Peltojen kipsikäsittelyn aiheuttaman vesistöjen sulfaattikuormituksen arviointi

Marie Korppoo and Markus Huttunen (24/06/2020)

1. Background

The aim of this project was to use the nutrient loading model WSFS-VEMALA to simulate the impact of gypsum treatment, applied on agricultural fields, on the sulphate concentrations in the water bodies of the Archipelago Sea catchment area. Using the sulphate specific load figures of gypsum-treated fields, provided by Petri Ekholm, and the calibration of the background loading prior to gypsum application as input data, the variation in sulphate load and concentration of rivers in the Archipelago Sea catchment area (catchments 24-31 and 82 except intermediate catchment areas, not Åland) in different weather conditions is simulated. VEMALA is run over the period 2010-2019 to account for weather variability and the annual maximum is averaged over the 10-year period for each stretch of river within the Archipelago Sea area. The results are presented in the form of a map and associated ascii files are provided to Varsinais-Suomen ELY-keskus to make a risk assessment of gypsum application to trout spawning areas in the Archipelago Sea catchment.

2. Methods

2.1. Description of the task

The specific load values for sulphate in forested areas, fields and plastered fields, as estimated by Petri Ekholm, are used as the starting data for the VEMALA simulations. The WSFS-VEMALA model simulates the transport of gypsum leaching from fields and forests in water bodies as sulphate concentrations. The simulation is performed for a period of 10 years to see the effect of the gypsum treatment under different water conditions. The simulation considers the maximum scenario of gypsum treatment so that the gypsum treatment is applied to all potential field plots within a catchment, i.e. those plots that are not in the catchment areas of lakes and whose soil type are not organic.

2.2. Experimental data

Using the data provided by Petri Ekholm (SYKE) on the experiments of gypsum application in Savijoki catchment, over the period 2016-2018, including runoff (mm) and annual sulphate loading from fields applied with gypsum as well as control fields (kg/km2/y), we calculated the extra concentration leached from gypsum applied fields per year (Table 1). We hypothesized that the sulphate leaching would return to background leaching on the 5th year after application. Using the observed extra sulphate concentrations available per year we used a logarithmic trend to predict the simulated extra sulphate concentrations per year from gypsum fields (Figure 1).
Table 1: Data provided by Petri Ekholm from the Savijoki experiment on gypsum application over the period 2016-2018 and data calculated for this project.

<table>
<thead>
<tr>
<th>Year after gypsum application</th>
<th>Runoff (mm)</th>
<th>Annual sulphate loading from gypsum fields kg/km²/y</th>
<th>Annual sulphate loading from control fields kg/km²/y</th>
<th>Extra sulphate concentration observed from gypsum fields (mg/L)</th>
<th>Extra sulphate concentration simulated from gypsum fields (mg/L)</th>
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<tbody>
<tr>
<td>1</td>
<td>274</td>
<td>41031</td>
<td>2708</td>
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<tr>
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<td>11630</td>
<td>2108</td>
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<td>75</td>
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<td>3</td>
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<td>54</td>
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<td>5</td>
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<td></td>
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<td>0</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td>2191</td>
<td>53</td>
</tr>
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</table>

Figure 1: Average extra annual sulphate concentration per year after gypsum application at the Savijoki experiment.

2.3. Simulation with VEMALA

2.3.1. Background simulation

The background simulation of sulphate concentrations is correlated in VEMALA to the runoff class although there was a very weak correlation in the Savijoki catchment between sulphate concentrations and discharge (Figure 2). The simulation using runoff classes allowed for a larger range of concentrations than the simulation of an average sulphate concentration from fields and forests. There are 5 runoff classes (mm) in this simulation; each associated with a leaching sulphate concentration (mg/L). The runoff classes are 0-0.03mm, 0.03-0.5mm, 0.5-3mm, 3-5mm, >5mm. The specific concentrations for each runoff classes are calibrated at the catchment scale with the sulphate concentrations observations for each catchment. Halikonjoki (26), Mynäjoki (30) and the coastal area of the Archipelago Sea catchments have no observations of sulphate concentrations; thus, we used the simulations of respectively Paimionjoki (27), Laajoki (31) and Aurajoki (28) catchments for the simulation of the background concentrations in these catchments.
2.3.2. Gypsum application

The agricultural fields where gypsum could be applied omitted agricultural fields on organic soil and agricultural fields within the catchment of a lake. For the purpose of understanding the impact of the sulphate concentrations in the water bodies regarding the sensitivity of salmon trout and mussels to sulphate concentrations in the water, two scenarios were chosen:

- Scenario 1: 100% of the fields where gypsum could be applied were simulated for Year1 leaching concentrations (132mg/L). The simulation was run over 2010-2019 period and calculation of the average maximum annual sulphate concentration was recorded per stretch of stream.
- Scenario 2: 100% of the fields where gypsum could be applied were simulated with an average extra concentration (53mg/L) representing a gypsum application of 20% of the catchment every year for 5 years. The simulation was run over 2010-2019 period and calculation of the average maximum annual sulphate concentration was recorded per stretch of stream.

3. Results

3.1 Background loading

Figure 3 presents the calibrated background loading simulations from VEMALA of the sulphate concentrations and loadings in most observation points including sulphate concentration records in the Archipelago Sea catchment. At most locations the model was able to simulate the mean of the sulphate concentrations as well as some of the intra-annual variation, except or the Aurajoki outlet (Aura 54, ohikulku va 6401) where the model underestimated the sulphate concentration in the river. The upstream observation point of Savijoki (Savi 12 mittapato) is on the contrary well simulated. Possible acid sulphate soil closer to the coast could explain this increase in sulphate concentrations at the outlet of Aurajoki catchment. Indeed, catchments with confirmed acid sulphate soils (Hirvijoki, Mynäjoki and Laajoki) have increase averaged sulphate concentrations (Figure 3).
Figure 3: Sulphate concentrations (mg/L) and loads (t/day) from the National observation points at the outlet of the Archipelago Sea catchments and from smaller rivers Savijoki, Vähäjoki, Hirvijoki and Lajajoki with observations in black cross and simulations in red line.
The analysis of the sulphate concentrations simulated and observed at Savi 12 mittapato over the period 2000-2020 show that the VEMALA model does not simulate well concentrations (Figure 4a), however sulphate loadings are very well simulated with an $r^2$ above 0.8 (Figure 4b).

<table>
<thead>
<tr>
<th>Alue</th>
<th>Pellot luonnon-huuh-touma t/v</th>
<th>Metsät luonnon-huuh-touma t/v</th>
<th>Kuorma pelto kg/km2/v</th>
<th>Kuorma Metsä kg/km2/v</th>
<th>Valuma mm/v</th>
<th>Pelto pinta-ala km2</th>
<th>Metsä pinta-ala km2</th>
<th>Maa pinta-ala km2</th>
<th>Koko pinta-ala km2</th>
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<td>3940</td>
<td>2171</td>
<td>296</td>
<td>308</td>
<td>560</td>
<td>868</td>
<td>875</td>
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<td>734</td>
<td>910</td>
<td>2392</td>
<td>1625</td>
<td>296</td>
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<td>560</td>
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<td>875</td>
</tr>
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Sulphate loading from various land use were also measured during the Kipsi project. Data from the project provided by Petri Ekholm showed an average background loading from agricultural fields of 2400 kg/km2/year and from forests on mineral soils of 1640 kg/km2/year. The results from the background simulations calibrated with VEMALA showed a higher sulphate loading from both agricultural fields (3940 kg/km2/year) and forests (2200 kg/km2/year) (Table 2). According to Ekholm et al. (2020), these loading values are too high with estimates of sulphate loading from forests of 1080 kg/km2/year. In these two simulations, urban areas are not contributing to the sulphate loading. This could explain an increased loading calibration from agricultural and forested areas to compensate for the omitted sulphate urban loading and other point sources.

### 3.2 Scenario 1

Scenario 1 depicts the effect of gypsum application on 100% of the agricultural areas of a catchment over one year. Although this is not realistic on a large scale, smaller catchments with fish spawning areas could see this scenario implemented.
3.2.1. Savijoki

During the KIPSI project, water samples were collected from Savi 10-tie Yliskulma and Savi Bränikkälentie on top of the regular sampling points of Savi 12 mittapato and Aura 54 ohikulku va 6401. In the KIPSI extra observation points, the highest sulphate concentrations (130 and 180 mg/L) occurred on the 23/11/2016 (Figure 5). Application of the gypsum in the Savijoki catchment took place between the 1/11/2016 – 31/12/2016. This maximum in not simulated by the VEMALA model, however the first year after application (2017) is well simulated by scenario 1. Therefore, the Autumn during gypsum application is the most sensitive time for the fish spawning areas with the highest recorded concentrations in the experimental application in Savijoki. VEMALA simulates well the high concentrations found after gypsum application, but not during the first autumn. VEMALA simulates maximum sulphate concentrations of about 67mg/L and 63mg/L for Savijoki and Aurajoki respectively (Figure 5).

3.2.2 Vähäjoki

VEMALA simulates maximum sulphate concentrations of about 62mg/L and 70mg/L for Vähäjoki and Paimionjoki respectively (Figure 6).
3.2.3. Archipelago Sea

The average maximum annual sulphate concentrations (mg/L) simulated by VEMALA over the Archipelago Sea area under Scenario 1 are presented in Figure 7 by range of concentrations from 0-25mg/L, 25-50mg/L, 50-100mg/L and above 100mg/L for each river stretch (associated file result: an1_kartta.asc). The map shows the areas most vulnerable to gypsum application like acid sulphate soil areas in Hirvijoki, Mynäjoki and Laajoki and upstream catchments of Uskelanjoki, Halikonjoki and Paimionjoki. The map also shows that if scenario 1 is implemented, meaning that gypsum is applied on
entire catchments within the same year, most of the Archipelago Sea catchment would reach sulphate concentrations above 50mg/L.

3.3 Scenario 2

Scenario 2 depicts the effect of gypsum application on 100% of the agricultural areas of a catchment over a five-year period (20% of the fields are applied each year).

3.3.1 Savijoki

VEMALA simulates maximum sulphate concentrations of about 36mg/L and 33mg/L for Savijoki and Aurajoki respectively (Figure 8).

3.3.2 Vähäjoki

VEMALA simulates maximum sulphate concentrations of about 34mg/L and 35mg/L for Vähäjoki and Paimionjoki respectively (Figure 9).

Figure 8: Sulphate concentrations (mg/L) from the Savijoki catchment and at the outlet of Aurajoki catchment with observations in black cross and simulations from scenario 2 in red line.

Figure 9: Sulphate concentrations (mg/L) from the Vähäjoki catchment and at the outlet of Paimionjoki catchment with observations in black cross and simulations from scenario 1 in red line.
3.3.3. Archipelago Sea

The average maximum annual sulphate concentrations (mg/L) simulated by VEMALA over the Archipelago Sea area under Scenario 2 are presented in Figure 10 by range of concentrations from 0-25mg/L, 25-50mg/L, 50-100mg/L and above 100mg/L for each river stretch (associated file result: an2 kartta.asc). The map shows that in this scenario, where gypsum is applied on 20% only of the catchments within the same year, no stretch of river exceeds an annual maximum concentration of 100mg/L unlike in Scenario 1 results. Also most of the Archipelago Sea catchment would not exceed sulphate concentrations above 50mg/L. However, there are still areas exceeding 50mg/L after gypsum application like acid sulphate soil areas in Hirvijoki, Mynäjoki and Laajoki and upstream catchments of Uskelanjoki, Halikonjoki and Paimionjoki.

4. Conclusion

The results presented in this report show the relative vulnerability of certain areas to gypsum application, especially the acid sulphate soil areas in Hirvijoki, Mynäjoki and Laajoki and upstream catchments of Uskelanjoki, Halikonjoki and Paimionjoki. These areas should be analysed regarding trout spawning areas to better understand the sulphate sensitive areas in the Archipelago Sea coastal areas. The results presented in this report are also provided as ascii files for further GIS analysis (an1 kartta.asc and an2 kartta.asc). Moreover, the VEMALA results for this project are published on the VEMALA interface under the title Kipsi and include background simulations, scenario 1 and 2 results for catchments (24, 25, 26, 27, 28, 29, 30, 31 and 82). Training on the use of the VEMALA interface to visualise and print the results at various locations and under various scenarios was also provided during this project to Pekka Salminen and Mirka Vainiomäki.
References


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