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ORIGINAL ARTICLE

Nitrates in drinking water: relation with intensive livestock production

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Key words

Nitrates • Drinking water • Fish

Summary

Introduction. *An excess of nitrates causes environmental pollution in receiving water bodies and health risk for human, if contaminated water is source of drinking water. The directive 91/676/CEE [1] aims to reduce the nitrogen pressure in Europe from agriculture sources and identifies the livestock population as one of the predominant sources of surplus of nutrients that could be released in water and air. Directive is concerned about cattle, sheep, pigs and poultry and their territorial loads, but it does not deal with fish farms. Fish farms effluents may contain pollutants affecting ecosystem water quality.*
Methods. *On the basis of multivariate statistical analysis, this paper aims to establish what types of farming affect the presence of nitrates in drinking water in the province of Cuneo, Piedmont, Italy. In this regard, we have used data from official sources on nitrates in drinking water and data Arvet database, concerning the presence of intensive farming in the considered area. For model selection we have employed automatic variable selection algorithm.*
Results and discussion. *We have identified fish farms as a major source of nitrogen released into the environment, while pollution from sheep and poultry has appeared negligible. We would like to emphasize the need to include in the "Nitrate Vulnerable Zones" (as defined in Directive 91/676/CEE [1]), all areas where there are intensive farming of fish with open-system type of water use. Besides, aquaculture open-system should be equipped with adequate downstream system of filtering for removing nitrates in the wastewater.*

Introduction

Organic wastes are utilized in agriculture for improving the soil properties and as nutrient for growing crops [2]. Nitrogen surpluses increase levels of nitrogen compounds in surface and groundwater and become a health risk for animals [3] and humans, when polluted water is used to produce of drinking water [4]. In humans nitrate is reduced to nitrite that convert hemoglobin to methemoglobin, unable to transport oxygen [5]. The most appropriate means of controlling nitrate concentrations is the prevention of contamination [6]. Nitrate concentrations have increased in Europe in the last years and have doubled over the past 20 years. In the United Kingdom an average annual increase of 0.7 mg/l has been observed in some rivers [7]. In Denmark and the Netherlands nitrate concentrations are increasing by 0.2-1.3 mg/l per year [8]. In order to reduce excess of nitrogen, due to assessed agricultural sources and livestock farming, the Directive 91/676/CEE [1] was adopted by the European Commission. Such "Nitrates Directive" defines the "Nitrate Vulnerable Zones" as "areas draining into waters which are or could be affected by pollution and which contribute to pollution by intensive use of fertilizers or intensive livestock production". Nitrates Vulnerable Zones are areas where nitrate concentration in ground and in drinking water amount to 50 mg/l or more. In these zones the intensive use of fertilizers and the high animal densities contribute to environmental nitrate pollution, as acknowledged by European Water Framework Directive [9]. For reducing nitrate concentrations, specific and programmatic agricultural practices are adopted. To this purpose the Directive cares to report densities of some animal species farmed in Europe: cattle and dairy cattle, swine, poultry and sheep. However, the Directive does not seem to consider the potential environmental impact of fish farms, despite the fact Ling et al. [10] have shown that aquaculture is the major contributor to increasing the level of ecosystem pollution. According to Troell et al. [11], fish farms represents continuous or intermittent source of pollution. As a matter of fact, effluents may contain pollutants which have significant effects on water quality of ecosystem, especially when "flowthrough" o "open-system type" is adopted, discharging residues into water bodies surrounding [12]. Nitrogen compounds are the most widespread contaminants released by these types of breeding. Ryther and Dunstan [13] have shown that this type of pollution is a limiting factor in the growth of phytoplankton in costal and estuarine habitats and then it may lead to eutrophication. Therefore, it is reasonable to assume that the groundwater may be contaminated, thus having important effects on water for human consumption.

Methods

The analysis has focused on the drinking water supplied by water companies of 86 local municipalities in the province of Cuneo (44° 23' 00'' N, 7° 33' 00'' E). Data refer to 2012 and are obtained from Alpi Waters Spa website [14] and from the site www.cheacquabeviamo.it [15].
The studied area is characterized by relatively high degree of agricultural and breeding activity. Natural water is extracted from underground by about a thousand springs or wells, drilled in the mountains in the plains and starts in the ducts through tanks and reservoir. A small percentage comes from surface water. We have investigated the relationship between the content of nitrates in drinking water and the number of farms and the animal densities. These data refer to 2012 and are obtained from the Arvet dataset of the local Veterinary Service (ASL CN1).
Statistical analysis were performed using SAS program.

Results

The quantity of nitrate in the considered municipalities ranges from a minimum of 0.6 mg/l of drinking water and a maximum of 43.9 mg/l of drinking water. The mean, median and mode are respectively 11,01 mg/l, 6,95 mg/l, 1,5 mg/l (standard deviation 10,35; Skewness 1,45; Kurtosis 1,329). Using PROC UNIVARIATE we have rejected the null hypothesis of normal distribution (Shapiro-Wilk: $W = 0,815$ $p < 0,0001$; Kolmogorov-Smirnov: $D = 0,198$, $p < 0,0100$). For this reason, we have applied the logarithmic transformation to the data and then we have accepted the hypothesis of normality for the transformed dataset (Shapiro-Wilk: $W = 0,984$ $p = 0,3865$; Kolmogorov-Smirnov: $D = 0,060$, $p > 0,1500$).
According to the literature, we have investigated the relationship between the transformed Nitrate variable and the pollution from fertilizers and livestock or industrial wastewater. For this purpose, we have performed a simple regression analysis using the elevation of the municipalities, as the use of fertilizers and the presence of the waste decrease with the increase of altitude.
We have obtained the following equation:

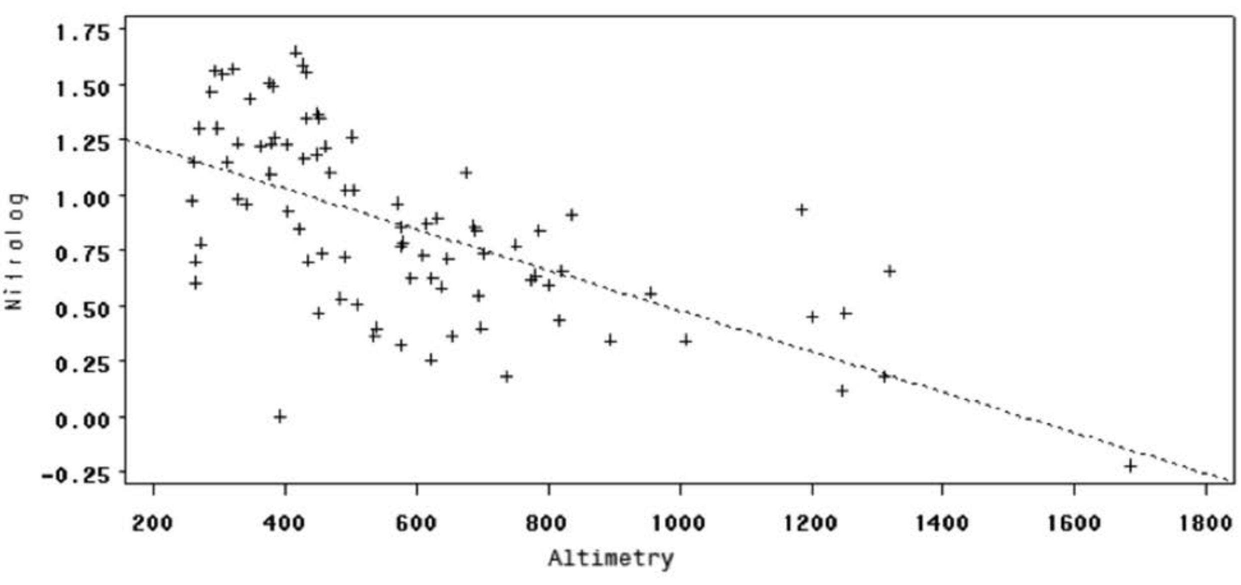
$$\text{Nitralog} = 1.39340 - 0.00091659*(\text{altimetry})$$

from which we can conclude that the logarithm of Nitrate concentration (Nitralog) negatively depends on the altimetry (Fig. 1). The t-test are significant ($p < 0.0001$) for both parameters.
Then we have considered several parametric models for predicting the dependence of the Nitralog variable on different types of farm. In particular, we have considered the following independent variables: altimetry, densities of cattle, sheep, horse, pig, poultry, rabbit and the density of fish farms. For the model selection we have employed the stepwise procedure of PROC REG. Using the adjusted R-squared (= 0.6016) and the Cp method (Cp = 3.8949), we have obtained the following model:

$$\text{Nitralog} = + (\text{cattle density}) + (\text{fish farms density}) + (\text{altimetry})$$

For the three independent variables the F-test are significant ($F = 35.68$, $p < 0.0001$; cattle density: $p < 0.0001$; fish farms density $p = 0.0183$; altimetry: $p = 0.0002$).

Fig. 1. Regression analysis: Altimetry vs Nitralog.



Tab. I. Estimates of the parameters with standard errors and p-values.

Parameter	Estimate	Standard error	*p*-value
β_0	0.95882	0.09911	< 0.0001
β_1	0.00171	0.00033369	< 0.0001
β_2	2.34190	0.96341	0.0183
β_3	-0.00049899	0.00012573	0.0001

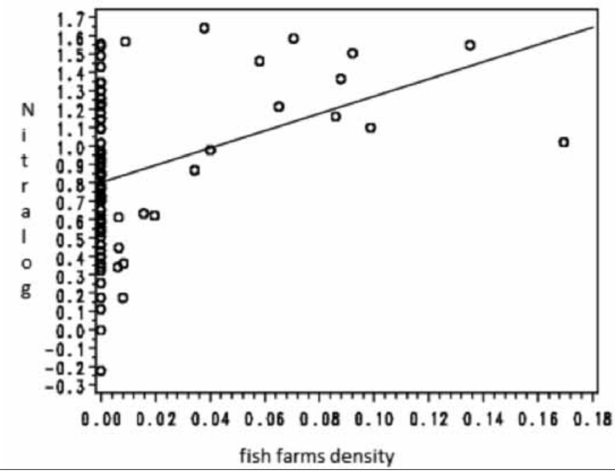
In the Table I we have reported estimates, their standard errors and p-values of the parameters.
The resulting model is given by:

$$\text{Nitralog} = 0.95882 + 0.00171*(\text{cattle density}) + 2.34190*(\text{fish farms density}) - 0.00049899*(\text{altimetry})$$

and explains 59% of the variability of Nitralog (= 0.5878; adjusted = 0.5727).

By means of PROC CORR we have shown in Figure 2 a positive correlation between the presence of nitrates in drinking water and density of fish farms, despite the fact that the correlation indices are not high (Pearson = 0.35854; Spearman = 0.24225).

Fig. 2. Regression analysis: Fish farms density vs Nitralog.



Discussion and conclusions

Nitrate pollution is widespread in the lowlands where livestock farms are more common than in mountain and foothill areas. About 59% of the nitrate variability is explained by the proposed model. On the basis of available data, it may be that there are other sources of nitrate pollution not included in the model (e.g. industrial and domestic effluents). However, we think that fish farms could play a role in increasing this type of pollution. As a matter of fact, large quantities of water that has not been properly filtered and has hosted a high concentration of farmed fish with protein feed, can release into to the environment a significant amount of nitrates and pollute the groundwater.
So, we believe that authorities responsible for controlling nitrates in surface and deep waters and for identifying the "Nitrate Vulnerable Zones", should also consider all areas where aquaculture is widespread. Moreover, such areas should be protected, making sure that the fisheries that adopt "open" farming method are equipped with appropriate filters for the uptake of nitrate and with systems for removing excess nutrients and fecal material before releasing the exploited water into the environment. This measure could be included as a part of good agricultural practices aimed at reducing the concentration of nitrates in water bodies of ecosystems.

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