# Decision Making Support Tool for Small Scale Water Supply located in Nitrates Vulnerable Zones

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**Abstract**
The paper presents a methodology to establish an environmental health risk index to be used as a decision making support tool for the designated Nitrates Vulnerable Zones (NVZ). In Romania there is a priority to elaborate action plans against water resources' pollution with nitrates from agricultural sources because the whole territory is declared vulnerable. The field work to ground the index was carried out within the project „Integrated Control of Nutrient Pollution", coordinated by the Ministry of the Environment, financed by GEF, and IBRD and covering 87 rural localities as demonstration centers.

**Keywords**
Nitrate vulnerable zones; small scale water supply; GIS; risk index; integrated control of nutrient pollution

## INTRODUCTION

The designation of nitrates vulnerable zones (NVZ) from agricultural sources (2008) showed that 60% of Romania's territory has to face this problem. The situation requires a tailored management that was developed within the Romanian Ministry of Environment's project "Integrated Nutrient Pollution Control", following three main directions: (i) reducing nutrient discharge into water bodies; (ii) promoting behavioral change at regional level; (iii) providing support to strengthen the regulatory framework and institutional capacity.

The presence of nutrients in the environment is vital for ecosystems, but whenever their concentrations exceed some limits the balance is broken and they contribute to the pollution of shallow aquifers used for drinking purpose in rural areas, or enhance the eutrophication of surface waters. Nitrogen and phosphorus compounds (nitrates, nitrites, ammonia, organic nitrogen, and phosphates) are considered to be polluting nutrients.

Danube is affected by nutrients' pollution; only during the period 1988-2005, the River transported to Romania an annual average of 35,000 tons of phosphorus and 40,000 tons of inorganic nitrogen. Among the 14 countries within the Danube basin, Romania has the largest drained area (29% of the total area of the basin) and the largest population (27%).

At the level of European Union, the management of waters' quality is established by a legal framework, represented by:

- Water Framework Directive (2000/60/EC), involving a quantitative and qualitative water management to support healthy ecosystems. The aim is to achieve the "good status" of waters by 2015;
- Directive on the conservation of waters against pollution caused by nitrates from agricultural sources (91/676/EEC), including connected issues of the protection of surface water intended for abstraction of drinking water (Directive 75/440/EEC) and the Directive on sludge from treatment plants (86/278/EEC);

- Directive on the quality of water intended for human consumption (98/83/EEC), with its further amendments.

Romania has committed to implement the obligations arising from EU Directives by achieving ecological and chemical status of water by management measures concerning organic pollutants, nutrients and hazardous substances, following the provisions of Law 107/1996 and GD 964/2000, representing the national transposition of EU legislation. In order to reach this target, the Romanian authorities received a loan from the World Bank and a financial aid from Global Environmental Fund (GEF). The rest of the budget for the implementation of Nitrates Directive is supported from National Administration of Romanian Waters' (ANAR) budget and by the contribution of local authorities. Within the implementation process, Romania has initially assigned in 2003 nitrate vulnerable zones (NVZ) for 255 regions, representing 8.64% of the total surface of the country, and 13.93% of the total agricultural surface.

The criteria to designate vulnerable areas were: natural status of soil, and two factors involved in the transfer of nitrate to ground and surface water - climate and hydrogeology. Based on nitrogen balance (nitrogen content of manure - nitrogen used by plants), have been identified three types of NVZs:

- *Potentially vulnerable areas*: favorable conditions for the transfer of nitrogen to water bodies, no positive nitrogen balance in the area, and less than 50 mg/l nitrate concentration in groundwater measured by ANAR network;
- *Areas vulnerable to actual sources*: favorable conditions for the transfer of nitrogen to water bodies, and a positive nitrogen balance in the area;
- *Vulnerable areas because of historical sources*: favorable conditions for the transfer of nitrogen to water bodies, no positive nitrogen balance of the area, presence of livestock, and nitrate concentration higher than 50 mg/l groundwater, measured by ANAR network.

The updated designation of NVZ (December 2008) increased their number to 1,963 communes, meaning 60% of the country's surface, and as a result of the update in 2012, EU Commission recommended to Romania to designate all its territory as a vulnerable area for pollution with nitrates. This situation requires measures for reducing nutrient discharge into water bodies, and promoting behavioral change at regional level. The development of a decision making support tool for small scale water supplies located in NVZ was necessary in order to enable the responsible authorities to make environmental interventions and minimize the health risk due to the consumption of drinking water contaminated with nitrates, such as Blue baby syndrome.

## METHODOLOGY

The field study presented in this paper is based on the assessment of the access of rural population living in NVZ to public water supply and sanitation, and measurements of well water quality that can be affected by agricultural practices and improper sanitation (pit latrines). The study aims to generate a tool for decision makers to ground the environmental investments and public health interventions in hot spot areas.

The model of establishing the risk index is based on the aggregation of data regarding drinking water supply, coverage with sewage services, level of nitrates in shallow wells used for drinking purposes in rural areas, aquifer depth, health risk score based on wells' sanitary inspection, degree of public awareness and education, existence of manure disposal facility, information that is vital for decision makers and public.

GIS tool was used to built a database and overlap the layers of information. The risk index was built to support the environmental decision (water resource protection, code of good agricultural practices, investments in manure disposal platforms, investments in water and sewage infrastructure, bins for domestic garbage), and public health protection (awareness programs for target groups within the health risk areas, adequate behavior to prevent the occurrence of Blue baby disease, and train the trainers programs).

## RESULTS

87 rural localities representative for NVZ, located in 34 counties all over the country, having a population in range of 1,000-37,000 inhabitants, were selected. In each locality, water samples from private and public drinking water supplies were analyzed on site, using rapid field kits for nitrates (110092 Merckoquant® Nitrate). The sampling points were recorded and represented in Geographic Information System (GIS) format, and the concentration of nitrates found in each sample was compared with the maximum admissible concentration (MAC) of 50 mg/l $NO^{-}_{3}$.

45% of population is living in rural areas in Romania, and many villages located in NVZ are not connected at centralized drinking water (DW) and sewage systems, see table 1. In rural localities sanitation means a pit latrine that allow the infiltration of fecal material into the soil and aquifer, polluting the shallow wells used for drinking purposes with nutrients and pathogens. EU Guidelines recommend sealed septic tanks and the transportation of their content to a waste water treatment plant; Romania adopted the same requirements.

**Table 1.** Population coverage by public water supply and sewage systems

| Crt. No. | Locality | County | Population | Population connected to public DW systems % | DW Treatment Station | Population connected to sewage systems % | Waste Water Treatment Plant |
|---|---|---|---|---|---|---|---|
| 1. | Todirești | Suceava | 6,500 | - | - | - | - |
| 2. | Gura Humorului | Suceava | 15,800 | 78 | yes | 70 | |
| 3. | Gălănești | Suceava | 2,700 | - | - | - | - |
| 4. | Vicovu de Sus | Suceava | 14,700 | 65 | yes | - | - |
| 5. | Frasin | Suceava | 5,900 | 25 | yes | - | - |
| 6. | Gherăești | Neamț | 6,500 | 65 | yes | 50 | yes |
| 7. | Bodești | Neamț | 5,150 | 65 | yes | - | - |
| 8. | Costișa | Neamț | 3,650 | - | - | - | - |
| 9. | Zănești | Neamț | 6,135 | 90 | yes | - | - |
| 10. | Prejmer | Brașov | 9,300 | 80 | yes | - | - |
| 11. | Halchiu | Brașov | 4,100 | 100 | yes | - | - |
| 12. | Dumbrăvița | Brașov | 5,100 | 100 | yes | - | - |
| 13. | Ozun | Covasna | 4,350 | 51 | - | 44 | yes |
| 14. | Cernat | Covasna | 4,000 | 90 | yes | 50 | yes |
| 15. | Sântimbru | Alba | 3,000 | 85 | yes | 60 | yes |
| 16. | Geoagiu | Hunedoara | 5,000 | 60 | yes | 60 | yes |
| 17. | Bălești | Gorj | 7,600 | 45 | yes | 40 | yes |
| 18. | Ghercești | Dolj | 1,650 | 35 | yes | - | - |
| 19. | Fărcaşele | Olt | 1,700 | 40 | yes | - | - |
| 20. | Traian | Olt | 3,300 | - | - | - | - |
| 21. | Odorheiul Secuiesc | Harghita | 33,000 | 99 | yes | 95 | yes |

| Crt. No. | Locality | County | Population | Population connected to public DW systems % | DW Treatment Station | Population connected to sewage systems % | Waste Water Treatment Plant |
|---|---|---|---|---|---|---|---|
| 22. | Gârla Mare | Mehedinţi | 3,500 | 25 | yes | 10 | yes |
| 23. | Crăieşti | Mureş | 883 | - | yes | - | - |
| 24. | Gorneşti | Mureş | 5,856 | 70 | yes | 5 | yes |
| 25. | Bocsig | Arad | 3,200 | 100 | yes | | |
| 26. | Macea | Arad | 5,680 | 90 | yes | - | - |
| 27. | Pecica | Arad | 13,500 | 30 | yes | 10 | yes |
| 28. | Maşloc | Timiş | 2,315 | 30 | yes | - | - |
| 29. | Parţa | Timiş | 2,200 | 100 | yes | - | - |
| 30. | Peciu Nou | Timiş | 5,213 | 90 | yes | 25 | yes |
| 31. | Şag | Timiş | 3,000 | 90 | yes | - | - |
| 32. | Gătaia | Timiş | 5,400 | 60 | yes | 20 | - |

Water samples from 408 wells used for drinking purpose were analyzed during the period June–September 2012, the mean values of the nitrates concentrations being shown in table 2. Nitrates concentrations exceeded MAC of 50mg/l in 47% of the analyzed wells' water samples.

**Table 2.** $NO^-_3$ levels in well water from rural localities designated as NVZ

| Crt. No. | Locality | County | Well water quality (% wells) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0 – 10 mg $NO^-_3$/l | 11 – 25 mg $NO^-_3$/l | 26 – 50 mg $NO^-_3$/l | 51 – 100 mg $NO^-_3$/l | 101 – 500 mg $NO^-_3$/l |
| | | | <MAC (50mg/l) | | | >MAC (50mg/l) | |
| 1. | Todirești | Suceava | - | - | 16.66 | 83.33 | - |
| 2. | Gura Humorului | Suceava | 16.66 | 50 | 33.33 | - | - |
| 3. | Gălănești | Suceava | 40.00 | 40.00 | 20.00 | - | - |
| 4. | Vicovu de Sus | Suceava | 20.00 | 60.00 | 20.00 | - | - |
| 5. | Frasin | Suceava | 75.00 | 25.00 | - | - | - |
| 6. | Gherăești | Neamț | - | - | - | 40.00 | 60.00 |
| 7. | Bodești | Neamț | - | 100 | - | - | - |
| 8. | Costișa | Neamț | 33.33 | 33.33 | 33.33 | - | - |
| 9. | Zănești | Neamț | 20.00 | | 80.00 | - | - |
| 10. | Dumbrava Roșie | Neamț | 20.00 | 20.00 | 60.00 | - | - |
| 11. | Prejmer | Brașov | 100 | - | - | - | - |
| 12. | Halchiu | Brașov | 100 | - | - | - | - |
| 13. | Ozun | Covasna | - | - | - | 33.33 | 66.66 |
| 14. | Cernat | Covasna | - | - | - | 66.66 | 33.33 |
| 15. | Sântimbru | Alba | 50.00 | - | 16.66 | 16.66 | 16.66 |
| 16. | Geoagiu | Hunedoara | - | 20.00 | 40.00 | 40.00 | - |
| 17. | Bălești | Gorj | 25.00 | 37.50 | 37.50 | - | - |
| 18. | Ghercești | Dolj | - | - | 16.66 | 16.66 | 66.66 |
| 19. | Fărcaşele | Olt | - | - | 40.00 | 60.00 | - |
| 20. | Traian | Olt | - | - | 25.00 | 75.00 | - |
| 21. | Odorheiu | Harghita | 60.00 | 20.00 | 20.00 | - | - |

| Crt. No. | Locality | County | Well water quality (% wells) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0 – 10 mg $NO^-_3$/l | 11 – 25 mg $NO^-_3$/l | 26 – 50 mg $NO^-_3$/l | 51 – 100 mg $NO^-_3$/l | 101 – 500 mg $NO^-_3$/l |
| | | | <MAC (50mg/l) | | | >MAC (50mg/l) | |
| | Secuiesc | | | | | | |
| 22. | Gârla Mare | Mehedinţi | - | - | 28.57 | 42.85 | 28.57 |
| 23. | Crăieşti | Mureş | 33.33 | 16.66 | - | 33.33 | 16.66 |
| 24. | Gorneşti | Mureş | 14.28 | 14.28 | 57.14 | 14.28 | - |
| 25. | Bocsig | Arad | - | 28.57 | 42.85 | 14.28 | 14.28 |
| 26. | Macea | Arad | - | 10.00 | 15.00 | 30.00 | 45.00 |
| 27. | Pecica | Arad | - | - | - | 25.00 | 75.00 |
| 28. | Maşloc | Timiş | 36,36 | 18.18 | 9.09 | - | 36.36 |
| 29. | Parţa | Timiş | 22.22 | - | 11.11 | 22.22 | 44.44 |
| 30. | Peciu Nou | Timiş | 14.28 | 14.28 | - | - | 71.42 |
| 31. | Şag | Timiş | 50.00 | 8.33 | 16.66 | 8.33 | 16.66 |
| 32. | Gătaia | Timiş | 50.00 | - | 25.00 | - | 25.00 |

Rural localities included in the study and nitrates levels in well water samples are the layers of information represented in GIS, in figure 1.

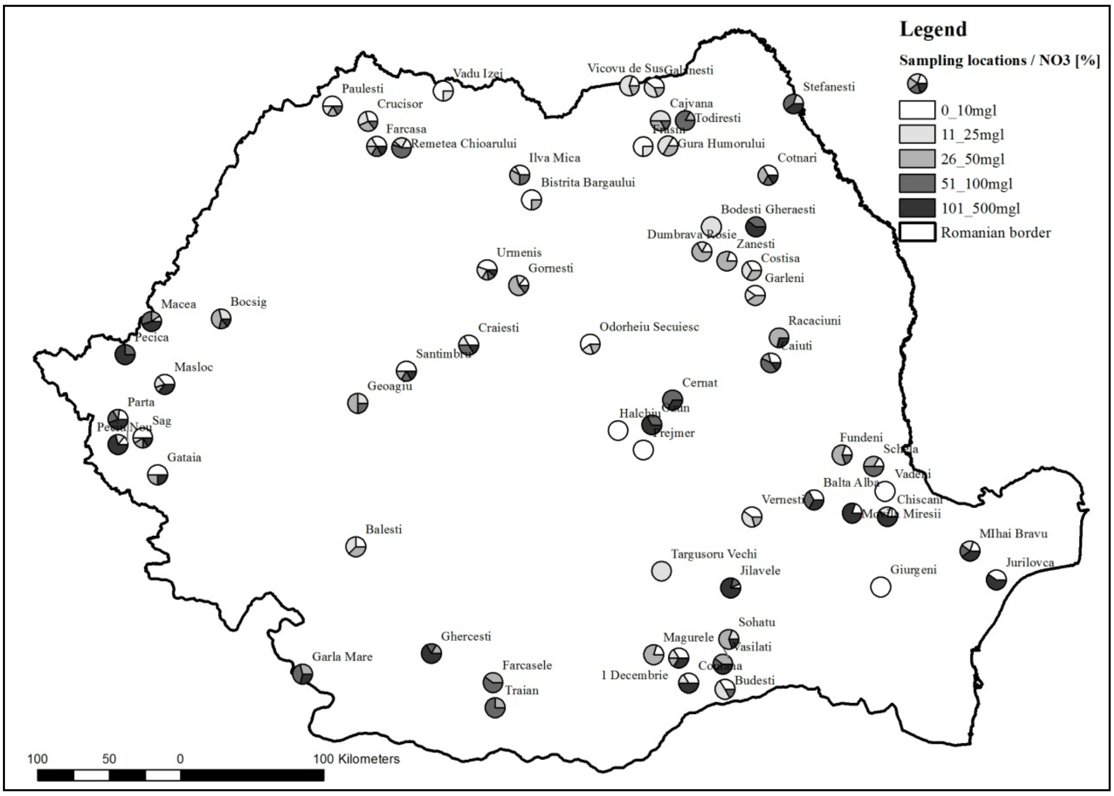


**Figure 1.** Nitrates levels in well water located in NVZ

Wells from which samples were taken to be analyzed were also subject to a sanitary inspection that looked at the condition of wells' construction and hygiene, highlighting several weak points: nitrates' pollution from agricultural sources, is complemented by: (i) inadequate sanitation (human faces); (ii) lack of household and yard hygiene; (iii) inadequate location of the well towards the house, animal barn, manure disposal, pit latrine, domestic garbage, vegetable garden, house.

For the first attempt of risk index (RI) calculation it was considered a sample of 12 localities, the calibration of the formula being carried out on 32 rural localities presented in this paper. The components of the index have been designed to assess the risk for the population and as subordinate priority to the environment (e.g. eutrophication). The formula for risk index calculation is:

$$RI = kr*WS+kr*SW+kr*N+kr*GWL+kr*WRS+kr*PK+kr*SF+kr*AP$$

Where: kr = coefficient of relevance, WS = connection to water supply, SW = connection to sewage system, N = nitrate concentration in well water, GWL = ground water level, WRS = well's risk score, PK = population level of knowledge, SF = storage facility, and AP = size of affected population. The higher is RI value, the higher is the risk for the population.

The coefficient of relevance (kr) is a parameter characterizing the locality, not the household, and the components N, GWL, WRS and PK are the average values from at least 10 sampling points with a relevant distribution in the village. Kr indicates the significance of the contribution of each parameter to the final component of the risk index, see table 3.

**Table 3**. The weight of each parameter in the correlation coefficient

| Component | WS | SW | N | GWL | WRS | PK | SF | AP Size |
|---|---|---|---|---|---|---|---|---|
| Coefficient of relevance | 4 | 3 | 2 | 2 | 1 | 2 | 3 | 1 – (< 2,000)<br>2 – (2,001 – 5,000)<br>3 – (5,001 – 10,000)<br>4 (> 10,001) |

Data concerning population connection at central drinking water supply (WS) is quantified with 1 if the answer is NO, and [1-(%/100)] if the answer is YES. Data concerning population connection at central sewage system (SW) is quantified with 1 if the answer is NO, and [1-(%/100)] if the answer is YES. The level of nitrate in ground water (N), measured on site, receives a score according to its range of concentration: 0 for 0-50 mg/l; 1*kr for 50.1–100 mg/l; 2*kr for 100.1–250 mg/l, and 3*kr for > 250.1 mg/l. Level of groundwater (GWL) measured on the field during the sanitary inspection, receives the following scores: 1 for >10.1m depth; 2 for 5.1-10m depth; 3 for 2.1-5m depth; 4 for 0-2m depth. The risk score of the well (WRS) calculated based on sanitary inspection recording forms is quantified as follows: 0 for 0-2 risk points; 1*kr 2.1-5.9 risk points; 2*kr for 6-8.9 risk points; 3*kr for 9-12 risk points. The knowledge level of population (PK) concerning the sources of pollution with nutrients and the impact on public health, based on questions addressed to the owners of the wells is quantified as follows: 0 for good level; 1 for average; 2 for poor. The presence or absence of a disposal facility for manure (SF) receives 0 for a platform complying with legal requirements, 1 for the existence of other similar storage facilities, and 2 for the absence of any manure storage facility. The size of affected population (AP) is linked in the calculation formula with population coverage with drinking water supply (WS), and sewage systems (SW).

Risk assessment score criteria generating a risk in the range of 2-62, is shown in table 4; the higher the score, the higher the risk is.

**Table 4.** Risk assessment scores

| Crt. No. | Criteria | Score | |
|---|---|---|---|
| | | minimum | maximum |
| 1. | Water Supply (WS) | 0 | 4 |
| 2. | Sewage System (SW) | 0 | 3 |
| 3. | Nitrates concentrations in ground water (N) | 0 | 6 |
| 4. | Ground water level (GWL) | 2 | 8 |
| 5. | Well's risk score (WRS) | 0 | 3 |
| 6. | Level of knowledge in population (PK) | 0 | 4 |
| 7. | Presence/ absence of manure storage platform/ similar facilities (SF) | 0 | 6 |
| 8. | Size of affected population (AP) | 0 | 28 |
| | **Total** | **2** | **62** |

The relevant information about the localities included in the study in order to calibrate the risk index RI is shown in table 5.

**Table 5.** Information about the sample of localities used to calibrate RI

| Crt. No. | Locality | County | Population | Population connected to public DW systems % | Population connected to sewage systems % | $NO^-_3$ in DW (mg/l)* | Ground water level (m)* | Well Risk Score* | Level of population information | Manure disposal facility |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Todirești | Suceava | 6,500 | - | - | 91.66 | 9.75 | 2.00 | Average | Yes |
| 2. | Gura Humorului | Suceava | 15,800 | 78 | 70 | 29.16 | 1.66 | 4.16 | Average | Yes |
| 3. | Gălănești | Suceava | 2,700 | - | - | 24.00 | 6.20 | 0.60 | Poor | Yes |
| 4. | Vicovu de Sus | Suceava | 14,700 | 65 | - | 25.00 | 13.40 | 2.20 | Poor | Yes |
| 5. | Frasin | Suceava | 5,900 | 25 | - | 8.75 | 15.75 | 2.50 | Average | Yes |
| 6. | Gherăești | Neamț | 6,500 | 65 | 50 | 160.00 | 5.50 | 0.00 | Poor | Yes |
| 7. | Bodești | Neamț | 5,150 | 65 | - | 24.00 | 6.40 | 0.60 | Poor | Yes |
| 8. | Costișa | Neamț | 3,650 | - | - | 25.00 | 6.00 | 4.33 | Poor | No |
| 9. | Zănești | Neamț | 6,135 | 90 | - | 42.00 | 7.20 | 0.40 | Average | No |
| 10. | Dumbrava Roșie | Neamț | 9,300 | 80 | - | 27.00 | 5.90 | 0.20 | Average | Yes |
| 11. | Prejmer | Brașov | 4,100 | 100 | - | 0.00 | 8.70 | 8.00 | Average | Yes |
| 12. | Halchiu | Brașov | 5,100 | 100 | - | 10.00 | 9.50 | 1.00 | Average | Yes |
| 13. | Ozun | Covasna | 4,350 | 51 | 44 | 200.00 | 12.00 | 4.33 | Average | Yes |
| 14. | Cernat | Covasna | 4,000 | 90 | 50 | 191.66 | 11.50 | 4.00 | Average | Yes |
| 15. | Sântimbru | Alba | 3,000 | 85 | 60 | 71.66 | 8.60 | 5.16 | Poor | Yes |
| 16. | Geoagiu | Hunedoara | 5,000 | 60 | 60 | 65.00 | 7.40 | 2.60 | Average | No |
| 17. | Bălești | Gorj | 7,600 | 45 | 40 | 30.62 | 6.50 | 2.37 | Average | Yes |
| 18. | Ghercești | Dolj | 1,650 | 35 | - | 316.66 | 7.30 | 1.33 | Average | Yes |
| 19. | Fărcaşele | Olt | 1,700 | 40 | - | 80.00 | 6.50 | 3.40 | Average | Yes |
| 20. | Traian | Olt | 3,300 | - | - | 87.50 | 6.80 | 3.75 | Average | Yes |
| 21. | Odorheiul Secuiesc | Harghita | 37,000 | 100 | 95 | 19.00 | 8.00 | 2.00 | Average | Yes |
| 22. | Gârla Mare | Mehedinţi | 3,500 | 30 | - | 164.00 | 6.00 | 4.00 | Average | Yes |
| 23. | Crăiești | Mureş | 883 | - | - | 82.50 | 2.33 | 3.66 | Poor | Yes |
| 24. | Gornești | Mureş | 5,856 | 70 | 5 | 46.42 | 5.00 | 4.00 | Poor | Yes |
| 25. | Bocsig | Arad | 3,200 | 100 | - | 78.57 | 17.00 | 4.00 | Poor | Yes |
| 26. | Macea | Arad | 5,680 | 90 | - | 202.50 | 4.72 | 4.12 | Poor | No |
| 27. | Pecica | Arad | 13,500 | 30 | 10 | 158.57 | 4.00 | 5.33 | Average | Yes |
| 28. | Maşloc | Timiş | 2,315 | 30 | - | 146.36 | 2.96 | 2.40 | Poor | No |
| 29. | Parţa | Timiş | 2,200 | 100 | - | 194.44 | 6.00 | 5.00 | Poor | No |
| 30. | Peciu Nou | Timiş | 5,213 | 90 | 25 | 289.28 | 4.40 | 6.00 | Poor | Yes |
| 31. | Şag | Timiş | 3,000 | 90 | - | 82.00 | 5.71 | 1.83 | Poor | No |
| 32. | Gătaia | Timiş | 5,400 | 60 | 20 | 77.50 | 3.40 | 4.00 | Average | No |

*) average value

The calculation of the risk index RI is summarized in table 6.

**Table 6**. Risk index (RI) for the localities included for calibration purposes

| Crt. No. | Locality | County | WS | SW | N | GWL | WRS | PK | SF | AP | **RI** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Todirești | Suceava | 4.00 | 3.00 | 2 | 4 | 0 | 2 | 0 | 21.00 | **36.00** |
| 2. | Gura Humorului | Suceava | 0.88 | 0.90 | 0 | 8 | 1 | 2 | 0 | 7.12 | **19.90** |
| 3. | Gălănești | Suceava | 4.00 | 3.00 | 0 | 4 | 0 | 4 | 0 | 14.00 | **29.00** |
| 4. | Vicovu de Sus | Suceava | 1.40 | 3.00 | 0 | 2 | 0 | 4 | 0 | 17.60 | **28.00** |
| 5. | Frasin | Suceava | 3.00 | 3.00 | 0 | 2 | 0 | 2 | 0 | 18.00 | **28.00** |
| 6. | Gherăești | Neamț | 1.40 | 1.50 | 4 | 4 | 0 | 4 | 0 | 8.70 | **23.60** |
| 7. | Bodești | Neamț | 1.40 | 3.00 | 0 | 4 | 0 | 4 | 0 | 13.20 | **25.60** |
| 8. | Costișa | Neamț | 4.00 | 3.00 | 0 | 4 | 1 | 4 | 6 | 14.00 | **36.00** |
| 9. | Zănești | Neamț | 0.40 | 3.00 | 0 | 4 | 0 | 2 | 6 | 10.20 | **25.60** |
| 10. | Dumbrava Roșie | Neamț | 0.80 | 3.00 | 0 | 4 | 0 | 2 | 0 | 11.40 | **21.20** |
| 11. | Prejmer | Brașov | 0.00 | 3.00 | 0 | 4 | 2 | 2 | 0 | 6.00 | **17.00** |
| 12. | Halchiu | Brașov | 0.00 | 3.00 | 0 | 4 | 0 | 2 | 0 | 9.00 | **18.00** |
| 13. | Ozun | Covasna | 1.96 | 1.68 | 4 | 2 | 1 | 2 | 0 | 7.28 | **19.92** |
| 14. | Cernat | Covasna | 0.40 | 1.50 | 4 | 2 | 1 | 2 | 0 | 3.80 | **14.70** |
| 15. | Sântimbru | Alba | 0.60 | 1.20 | 2 | 4 | 1 | 4 | 0 | 3.60 | **16.40** |
| 16. | Geoagiu | Hunedoara | 1.60 | 1.20 | 2 | 4 | 0 | 2 | 6 | 5.60 | **22.40** |
| 17. | Bălești | Gorj | 2.20 | 1.80 | 0 | 4 | 0 | 2 | 0 | 12.00 | **22.00** |
| 18. | Ghercești | Dolj | 2.60 | 3.00 | 6 | 4 | 0 | 2 | 0 | 5.60 | **23.20** |
| 19. | Fărcaşele | Olt | 2.40 | 3.00 | 2 | 4 | 1 | 2 | 0 | 5.40 | **19.80** |
| 20. | Traian | Olt | 4.00 | 3.00 | 2 | 4 | 1 | 2 | 0 | 14.00 | **30.00** |
| 21. | Odorheiul Secuiesc | Harghita | 0.00 | 0.15 | 0 | 4 | 0 | 2 | 0 | 0.60 | **6.75** |
| 22. | Gârla Mare | Mehedinți | 2.80 | 3.00 | 4 | 4 | 1 | 2 | 0 | 11.60 | **28.40** |
| 23. | Crăieşti | Mureş | 4.00 | 3.00 | 2 | 6 | 1 | 4 | 0 | 7.00 | **27.00** |
| 24. | Gorneşti | Mureş | 1.20 | 2.85 | 0 | 6 | 1 | 4 | 0 | 12.15 | **27.20** |
| 25. | Bocsig | Arad | 0.00 | 3.00 | 2 | 2 | 1 | 4 | 0 | 6.00 | **18.00** |
| 26. | Macea | Arad | 0.40 | 3.00 | 4 | 6 | 1 | 4 | 6 | 10.20 | **34.60** |
| 27. | Pecica | Arad | 2.80 | 2.70 | 4 | 6 | 1 | 2 | 0 | 22.00 | **40.50** |
| 28. | Maşloc | Timiş | 2.80 | 3.00 | 4 | 6 | 1 | 4 | 6 | 11.60 | **38.40** |
| 29. | Parţa | Timiş | 0.00 | 3.00 | 4 | 4 | 1 | 4 | 6 | 6.00 | **28.00** |
| 30. | Peciu Nou | Timiş | 0.40 | 2.25 | 6 | 6 | 2 | 4 | 0 | 7.95 | **28.60** |
| 31. | Şag | Timiş | 0.40 | 3.00 | 2 | 4 | 0 | 4 | 6 | 6.80 | **26.20** |
| 32. | Gătaia | Timiş | 1.60 | 2.40 | 2 | 6 | 1 | 2 | 6 | 12.00 | **33.00** |

The following risk thresholds and their significance for the population safety were established:

$2 \leq RI \leq 10$ = low risk for the population living in locality
$11 \leq RI \leq 20$ = average risk for the population living in locality
$21 \leq RI \leq 62$ = high risk for the population living in locality.



Within the group of localities taken into consideration for risk index calibration 3.13% have a RI score indicating a low risk, 28.13% present an average risk, and the rest of 68.74% are at high risk, values matching with the situation met in the field, see figure 2.

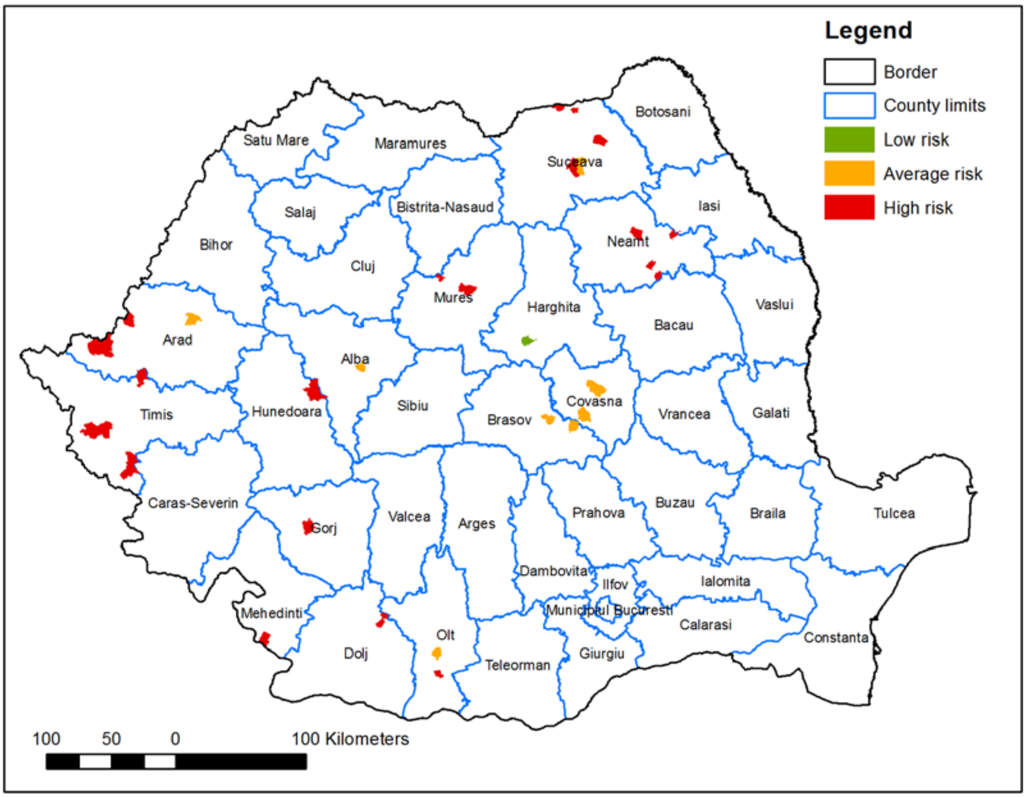


**Figure 2.** Risk index (RI) for the localities included for calibration purposes

**CONCLUSIONS**

Risk Index (RI) is based on the assumption that all risks are systematically identified, analyzed and evaluated. The risk index can be used as a decision making support to increase the efficiency of the environmental and public health interventions and investments to the hot spot areas; localities with a high RI should be addressed with priority. The study showed that this is the case of approximately 69% of rural localities that were the subject of the present analyses.

When well water is already heavily contaminated with nitrates, short term and medium term solution have to be provided to the population, as well as the advice for technical and health issues such the occurrence of Blue Baby Syndrome.

GIS proved to be a useful analysis tool for the various data characterizing small scale water supplies located in NVZ generating a risk index that gives the hierarchy of the problems needed to be addressed and carefully managed by the responsible authorities, for a successful implementation of the requirements of Nitrate Directive and Drinking Water Directive. GIS used as a decision making support could increase the efficiency of the environmental and public health interventions and investments in areas at risk.

Inter-institutional cooperation is vital for solving these kinds of problems. Population information and education is also a basic pillar for the behavioral changes on long term.

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