

A novel method to evaluate the hydrochemical interaction between *groundwater* and *surface waters* in Denmark



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INTRODUCTION

The hydrochemical interaction between groundwater and surface water was investigated in order to develop a method to evaluate the chemical impact from groundwater bodies (GWB) on surface water chemical quality in Denmark. The proposed method involves a 5-tier catchment analysis for evaluating, whether GWB are a significant source of nutrients and hazardous substances to streams or coastal waters. The method was tested in three pilot catchments in Denmark. Below the 5-tier method is presented for the Skjern River Catchment (1552 km²).

THE 5-TIER METHOD

TIER 1: Assesses whether there are exceedances of the general quality requirement (GQR) or 50% of the GQR or the maximum concentration quality requirement (MQR) and/or significant upward trends for specific nutrients and hazardous substances (Miljø- og Fødevareministeriet, 2017). For Skjern River Catchment concentrations of nickel, cadmium, zinc and DEHP are above GQR, MQR or 50% of GQR and will be further examined in tier 2.

TIER 2: Source apportionment of the specific substances identified as problematic in tier 1. A source apportionment of the yearly substance transport is performed using information about above-ground point sources. Only problem substances in which the 'diffuse' source constitutes more than 20% of the annual transport of the substance will proceed to the analysis in tier 3. For Skjern River Catchment all four substances will proceed to tier 3.

TIER 3: Analysis of the potential contact (PC) between the GWB and surface water bodies in the catchment based on the National Danish hydrological model (Trolborg et al, 2014). The analysis is performed using a distance requirement of less than 3 meter between the bottom of the stream and the water body for strong PC (red). For the Skjern River catchment many of the streams are red, which indicates a strong PC between the stream and associated GWB. Therefore, the assessment proceeds to tier 4.

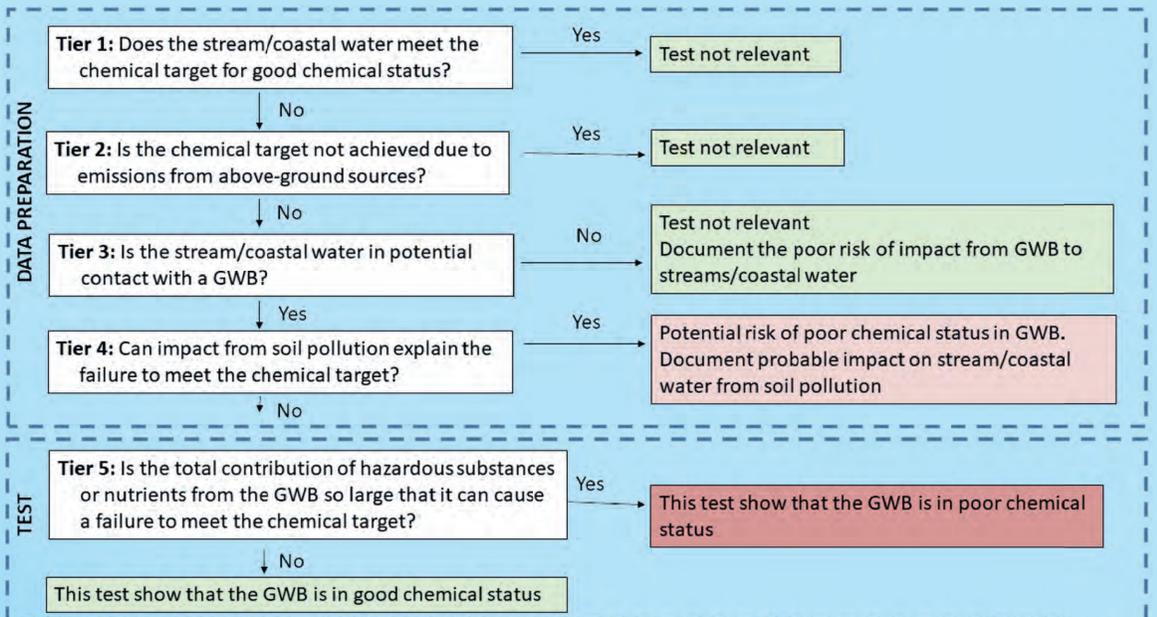
TIER 4: Quantification of the emission of relevant substances from sub-surface point sources to surface water bodies. The Danish Environmental Protection Agency's screening tool determines the areas with soil pollution that may be a risk for surface water. If the identified nearby soil pollution are considered to be significant source of the identified problem substances, the associated groundwater body is considered to be at risk of being in poor chemical status due to the sub-surface point sources. If the analysis rejects soil pollution as the probable source of the problem substances, the assessment proceeds to tier 5.

TIER 5: Analysis of the potential hydraulic contact (PHC) where the PC is supplemented by the PHC calculated by the DK-model. The contribution of groundwater in the stream coming from the GWB is calculated (Q95/Q50) and a screening is performed for the occurrence of the substances within a buffer of 250 m and 500 m. For the screening in Skjern River the available data for the substances are scarce. Seen the example for wells with zinc measurement within a 500 m buffer in Skjern. A combination of modelled groundwater discharge to the water body, chemical quality of the groundwater body and expert assessment of the substance transport and attenuation, the potential influence of each groundwater body for the chemical status of surface water is quantified and evaluated. Based on the available data, it cannot be excluded that the groundwater contributes to the pollution of Skjern river catchment with nickel and zinc.

CONCLUSION

The suggested screening method was found to be useful but it was seen that missing data made it impossible to complete some of the proposed tiers. Moreover, we concluded that more monitoring data for hazardous substances is needed in Denmark together with specific knowledge about the fate of hazardous substances between the GWB and surface waters, which is generally poorly established.

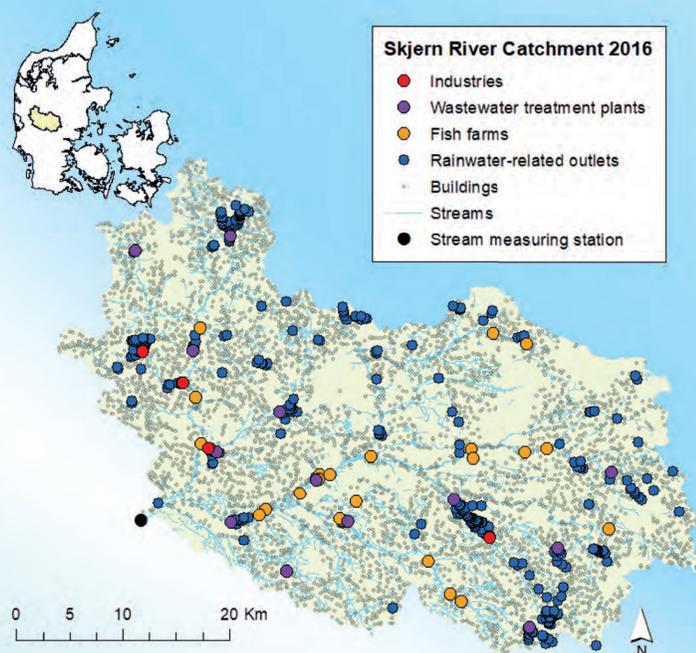
THE 5-TIER METHOD



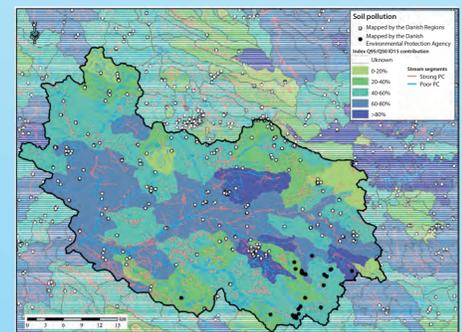
TIER 1

Tier 1: Skjern River Catchment				
Substances	Exceedances of the general quality requirement (GQR)	Exceedances of the max. conc. quality requirement (MQR)	50% of GQR	Trend
Nickel	-	-	+	-
Arsenic	-	-	-	Not possible
Barium	Not measured	Not measured	Not measured	Not measured
Mercury	-	-	-	Not possible
Copper	-	-	-	-
Cadmium	-	-	+	-
Zinc	+	+	+	+(not sig.)
Bentazone	-	-	-	+(not sig.)
BAM	-	-	-	-
Isoproturon	-	-	-	-
PFOs	Not measured	Not measured	Not measured	Not measured
DEHP	-	No MQR	+	+(sig.)
Trichloroethylen	-	No MQR	-	-
Vinylchloride	Not measured	Not measured	Not measured	Not measured

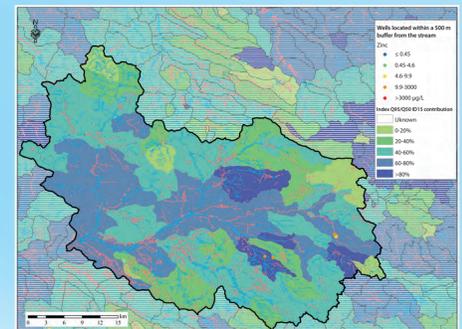
TIER 2



TIER 3 & 4



TIER 5



TIER 2

	Problem substances			
	DEHP**	Nickel	Zinc	Cadmium
Year	2006*	2016	2016	2016
Substance transport (kg/year)	712	2873	15557	29
Atmospheric deposit for surface water (kg/year)	-	1	55	-
From wastewater treatment plants in the catchment (kg/year)	22	54	609	1
From other point sources (subsurface and above-ground) and diffuse sources (kg/year)	690	2818	14893	28
From other point sources (subsurface and above-ground) and diffuse sources (%)	97	98	96	98

References

Miljø- og Fødevareministeriet (2017): Bekendtgørelse om fastlæggelse af miljømål for vandløb, søer, overgangsvande, kystvande og grundvand. BEK nr. 1625 af 27/12/2017. | Trolborg L., Sørensen B. L., Kristensen, M. og Mielby S. (2014): Afgrænsning af grundvandsforekomster. Tredje revision af grundvandsforekomster i Danmark. GEUS rapport 2014/58