Nitrates in drinking water: a case study of the Mygdonia region in Thessaloniki (Greece)

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1. Introduction

Mygdonia is a 99,03 km^2 region in Northern Greece, consisting of the settlements Lete, Drymos, and Melissochori with a total population of ~10500 inhabitants (2011 Greek Census). The region's main activity is agricultural, foremost the cultivation of cereal crops. Mygdonia is situated atop of an extensive groundwater body[1], all drinking and irrigation water originating therefrom. High concentrations of nitrate ions (NO_3^-) have been recorded by the municipal authorities in the last decade (2008–2017), causing widespread alarm as drinking water nitrates are linked to adverse health effects of both acute and chronic nature[2,3], while excessive soil nitrate is implicated in reducing crop growth and yield[3,4]. This study was undertaken in order to assess the extent of nitrate pollution in drinking water from Mygdonia, examine trends, causes and contributing factors, and determine whether high-nitrate water can negatively affect plant development.

2. Research Methods

Research was conducted on the following stages: a) measurement of concurrent nitrate concentrations in the drinking water of Mygdonia; b) experimental evaluation of phytotoxicity due to high nitrate concentration water; c) statistical analysis of past nitrate data from Mygdonia; d) collection of data on regional hydrogeological features.

For the determination of nitrate content in waters from Mygdonia the spectrophotometric 2,6-xylenol method was utilised, using the TNTplus 836 kit. A total of 10 samples were obtained; 9 from Mygdonia (3 for each settlement) and a tenth from the neighbouring Oraiokastro region, where no nitrate problem is present, to be used as a reference. Sampling and subsequent measurements with a Hach DR 3900 spectrophotometer at λ=345 nm were conducted twice (25 Jan 2018 & 1 Mar 2018).

A phytotoxicity test was also carried out to examine possible effects of waters high in NO_3^-on the germination of seeds and early plant growth. The test was performed on plant species *Sorghum saccharatum* and *Sinapis alba* with a MicroBio Tests Phytotoxkit, while strictly adhering to ISO standard 18763:2016[5]. For each species, 3 control group –with distilled water– and 3 test group plates –with Drymos water– were inoculated with 10 seeds each. In the water from Drymos, $NaNO_3$ was added so as to reach 300 mg/L of NO_3^-, emulating chronic plant exposure to nitrates[3,4]. After a 72 h incubation, phytotoxicity was estimated by the inhibition of 3 factors: *i*) seed germination; *ii*) root growth; and *iii*) shoot growth.

Data was collected from the respective municipal authority ("*DEYAO*") pertaining to past nitrate measurements in Mygdonia. Initially partitioned into two sets (2008–2010 & 2012–2017) as different sampling points were adopted in the two periods, further information was requested on the water network structure enabling a uniform expression of data, in relation to supply sources rather than sampling points. Statistical trends were then calculated and graphed.

Lastly, the hydrogeological profile of Mygdonia was examined considering data from *DEYAO* and literature[1]. The plains of Mygdonia (Lete–Drymos–E. Melissochori) were found to be composed of extensive Quaternary sedimentary layers (sand, gravel, sandy clays, *etc.*), while the mountainous W. Melissochori lay on top of a calcareous flysch deposit. The main groundwater body is located in the respective sandy/phyllitic strata, mean well depths being 140–260 m.

3. Results

Table 1 - NO_3^- measurement results (NO_3^- mg/L)

Settlement			
Lete	Drymos	Melissochori	Oraiokastro
57,8	**66,7**	**7,5**	
59,3	**66,9**	**7,7**	**1,5**
60,4	**70,8**	**7,0**	

The sampling points' average results of the nitrate measurements conducted are briefly presented in Table 1. Levels higher than the maximum allowable (50 mg/L in the EU) were observed in Lete and Drymos, while samples from Melissochori were deemed acceptable.

The phytotoxicity experiment returned the following for *Sorghum saccharatum* and *Sinapis alba*, respectively: *i*) germination inhibition 0,00% & 3,45% (p=0,25); *ii*) root length inhibition 22,88% (p=0,03) & 30,31% (p=0,002); *iii*) shoot length inhibition 9,94% (p=0,30) & 4,68% (p=0,41). This demonstrates a significant hindrance of early plant growth caused by nitrate-rich water (in contrast to previous studies focusing only on soil nitrate content[4]), as root growth is the primary indicator thereof[5].

The statistical analysis of past data of nitrate levels in Mygdonia revealed consistently high (>50 mg/L) concentrations and corresponding slightly positive trends (+0,84 to +1,68 $mg \cdot L^{-1} \cdot annum^{-1}$) in the plain regions of Mygdonia, *per contra* to the acceptable levels and minimal negative trends of W. Melissochori (-0,66 to -0,29 $mg \cdot L^{-1} \cdot annum^{-1}$). Possible causes are discussed, the main focus being on use of N-fertilisers in crop production as has been targeted many times in existing literature[2,3].This was combined with the local hydrogeological characteristics, which indicate great vulnerability to nitrate penetration[2,3] for the granular soil of the plains of Mygdonia and a probable differentiated response of the mountainous flysch deposits. Finally, some suggestions for the nitrate problem's mitigation[2] are presented, relating to: fertiliser regulation and efficient use, catch-crop treatment, denitrifcation beds, modified water well construction, closer monitoring and complete mapping of the aquifer, *etc*.

4. Conclusion

Higher than allowable drinking water NO_3^- concentrations and rising trends were found in the plains of Mygdonia, the most populous part of the region. The situation is reversed in the mountainous part. Statistical data shows that this issue has been present for at least 10 years, while local lithostratigraphy implies increased sensitivity thereto. Phytotoxicity results hint danger to crops due to nitrate-rich groundwater, whereas agricultural activity is also the likely cause. Appropriate action for prevention and remediation is required.

5. References

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[5]*ISO 18763:2016(en)*; ISO: Geneva, CH, 2016.