:
    - sustainability/energy/resource use
    - handling of residual products (sludge, GHG)

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Principles

- Also, standard has to be:
  - Well defined (to minimise discussions)
  - Easily understood by:
    - Environmental authorities
    - Dischargers
  - Operational, i.e. easy compliance testing
  - Minimising risk of false compliance failure (due to sampling variability)

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Principles

- Compliance assessment =
  evaluation of whether a given WWTP effluent meets the criteria defined in the effluent standard
- Includes:
  - Limit values of the standard
  - Specification of the methods for
    - Sampling (grab, composite)
    - Analysis (APHA, DIN, CEN, …)
    - Assessment of the data (e.g. rejection, statistics)

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Compliance testing

- Historical, country-specific

- Sampling procedures
- Analytical methods
- Data exclusion approaches
- Compliance assessment methods

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Compliance testing: Sampling

- Number of samples per year:
  - 4, 12, 24, 26, 48, 52, 104, 365, continuous
  - Sampling interval: 6 days (Australia, weekend effect)
- Grab sampling (during daytime …)
- Composite sampling (time or flow proportional)
  - 24-hour / 7-day composite samples (Norway, Sweden)
  - Since flow and concentration are synchronised result is higher for flow- than for time-proportional
- Grab = 15% higher than composite (FWR, 1994)

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Compliance testing: Analysis

- National methods (EWPCA, 1997)

Code	Country	COD	BOD	Total N	Total P	Susp.Solids
EU	European Union	Potassium dichromate	ATU modified	Mol. Abs.Spectrom.	Mol. Abs. Spectrom.	0.45 um filter or centrifug.
A	Austria	M 6265	M 6277	DIN 38409-H27	M 6237	DIN 38409-H2
B-Flan	Belgium	NBN T91-201	NBN 407	NBN T91-255	NBN 682	38405-H2-3
B-Wal	Belgium	NF T90-101	NF T90-103	CEN 25663	CEN 1185 (draft)	CEN 870 (draft)
CH	Switzerland	DIN 38409-H41	DIN 38409-H51	DIN 38409-H27	DIN 38405-D11-4	DIN-38409-H2-3
D	Germany	DIN 38409-H41	DIN 38409-H51	DIN 38409-H27	DIN 38405-D11-4	DIN-38409-H2-3
DK	Denmark	DS 217	DS/R 254	DS 221 / DS 242	DS 292	DS 207
E	Spain	Standard Methods	Standard Methods	Standard Methods	Standard Methods	Standard Methods
EST	Estonia	SS 028142	SS 028143-BOD7	SS 028131	SFS 3026	SFS 3037
F	France	NFT 90101	NFT 90103	NFT 90110	NFT 90023	NFT 90105
FIN	Finland	SFS 5504	SFS 5508	SFS 3031/SFS 5505	SFS 3026	SFS 3037
HR	Croatia	Standard Methods	Standard Methods	Standard Methods	Standard Methods	Standard Methods
I	Italy	IRSA-CNR 5110	IRSA-CNR 5100	IRSA-CNR 4010+4020+4030+5030	IRSA-CNR 4090	IRSA-CNR 2050
IR	Ireland	Standard Methods	Standard Methods	Standard Methods	Standard Methods	Standard Methods
L	Luxembourg	DIN 38409-H41	DIN 38409-H51	-	DIN 38405-D11	DIN-38409-H2-3
N	Norway	NS 4748	NS 4758	NS 4743	NS 4725	NS 4733
NL	Netherlands	NEN 6633	NEN 6634	CEN 25663 / NEN 6652	NEN 6663	NEN 6621
P	Portugal	Standard Methods	Standard Methods	Standard Methods	Standard Methods	Standard Methods
RUS	Russian Federation	Russian standards	Russian standards	Russian standards	Russian standards	Russian standards
S	Sweden	SS 028142	SS 028143-2,BOD7	SS 028131 / 028101	SS028127-2	SS 028112-3
SK	Slovakia	SK STN 830540	SK STN 830540	SK STN 830540	SK STN 830540	SK STN 830540
UK	United Kingdom	SCA	SCA	SCA	SCA	SCA

Compliance testing: Analysis

- National methods
- Not easy to change (tradition, lab equipment)
  Examples:
  - BOD_5 vs BOD_7 (conversion factor: BOD_5=0.85 BOD_7)
  - Suspended solids to be measured on 0.45 µm MF, but often glass filters (with larger pore size) are used
- Conclusion:
  - More exception than rule
    that the same analytical methods are used
  - Not studied whether it affects the results significantly

Compliance testing: Data exclusion

- "*Extreme values for water quality shall not be taken into consideration when they are the result of unusual conditions such as those due to heavy rain*" (EU UWWT Directive, Annex I, D.5)
- Problem: No definition of "unusual"
- If no exclusion allowed => stricter regulation
- Not problem if regulation is based on percentiles

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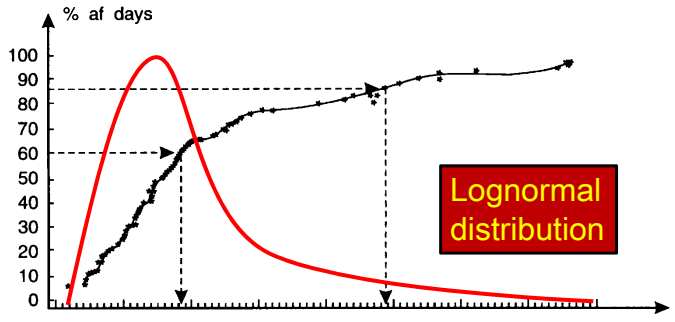
Compliance testing: Assessment

- Six categories (Wenzel & Bangsbo, 1991)
  1) Each sample should comply



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Compliance testing: Assessment

- Six categories (Wenzel & Bangsbo, 1991)
  1) Each sample
  2) A certain % of the samples (e.g. 95%)
  3) A variable number of samples (depending on number of samples taken)

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Compliance testing: Assessment

- EU UWWT Directive, Annex 1, 90th %ile

Samples/yr	exceedances	Samples/yr	exceedances
4– 7	1	172–187	14
8– 16	2	188–203	15
17– 28	3	204–219	16
29– 40	4	220–235	17
41– 53	5	236–251	18
54– 67	6	252–268	19
68– 81	7	269–284	20
82– 95	8	285–300	21
96–110	9	301–317	22
111–125	10	318–334	23
126–140	11	335–350	24
141–155	12	351–365	25
156–171	13		

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Compliance testing: Assessment

- Six categories (Wenzel & Bangsbo, 1991)
  1) Each sample
  2) A certain % of the samples (e.g. 95%)
  3) A variable number of samples (depending on number of samples taken)
  4) The average of the samples
  5) The average of the samples + standard deviation
  6) The average percentage of pollution reduction
- How do they compare? e.g. 1) is most stringent

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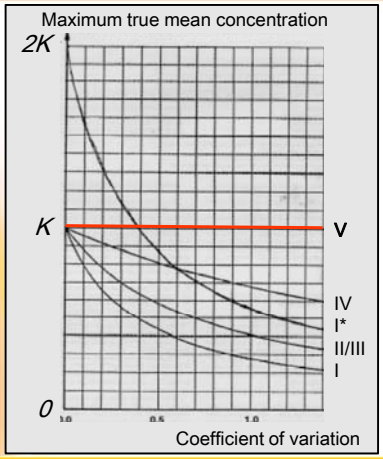
Compliance testing: Assessment



- Translation key between assessment methods for the same standard *K*
- Maximum true mean effluent concentration
- Assumptions:
  - 12 samples/year
  - Normal distributions of errors
  - 95% confidence that WWTP has truly failed
  - All methods are the same

Jacobsen & Warn (1999)

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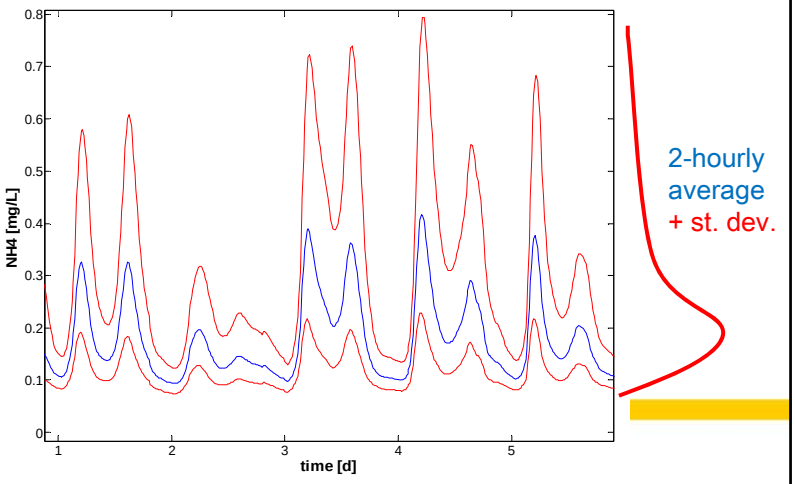
Compliance testing: Assessment

- Coefficient of variation also depends on sampling rate



Compliance testing: Assessment

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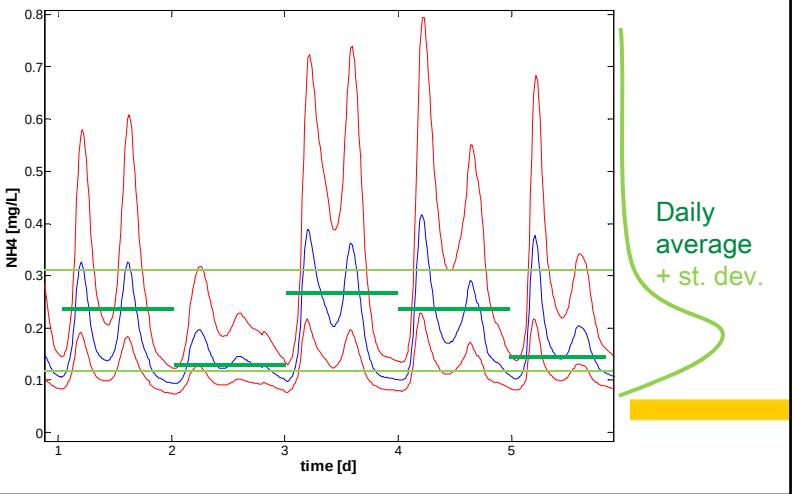

Compliance testing: Assessment

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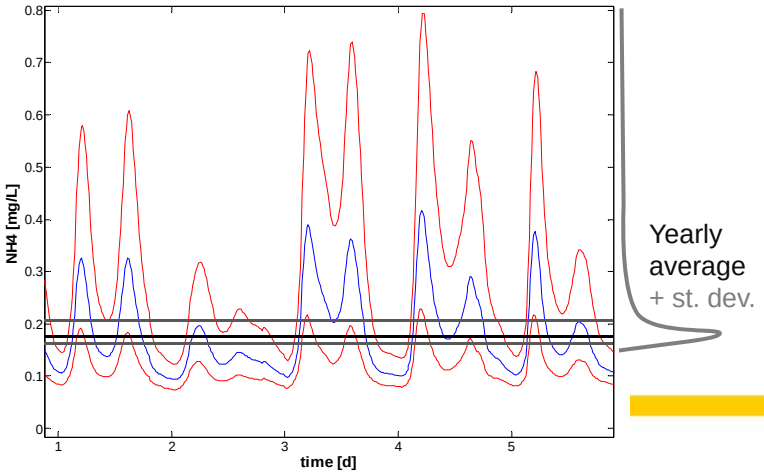

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Standards: Questionnaire

- Questionnaire (32 of my friends - 18 countries)
- Response from 16 of my friends - 12 countries
- Questions:
  - What variables are considered
  - What limit values are used
  - What compliance assessment method is applied
  - Where do these regulations originate from

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Standards: Questionnaire

- Australia (Jurg Keller)
- Brazil (Marcos von Sperling)
- China (Guo Yaping, Yongmei Li)
- Ecuador (David Matamoros)
- Egypt (Usama Zaher)
- Germany (Frank Blumensaat)
- South-Korea (Dae Sung Lee)
- Slovenia (Darko Vrecko, Meta Levstek)
- South-Africa (Philip Raj, Chris Brouckaert)
- Sweden (Doug Lumley)
- Switzerland (Marc Neumann)
- UK (Jeremy Dudley, Bob Crabtree, Ed Bramley)

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Standards: Australia

- Standards
  - P_{tot}: 0.07 - 2 mg P/L
  - N_{tot}: 3-10 mg N/L
  - NH_4: 5 mgN/L
- Compliance testing
  - P_{tot}: 50 %ile
  - N_{tot}: 50 %ile
  - NH_4: 50 %ile
  - 6 day sampling interval
- Origin:
  - Sensitivity analysis (Great Barrier Reef)
  - Load-based limits
- Comments:
  - Standards depend very much on location
  - Ocean outfalls

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Standards: Brazil

- Standards
  - N_{tot}: 1.27 mgN/L (lentic)
  - N_{tot}: 2.18 mgN/L (lotic)
  - NH_4: 20 mgN/L
- Compliance testing
  - Not specified
- Origin:
  - Water use classes
  - Receiving water standards translated into discharge standards on the basis of reference flow (e.g. Q90)
- Comments:
  - Industry is easier to make compliant than municipalities

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Standards: China

- Standards
  - P_{tot}: 0.5 mgP/L
  - N_{tot}: 15 mgN/L
  - NH_4: 5 mgN/L
- Origin:
  - Water usage of the receiving body
  - Negotiations municipality - EPA
- Compliance testing
  - Not specified
- Comments:

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Standards: Ecuador

- Standards
  - P_{tot}: 10 mgP/L
  - NO_x: 10 mgN/L
  - TKN: 15 mgN/L
- Origin:
  - Environmental Law (2000) – Technical Guidance not ready
- Compliance testing
  - Not specified
- Comments:

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Standards: Egypt

- Standards
  - PO_4: 5 mgPO_4/L
  - NO_3: 40 mgNO_3/L
- Compliance testing
  - Average daily composite
  - 90-95%ile
- Origin:
  - Environmental Protection Law No. 4
  - Only for marine outlets
- Comments:
  - Most WWTP discharge into agricultural drains for fertilization

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Standards: Germany

- Standards
  - P_{tot}: 1-2 mgP/L
  - NH_4: 10 mgN/L
  - N_{tot}: 13-18 mgN/L
- Compliance testing
  - 2 hr composite sample
  - 4 out of 5 must comply
  - Outlier not more than 2xK
  - NH_4-standard:
    - Not if Temp < 12 ºC
    - Only from 1 MAY - 31 OCT
- Origin:
  - EU UWWT Directive
- Comments:

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Standards: Luxembourg

- Standards
  - P_{tot}: 1-2 mgP/L (80% removal)
  - N_{tot}: 10-15 mgP/L (70-80% removal)
- Compliance testing
  - 24 samples/yr
  - 24 hr flow composite
- Origin:
  - EU UWWT Directive
- Comments:

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Standards: Slovenia - Ljubljana

- Standards
  - P_{tot}: 1 mgP/L
  - N_{tot}: 20 mgN/L
  - NH_4: 5 mgN/L
- Compliance testing
  - 24 samples/yr
  - 24 hr flow composite
  - 20% of the results can be over the limits
- Origin:
  - EU UWWT Directive
  - Depends on location (sensitive area or not)
- Comments:

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Standards: South-Africa

- Standards
  - PO_4: 1 – 10 mgP/L
  - NH_4: 2 – 6 mgN/L
  - NO_x: 1.5 – 15 mgN/L (Sensitive – Non-sensitive)
- Compliance testing
  - Grab sampling
  - Monthly (municipal)
  - Weekly (industrial)
- Origin:
  - "What would the discharge quality have to be to meet the Water Quality Guidance for specific water users downstream the discharge"
- Comments:
  - Before: "What would the quality have to be if the discharge was the only flow in the river"

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Standards: South-Korea

- Standards
  - P_{tot}: 2 - 8 mgP/L
  - N_{tot}: 20 – 60 mgN/L (Less strict DEC-FEB)
- Compliance testing
  - Flow proportional samples
  - Weekly required
- Origin:
  - Sewerage act, based on loading of the receiving water body
- Comments:
  - 365 samples taken!

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Standards: Sweden - Gothenburg

- Standards
  - P_{tot}: 0.4 mgP/L
  - P_{tot}: 0.3 mgP/L
  - N_{tot}: 10 mgN/L
- Origin:
  - Tailored to local recipient
  - Inland waters: P-limit
  - Coastal waters: N-limit
  - Local county decides on permits
- Compliance testing
  - P_{tot}: yearly average
  - P_{tot}: 3-month average for MAR-MAY / JUN-AUG
  - N_{tot}: yearly average
  - Daily flow proportional into weekly composite
  - No exceedance permitted
- Comments:
  - P-limit since 1960s
  - Here: EU sensitive areas

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Standards: Switzerland - Berne

- Standards
  - P_{tot}: 0.5 mgP/L
  - NH_4: 2 mgN/L
  - N_{tot}: 15 mgN/L
  - NO_2: 0.3 mgN/L
- Origin:
  - Swiss National Law (Based on EU WFD)
  - Canton law
- Compliance testing
  - P_{tot}: yearly av.
  - NH_4: 90%ile
  - 24h volume prop.
  - Random weekday
  - Nr of samples: 12-24/yr
- Comments:
  - Effluent load fees (COD, NH_4, NO_3, P_{tot}) (used for upgrade investment)

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Standards: UK – Yorkshire Water

- Standards
  - NH_4: 5 mgN/L

  For EU sensitive areas
  - NO_3: 50 mg NO_3/L (WHO)
  - PO_4: 1-2 mgP/L
- Compliance testing
  - N_{tot}:
  - 95%ile compliance
  - Grab samples
  - 12 to 365 samples/yr
- Origin:
  - EU UWWT/Habitats/Fresh Water Fish/WFD directives
  - MC SIMCAT WQ simulations of recipient to set standard
- Comments:
  - Prosecution only if there has been a resulting WQ deterioration

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Discussion: Standards comparison

- Direct comparison between effluent standards can be very misleading due to differences in:
  - Sampling methods
  - Analytical methods
  - Compliance assessment
- All these elements should be in the standard
- Theoretical study shows one can compensate by adjustments based on statistical analysis
- Assumptions must be checked! (Further work needed)
- Data exclusion policy: needs definition

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Discussion: Standards comparison

- What are standards for?
- Reminder: A WWTP effluent standard reflects the requirements in terms of:
  - Quantity
  - Quality

  to meet the water quality objectives of a receiving water

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Discussion: Standards comparison

- What are standards for?
- Should we regulate average (e.g. yearly av.) or extreme values (%iles of daily values)?
  - Extremes for:
    - Oxygen
    - Hygiene
    - Aesthetics
  - Average for:
    - Eutrophication
    - Bioaccumulation

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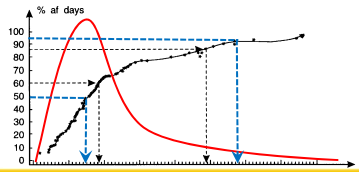
Discussion: Standards comparison

- "No exceedance" or "percentile" standards?
  - No exceedance: easy to administer
  - There is always a risk to fail to comply
  - The more you monitor, the higher the risk of failing = counter-productive!
  - Statistical analysis has become feasible at the plant
  - <u>Proposal:</u>
    - Long-term effects: 50 %ile
    - Short-term effects: 95 %ile



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Discussion: Standards comparison

- Standards:
  - P_{tot}: 0.07 – 10 mgP/L (developing/developed nations)
    (sensitive/non-sensitive areas)
  - N_{tot}: 3 – 60 mgN/L
  - NH_4: 2 – 20 mgN/L
  - NO_x: 1.5 – 15 mgN/L
  - NO_2: 0.3 mgN/L (Switzerland)

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Discussion: Standards comparison

- Origin:
  - Sensitive versus non-sensitive areas
  - Based on water quality uses *QBEL*
    - WQ simulations
    - Dilution with reference flow (Q90)
  - Best available technologies *TBEL*
  - National law, local permitting body
  - Negotiations between discharger – local body
  - EU UWWT directive

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Discussion: Standards comparison

- Compliance testing:
  - Not specified (developing & emerging countries)
  - Grab versus daily composite sampling (x0.85)
  - Number of samples (intervals):
    - 2hr
    - Daily
    - Weekly (every 6 days to capture weekend effects)
    - Monthly
  - Averaging over week, 3 months, year
  - No exceedance vs. %ile exceedance (50-80-90-95%)

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Conclusions

- Consensus on variables to consider
  - P_{tot}, N_{tot}, NH_4, NO_x
- Diversity of:
  - Standards
  - Analytical methods
  - Compliance testing approaches
- Lack of specification of:
  - Exclusion of outliers
  - Composite sampling approach (flow / time-prop.)

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Conclusions

- Standard should include:
  - Variables
  - Analytical method
  - Sampling approach (nr of samples, grab/prop.)
  - Exclusion policy
  - Compliance assessment method

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Conclusions

- Compliance assessment should :
  - Differentiate between impacts:
    - Long-term (Eutrophication, Bioaccumulation)
    - Short-term (Oxygen, Hygiene, Aesthetics)
  - Long-term → averages, 50%ile over a year
  - Short-term → 80-95 %ile on daily values
- "No exceedance" policy is counter-productive because it punishes the one that monitors frequently
- Statistics to work with %ile approaches are available

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Acknowledgement

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