# Delineation of background levels and threshold values for Estonian groundwater bodies

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**WaterAct**

Joint actions for more efficient management of common groundwater resources

# Outline

- Introduction;
- Methodology used to update background levels (BL) and threshold values (TV) for Estonian groundwater bodies (GWBs) by Marandi et al. (2019);
- Results:

✓Threshold values for total-N and total-P in groundwater;

✓Suggestions for future determinations of BLs and TVs in Estonia;

✓Alternative methodologies for BL determination

# Introduction

- **Marandi, A., Osjamets, M., Polikarpus, M., Pärn, J., Raidla, V., Tarros, S., Vallner, L., 2019. Characterization of the groundwater bodies, evaluation of pressures and compilation of hydrogeological conceptual models. Geological Survey of Estonia, Rakvere**

- ***Groundwater quality standard*** **-** environmental quality standard expressed as the concentration of a particular pollutant, group of pollutants or indicator of pollution in groundwater, which should not be exceeded in order to protect human health and the environment;

| | |
|---|---|
| **Nitrate** | **50 mg/L** |
| **Pesticides** (including their relevant metabolites, degradation and reaction products) | **0,1** µg/L (for one substance) or<br>**0,5** µg/L (total concentration in a sample) |

- ***Threshold value (TV)*** **-** a groundwater quality standard set by EU member states for the pollutants, groups of pollutants and indicators of pollution which, within the territory of a member state, have been identified as contributing to the characterization of bodies or groups of bodies of groundwater as being at risk;

- ***Background level (BL)*** **-** a concentration of a substance or the value of an indicator in a body of groundwater that corresponds to no, or only very minor, anthropogenic alterations.

# Materials and methods – background levels

- Marandi et al., (2019) updated the BLs and TVs for the Estonian GWBs based on previously established values (Infragate, 2013) and the simplified version of the BRIDGE methodology (Müller et al. 2006; Hinsby et al. 2008)
- **High concentrations of substances and indicators in groundwater - from water-rock interaction, biological processes (e.g. redox reactions), inflow from adjacent aquifers, anthropogenic alterations**.
- **The BLs were derived as the 90th percentiles of a preselected dataset, using the following pre-selection criteria** (Hinsby et al. 2008):

1. Chemical data from the period 2004-2017. To establish the natural baseline for the groundwater macro components (e.g. Cl, SO4), data from earlier periods was also considered (e.g. Tšeban, 1966);
2. Only samples where seven groundwater macro components (Ca, Mg, Na, K, HCO3, Cl, SO4) were analyzed were considered, enabled the calculation of an ion balance;
3. Samples with incorrect ion balance (exceeding 10%), unknown depth and unknown aquifer type were excluded;
4. Time series at each monitoring point were converted to average values (to assure that long time series do not bias results and that all sampling sites contribute equally to the background level derivation).

# Materials and methods – threshold values I

- Firstly, ***receptors*** which can be influenced by the status of groundwater were chosen.
- Drinking water, groundwater dependent ecosystems (GDEs) and saltwater intrusion were considered the most important receptors in Marandi et al. (2019).
- Secondly, two types of ***criteria*** for delineating TVs:

1. **Environmental criteria**:

✓TVs that aim to protect the GDEs;

✓TVs which help to designate abstraction related saltwater intrusion into a GWB.

2. **Usage criteria**:

✓TVs that aim to protect drinking water in Drinking Water Protected Areas (DWPA);

✓TVs to protect other legitimate uses of groundwater (e.g. crops irrigation, industry).

# Materials and methods – threshold values II

- ***The criteria value (reference value)–*** concentration of a pollutant, which is designated not taking into account natural background concentrations, but if exceeded may lead to a failure of the good status criterion concerned (European Commission, 2009).
- Criteria values in Marandi et al., (2019) – drinking water quality standards, environmental quality standards for GDEs and environmental quality standards for dangerous substances.
- **Establishing TVs using BLs and criteria values** (European Commission, 2009):

1. **BL < criteria value**: Member state will define the TV according to national strategies and a risk assessment (enabling a TV to be established above the BL providing it can be clearly justified). In our case expert judgement.
2. **BL > criteria value**: the TV should be equal to the BL.

- **A change to a previous TV was proposed by Marandi et al. (2019), when**:

1. previous TV did not take into account the active pressures acting on a GWB (e.g. no active pollution sites where a given substance may originate is present in a GWB);
2. previous TV did not take into account the natural background levels in a GWB;
3. previous TV did not take into account the potential influence of groundwater quality on the GDEs.

# Results I

- Considering the chosen receptors, substances/indicators, criteria and the BLs the following TVs were established for the following GWBs.
- **Most of the suggestions for threshold values were adopted in Estonian legislation**.

| Substance/Indicator | Unit | Proposed threshold value | GWB no. |
|---|---|---|---|
| ***Phenols*** | µg/L | **1** | 6, 7, 10, 14, 15, 16, 27, 28, 29 |
| ***Petroleum products*** | | **20** | 6, 7, 8, 10, 14, 15, 19, 24, 27, 28, 29 |
| ***Benzene*** | | **1** | 6, 7, 8, 10, 14, 15, 19, 24, 27, 28, 29 |
| ***PAH*** | | **0,1** | 6, 7, 8, 10, 14, 15, 19, 24, 27, 28, 29 |
| ***$SO_4^{2-}$*** | mg/L | **50** | 6, 28 |
| | | **100** | 5a, 27 |
| | | **250** | 7, 27 |
| ***$Cl^-$*** | | **60** | 27 |
| | | **250** | 2, 3, 4, 8, 9, 11, 12, 19, 29 |
| | | **350** | 5b |
| | | **450** | 20 |
| | | **550** | 1 |
| ***Total-N*** | | **3** | 6, 7, 12, 25 |
| | | **2,5** | 11, 14, 16 |
| | | **1** | 9, 10, 13, 15, 22, 23, 24, 26 |
| | | **0,5** | 27 |
| ***Total-P*** | | **0.08** | 6, 7, 12, 25 |
| | | **0,06** | 13, 23, 24, 26 |
| | | **0,02** | 9, 10, 11, 14, 15, 16, 27 |

# Results II

- For 3 groundwater bodies (Cambrian-Vendian Gdov, Ordovician-Cambrian Tartu and Middle-Lower Devonian Kihnu) a **chloride** TV > 250 mg/L was established (***BL > criteria value***). Due to natural conditions it may be impossible to abstract water within the drinking water limit from those GWBs.
- **Suggestion to establish total-N and total-P for GWBs where important GDEs are situated** (Terasmaa et al. 2015):

✓ To protect the receptor with the lowest criteria value (not drinking water but GDEs);

✓ Better assessment for the influence of groundwater quality on the chemical status of GDEs;

✓ Total-N and total-P used as indicators to assess the chemical status of surface water bodies (i.e. lakes and rivers), but these parameters are not measured during GWB status assessment (only nitrate-N, nitrite-N and ammonium-N separately). The same applies for P-species;

✓ Very hard to compare the groundwater quality and surface water quality in the same areas;

✓ The adoption of the proposed total-N and total-P values in legislation → many administrative problems as probably a high number of GWBs would to be in bad status;

✓ **Example**: **0,5** mg-N/L of total-N = **2,2** mg/L of $NO_3^-$; **3** mg-N/L of total-N = **13,3** mg/L of $NO_3^-$ (*NB! if all total-N is made up of $NO_3$-N*)

✓ **This suggestion was not adapted in legislation**.

✓ Strongly advised that as a first step the analysis of total-N and total-P should be added to the list of substances studied for GWB status assessment (a pilot project in the framework of the LIFE IP CleanEst project from 2019-2022).

# Things to improve upon – background levels

- **In the future, the number of pre-selection criteria for the dataset to determine BLs can be expanded. For example** (from Hinsby et al., 2008):

1. Data from monitoring points with median nitrate concentrations >10 mg/L considered polluted and thus be excluded;
2. If anaerobic samples (here defined as $O_2$< 1 mg/L) present in the dataset or denitrification occurs, the dataset evaluated separately for the aerobic and anaerobic samples (e.g., in anaerobic groundwater nitrate does not work as a pollution indicator since nitrate could have been reduced).

- **Other methods used to establish BLs/TVs for groundwater**:

✓ Example of Panno et al., (2002) for NO3 background levels in the Illinois' Sinkhole Plain, USA ;

✓ An approach borrowed from the field of mineral exploration;

✓ Data plotted on a cumulative probability plot, to establish various populations;

✓ Inflection points along the plots indicate the thresholds between populations;

✓ Background defined by the inflection point with the concentration above which higher concentrations indicative of recent anthropogenic alteration.

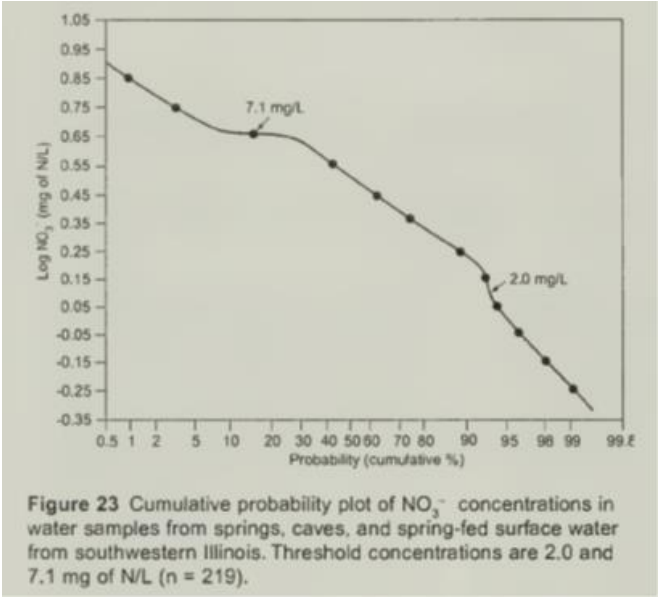


**Figure 23** Cumulative probability plot of $NO_3^-$ concentrations in water samples from springs, caves, and spring-fed surface water from southwestern Illinois. Threshold concentrations are 2.0 and 7.1 mg of N/L (n = 219).

from Panno et al. (2002)

# Things to improve upon – threshold values

- TVs established by Marandi et al. (2019) were based on either background levels (when *BL > criteria value*) or drinking water limits, environmental quality standards for GDEs and expert judgment (when *BL < criteria value*).
- **Process could have been more formalized** (Hinsby et al. 2008):

✓**Case 1 (*BL/REF* ≥ $\frac{1}{3}$)**: TV=(BL+REF)/2

*(in final BRIDGE methodology as BL/REF<1)*

✓**Case 2 (*BL/REF* ≤ $\frac{1}{3}$)**: TV=2*BL

✓**Case 3 (*BL/REF* ≥ *1*)**: TV=BL

*(in final BRIDGE methodology as BL/REF>1)*

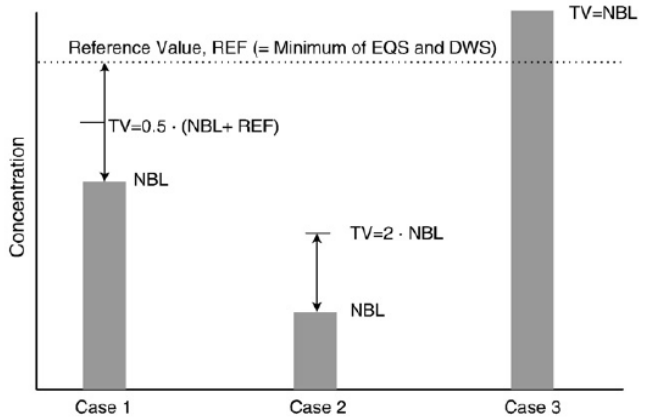


Fig. 2 – Derivation of threshold values at Tier 2a depending on ratio between NBL and a relevant reference value (REF = EQS, DWS etc.). Case 2 was removed from the final proposed method, but is evaluated in this paper together with the final proposed method, where TV = (NBL + REF)/2 if NBL < REF and TV = NBL if NBL ≥ REF.

from Hinsby et al. (2008)

- Thank you for your attention!

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