Chapter

Groundwater Protection Legislation in Slovenia: Theory and Practice

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Abstract

As an EU member, Slovenia implemented the Water Framework Directive (WFD) guidelines into national legislation quite successfully, but in many parts of the country, groundwater is still under threat, mainly from nitrate. The problematic areas, as is the case in many other EU countries, are mostly shallow-soiled alluvial plains. Their groundwater is the country's biggest source of drinking water, but at the same time, the fertile soil on their flat surface is considered to be the most suitable for agricultural activities. We are aiming to provide an overview of groundwater protection practices in Slovenia. To evaluate the "theory," we will take a close look at the national legislation concerning the subject. From the "practical" perspective, we will research what guidelines and solutions were drawn from legislation to comply with WFD objectives. Furthermore, we will also discuss the current activities aimed at improving Slovenia's groundwater status.

Keywords: groundwater protection, legislation, Water Framework Directive, nitrate, agriculture, best management practices, shallow soil, alluvial plain, drinking water

1. Introduction

Groundwater in Slovenia, as well as in many places across the globe, is the main source of drinking water. Apart from its use for drinking, it is often used for irrigation and other purposes. This makes groundwater valuable, and since it generally does not renew very quickly, it is often—as is the case in Slovenia—protected by national legislation. Quantity, however, is not the only issue we are facing in regards to groundwater. With the rapid increase in use of mineral nitrogen fertilizers and different agricultural as well as industrial chemicals in the past century, many of these substances found their way into groundwater. In last few decades—since the pollution was becoming more and more severe and even health threatening—a lot was done in terms of improving groundwater protection. Slovenia as an European Union member formed its legislation based on Water Framework Directive (WFD) and its recommendations. But despite that, groundwater status in some parts of the country is still not adequate, mostly because of the presence of nitrate. Main vulnerable areas are large alluvial plains—their flatness makes them very suitable for agricultural production, but their shallow soils make almost every activity on top of them affect the groundwater quality. The struggle is real, and on the following pages, we are about to uncover the theory and practice behind the groundwater protection in Slovenia.

2. Groundwater pollution in Slovenia—the background

Slovenia is not a big country at just over 20,000 km^2. It is, however, very diverse in terrain and climate. In north-west, it touches the Alps, in south-west, the Adriatic Sea, and in north-east, the Pannonian Basin. Except for the latter part, most of its relief consists of hills and mountains, and the only larger flat areas are alluvial plains, whose aquifers serve as storage for the majority of country's groundwater. Climate follows the characteristics of terrain, which means that the western parts of the country get 2,000 and up to 3,000 mm, while the north-east can get as little as 800 mm of rain in a year. The abundance of rain is the main reason for Slovenia's groundwater capacities, but the seasonal variability in recent years is not best suited for agriculture, as peaks are moving more and more into autumn, while in other seasons, rainfall is diminishing [1].

As mentioned above, main reservoirs of groundwater are located under alluvial plains. These are also centers of agricultural production, with intensive arable rotations and vegetable fields, but in some areas also orchards. According to National Environmental Agency (ARSO), the main problematic areas are Murska kotlina, Dravska kotlina, Savinjska kotlina, and Krška kotlina, labeled in top to bottom order in **Figure 1** with an exclamation mark sign. It is quite easy to notice that they share a similar type of an aquifer, and the depth from ground surface to it is often times as shallow as 1–2 m. Views from Murska kotlina and Krško polje can be seen in (**Figures 2** and **3**).

Speaking of pollution, there are various different substances causing it. As mentioned before, nitrate is one, but certainly not the only troublemaker. Pesticides can also pose significant threat, and in Slovenia, atrazine is the most common of them. In its reports, ARSO also mentions other pesticides, like bentazone, terbutilazine, isoproturon, chloridazon, etc., but these are mostly just detected, and do not pose

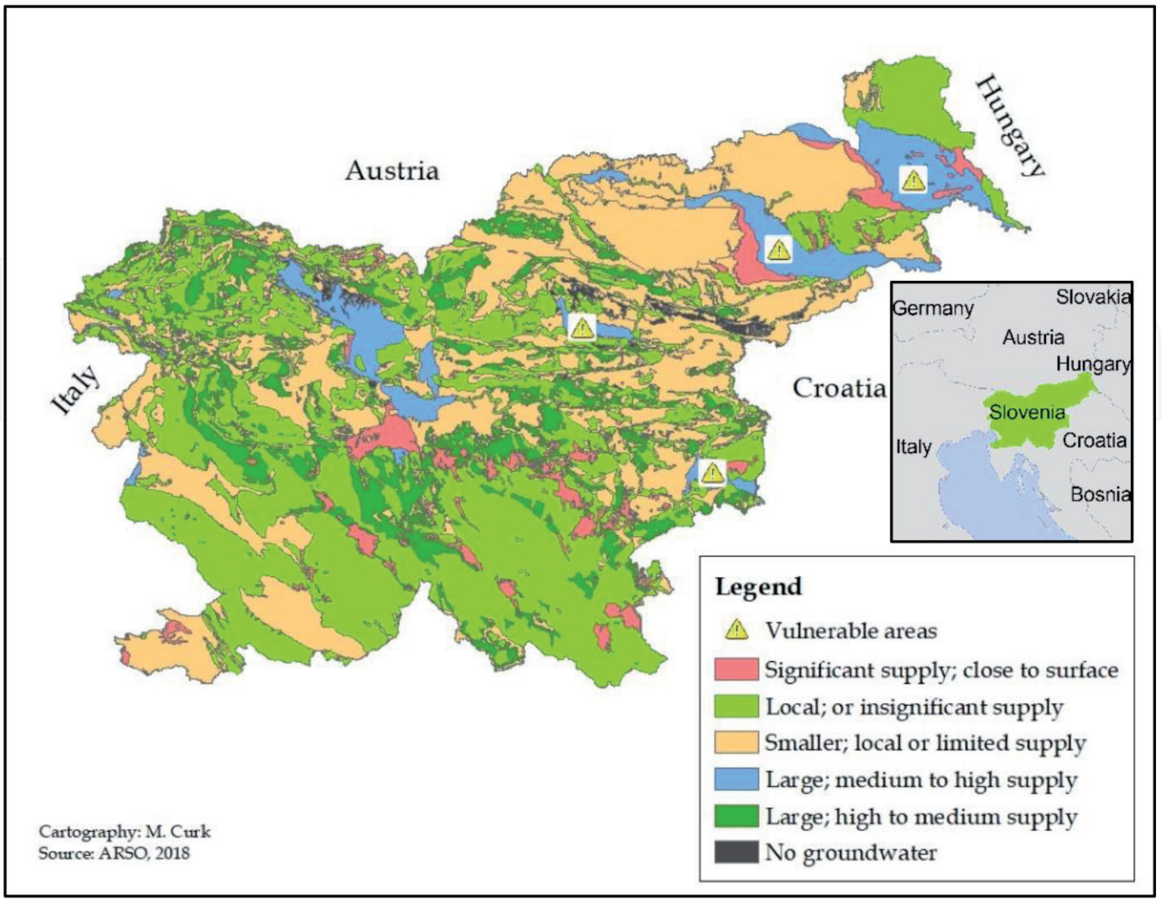

Figure 1.
Map of Slovenia with different aquifer types; blue color mostly corresponds to the main alluvial plains.

Figure 2.
Corn harvest on Murska kotlina plain (photo: Curk, 2017).

any threat. Atrazine and its metabolite desetil-atrazine are still found in quite high concentrations though, in places well above the EU threshold of 0.1 μg/L. What is interesting is that, despite atrazine being banned in EU (or rather its registration was not renewed) more than 15 years ago, it is still present in our groundwater (**Figure 2**).

3. Processes behind the pollution—a word on leaching

When speaking of groundwater pollution, leaching is generally the cause of it. Molecules that do not have the positive charge and therefore do not bind well to soil particles get washed through the soil profile as water passes through. Nitrate and many other substances have this exact property which makes them very easy to leach into groundwater. We will only talk about nitrate in the following lines, as it represents the process very well, and is common across the globe, unlike specific pesticides.

Nitrogen as an element is an essential component of plants, so in order for them to grow, we need to supply it to them. For centuries, this was done only with manures, but after the green revolution in the last century, a new source of nitrogen was introduced in form of mineral fertilizers. These allowed for a great increase in agricultural yields (up to 40%), but all the nitrogen from fertilizing did not make it into crops. Because of aforementioned leaching, much of it was lost into ground (or surface) water in the form of nitrate (NO_3^-). Fertilizers with other forms of nitrogen, like ammonia (NH_4^+) or nitrite (NO_2^-), are not much "safer" in this regard, as nitrogen forms are prone to quickly transform in nitrification and denitrification reactions. There was a debate in recent years about nitrification inhibitors, compounds used for decreasing of nitrate leaching by inhibiting conversion of ammonium into nitrate. Ammonium, having a positive charge, bounds to soil particles and is not as prone to leaching. But studies have shown that decreasing of nitrification results in ammonia volatilization increase, which, environmentally, is not any better [2, 3].

Some areas, however, have less trouble with leaching than others. As mentioned, leaching is strongly dependent on soil type, climate, and agricultural practice. Here are some examples: sandy soils that are not as good in water retention are notorious for leaching problems, while clayey soils are better in this regard; water and nitrate are held in root zone for longer, so plants can use more of them. Climate wise, the more problematic are areas with stormy weather and lots of rain during the spring to early summer period, when most of the fertilizer is applied; and thirdly, agrotechnical

Figure 3.
A view of agricultural land on Krško polje plain (photo: Curk, 2018).

practices, which are the only piece of the puzzle we can actually control, also influence leaching significantly. Fertilizing only once per year is way worse than in several small rations, where plants get as much as they need when they need it. Plowing fields in autumn is worse than in spring because winter rains do not leech the nutrients from decaying organic matter we buried in the soil. It is good to use cover crops when soil would otherwise be left bare and use crops with deeper root systems that catch nitrate in deeper layers as well [4–6]. Having all the best factors come together in one area is not realistic though. It is always necessary to compromise—if we have good soil and climate conditions, we could be a bit more "sloppy" with our agrotechnics and not get alarming monitoring results, but if soil and climate are not the most suitable, even the best agrotechnics might result in noticeable leaching. What is important in such cases is dialog between farming and water protection sectors to solve the dilemma of enough food versus clean environment. Most of the nitrate and pesticide problems could probably be alleviated by banning agriculture from vulnerable areas, like sandy shallow-soiled plains above drinking water reservoirs, and environmental side often tries to suggest this option. But in reality, such areas are many times the only areas suitable for intensive agriculture. This is why we adopted threshold values, which are a consensus between health and other benefits. European Union Water Framework Directive therefore recommends a nitrate threshold of 50 mg/L for water used for human consumption, because this concentration is low enough to ensure safe consumption, but high enough that it still allows for use of agricultural land (**Figure 3**).

4. Slovenian water protection legislation—the theory

Slovenia is not a very old state. For centuries, it was a part of different Germanic kingdoms like Austro-Hungarian Empire, but in twentieth century, it mostly existed as a state in different connections of South Slavic federations (most recently in the socialistic Yugoslavia). In 1991, Slovenians finally managed to form our own state, and in 2004, we decided to join the European Union. Since the secession from Yugoslavia, a lot of legislation was taken over from Yugoslavian, but in terms of water protection, major improvements were done since the accession negotiations with European Union (**Figure 4**).

The main piece of legislation concerning the subject is the Water Framework Directive (Directive 2000/60/EC of the European Parliament and of the Council)

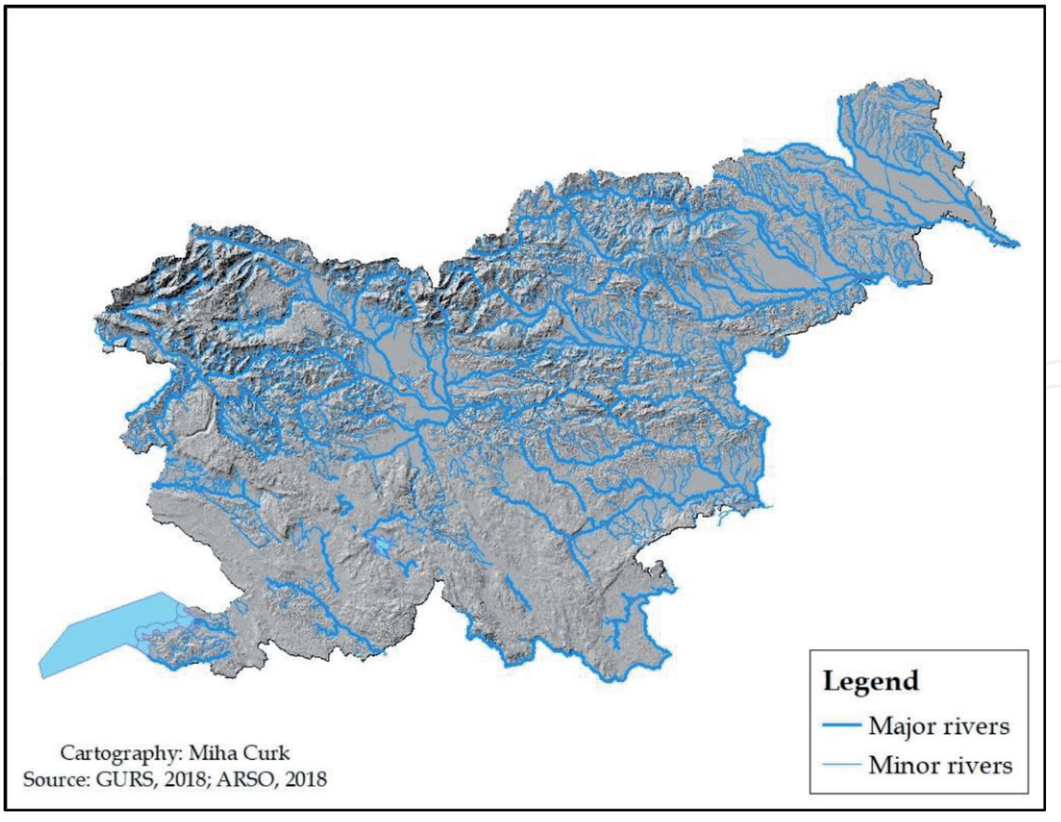

Figure 4.
Surface water and topography in Slovenia.

in force since October 23, 2000. Its main objective was establishing a framework for Community action in the field of water policy. Member states had to implement the necessary measures to prevent deterioration of the status of all bodies of surface water (art. 4.1(a)(i)); and protect, enhance, and restore all bodies of surface water to achieve good water status (art. 4.1(a)(ii)).

In Slovenia, Water Framework Directive resonated in acceptance of Waters Act [7]. Waters Act defines rules for management of waters (both surface and subsurface) in Slovenia, specifically for protection of waters, sustainable use of waters, good management of water use facilities, and other water-related questions. Waters Act imposes the formulation of a Program of Measures which is used to define measures needed to meet the objectives set for protection, development, and use of waters. A state-wide Program of Measures needs to be formulated every 6 years by the government with the help of interested public. More locally specific programs should be formulated for river-basins or other vulnerable areas when necessary. Different daughter rules were also brought to act, for example:

- Rules on determining water bodies of groundwater [8] (define water bodies of groundwater based on aquifer location, groundwater movement, groundwater quality, and human activity above the water body).

- Rules on criteria for marking a water protection zone and a bathing water zone [9] (define means of designation for water protection zones—different warning signs, fencing, signs with instructions for acting in case of emergency).

- Rules on determining and classification for water bodies on surface water [10] (define surface water bodies depending on types of water body, hydromorphological changes, anthropogenic changes, and state of water).

They offer more specific limitations concerning the subjects. Specific water protection zones are defined by decrees that define locally specific areas around drinking water reservoirs, which are shown in **Figure 5**. Red areas mark the inner-most part of the zone directly around the pumping station. Strictest measures apply here. Transitioning from red across orange, and yellow to green, less and less strict measures apply. The size of each zone was determined by different factors; for example, by aquifer type, speed of groundwater recharge, response time, pollutant retention time, dilutive capacities of groundwater body, etc. Different modeling approaches were also used in the process to help determine groundwater flow, dilutive properties etc. A common criterion for definition is the time it takes for pollutants to reach the well. Time for the first zone is usually 50 days and second zone is 400 days, while the third zone encircles the whole connected aquifer.

Another important piece of legislation is the decree on groundwater status [11]. It was transposed from European Union Ground Water Directive with the aim to define procedures for determining of groundwater quality, standards of quality, and corresponding threshold values, but also other demands concerning preparation of groundwater protection action plans, etc. For any given groundwater body, investigation of pollution was executed, and bodies with good chemical status were determined. Bodies that were not recognized as such are considered vulnerable and a program of measures has to be formed with an aim to prevent further pollution and restore the body to good chemical state.

A groundwater body is considered to be of good chemical status when:

- chemical composition is such that yearly average of sampling locations results does not exceed threshold values.

- pollutant concentrations do not indicate intrusion of salt water or other intrusions into water body, do not indicate deterioration of connected surface water status, do not cause damage to aquatic or land ecosystems.

- electrical conductivity changes show that there are no intrusions of salt water or other substances into water body.

Threshold values for pollutants in groundwater are presented in **Table 1**. Note that values are similar to European Union Drinking water directive (Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption). In Slovenia, as mentioned before, groundwater is used extensively for drinking (98% of drinking water comes from ground water), so EU drinking water values apply to all groundwater.

Apart from legislation that is more directly bound to groundwater issues, other legislation pieces are also important for our topic. Agriculture and industry influence groundwater quality significantly, so some relevant regulations also concern these sectors. Let us only concentrate on the agricultural part. For the most part, the framework for these regulations is the following European Union directives:

- Nitrates Directive (Council Directive 91/676/EEC of December 12, 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources).

- Pesticide Directive (Directive 2009/128/EC of the European Parliament and of the Council of October 21, 2009, establishing a framework for community action to achieve the sustainable use of pesticides).

- Sewage Sludge Directive (Council Directive 86/278/EEC of June 12, 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture).

In Slovenia, Environmental Protection Act [12] is the framework act concerning protection of the environment. Its aim is to set up a framework of principles, measures, monitoring, etc., to ensure sustainable environment protection. It refers to other, more specific regulations, though, and these are listed below:

- Decree on the protection of waters against pollution caused by nitrates from agricultural sources [13] (below: nitrates decree)
- Plant protection products act [14] (below: PPP act)
- Decree on the management of sewage sludge from the urban waste water treatment plants [15] (below: sewage sludge decree)

Main emphases are collected in **Table 2**.

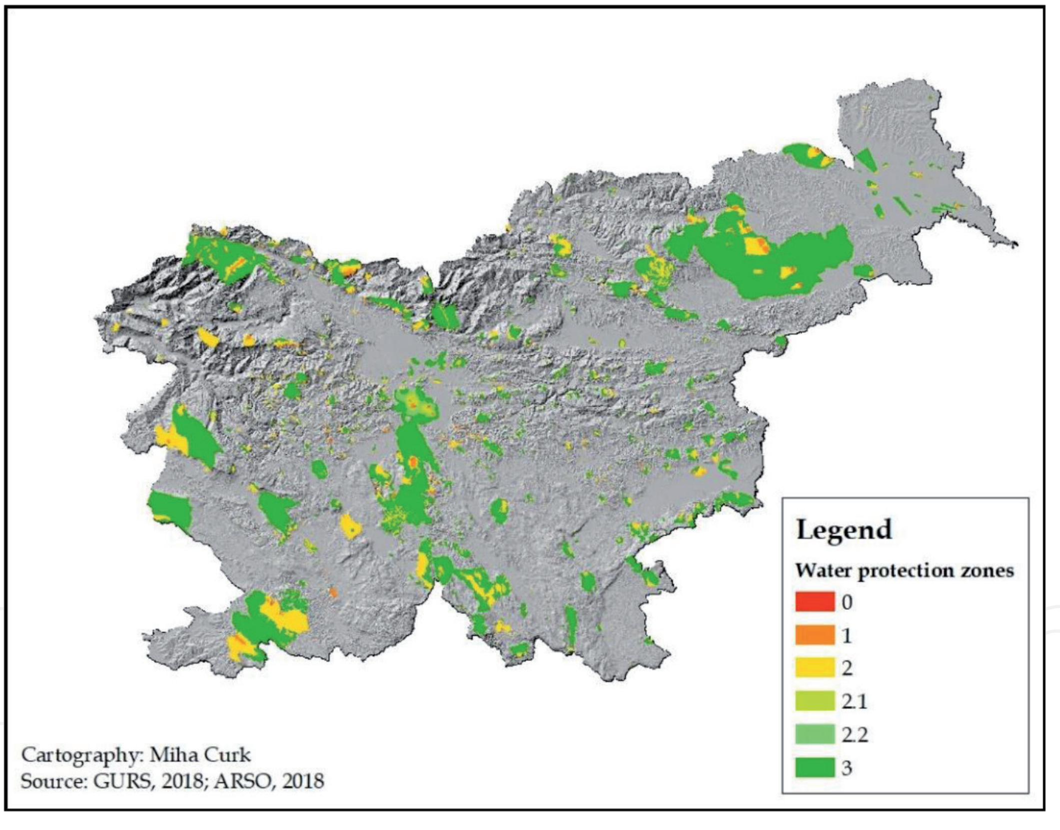

Figure 5.
Water protection zones in Slovenia—colors go from strictest (red) to least strict (dark green).

Pollutant	Threshold value	Unit
Nitrate	50	mg NO_3/L
Aldrin, dieldrin, heptachlor, heptachlor epoxide	0.03	µg/L
Other individual pesticides and their metabolites	0.12	µg/L
Sum of all detected pesticides and their metabolites	0.5	µg/L

Table 1.
Threshold values for pollutants from the decree on groundwater status [11].

Nitrates decree	Defines threshold values for agricultural nitrogen input into soil and water and measures for preventing water pollution. Yearly input of nitrogen should be less than 170 kg N/ha. Application of liquid manure is prohibited from November 15 till March 1 with some exceptions. Application of N containing mineral fertilizers is prohibited from October 15 till March 1. Any fertilization is prohibited on flooded, frozen, or snow covered ground regardless of these dates. Manure storage needs to be done in designated areas where leaching is limited. Crop rotation schedule needs to be prepared as a basis for well-balanced fertilizing.
PPP act	Defines means of proper use of plant protection products (PPP) in a way to allow for sustainable agriculture and safe environment for humans and animals. Also defines trading activities and their limitations. Only state-recognized PPP that are registered and published by responsible government department can be sold and used. PPP users need to undertake and pass a state-valid training program, special areas need to be designated for storage and mixing of PPP. Application equipment needs to be checked by responsible government department every 3 years. Treatment from air (i.e., with planes) is not allowed. Treatment close to streams or lakes is prohibited (15 m from the river bank).
Sewage sludge decree	Defines conditions and limitations of sewage sludge use in agriculture. Prescribes measures for processing of sludge before use, standards for processing, etc. Sewage sludge is considered problematic because of heavy metals. If a farm is involved in CAP payments, use of sewage sludge is prohibited.

Table 2.
Main emphases from nitrates decree, PPP act, and sewage sludge decree [13–15].

Apart from these state-wide valid limitations, special rules also apply to water protection zones. Three main zones are used (see **Figure 5** for reference) to divide land around groundwater reservoir depending on risk of harmful pollution. Such rules valid for water protection zones are:

- Soil nutrient analysis, as well as corresponding fertilization plan is obligatory for all zones.
- Only in first zone: application of fresh manures or slurry, mineral N, use of fertigation, and plowing of permanent grassland are all prohibited.
- Only in third zone: first-quality sewage sludge use is acceptable.
- In all three zones: storage of manure or sewage sludge is prohibited.

Apart from what was already mentioned, there are also many other minor or locally valid pieces of legislation, but these major laws present the main structure of Slovenia's legislation on groundwater protection.

5. Slovenian water protective measures—the practice

Legislation is very important when it comes to protecting the environment, but without the knowledge of how to meet the prescribed criteria, stakeholders would have a hard time meeting it. This is where the more practical part of water protection comes in. Based on scientific research, trials, and experimenting, several instructive manuals with guidelines have been published for Slovenian farmers. Several institutions are a part of collective effort to discover locally efficient measures and practices in Slovenia; listed below are just a few:

- Biotechnical Faculty, University of Ljubljana;
- Agricultural Institute of Slovenia;
- Faculty of Agriculture and Life Sciences, University of Maribor;
- Chamber of Agriculture and Forestry of Slovenia;
- Biotechnological School Rakičan;
- Agricultural School Grm Novo Mesto;
- Biotechnical Center Naklo.

Collecting the most recent knowledge in the field, Ministry of Agriculture, Forestry and Food publishes (with advice from above-listed research institutions) a yearly issue of technological instructions for different agricultural sectors:

- integrated arable crops production;
- integrated fruit production;
- integrated grapevine production;
- integrated vegetables production.

Periodically, similar instructions are also issued for organic production. These manuals are not meant to address only the issue of groundwater protection, though. They are written to give farmers a framework for integrated, that is an environmentally friendly, sustainable production, which, as it happens, already helps in terms of groundwater protection. But—as stated in the beginning of this chapter, Slovenia has several areas, where just some generic measures are not sufficient. For this reason, more specialized guidelines are also issued to showcase the stricter solutions. Only recent publications are presented below, as older practices may no longer be relevant. A good representation of such a guidelines manual is "Fertilization with Nitrogen on Water Protection Areas (Example of Aquifer Apače Field)" [16] written in 2017. Important thing to stress out at this point is that only farms that are a part of either integrated or organic production scheme are certified and therefore under state control. In practice, this means that other farms, which are not a part of certified schemes and use conventional practices often, do not comply with legislation standards, because they are not stimulated or controlled enough to do so. Stimulation program exists, though, as a system of direct payments from European Union is available to farmers who enter into integrated or organic scheme, and only then, they enter into control mechanisms as well. Measures that need to be implemented in order to qualify for funding change every 6 years and have to do with animal welfare, cover-crops, good agricultural practices, water-sources protection, biodiversity, etc.

Authors of the manual note that for their example, area almost half of the farms in second and third vulnerable zone are not a part of official certified schemes, and therefore, are not subjected to control from state officials. Not that these farmers want to be polluters, sometimes they are just not willing to adapt to the new ways and just stick to what their forefathers taught them. Dealing with the lack of knowledge, practical tips for farmers that do not know how to deal with fertilizing plans and balanced fertilizing are presented in the manual. Some tips are listed below:

- When plowing a meadow (it is prohibited in zone 1), farmer should note that plant matter holds from 60 to 120 kg N/ha, and incorporate this quantity into his fertilizing plan.

- Soil samples for N analysis are best taken before first additional fertilization, and should be taken in regards to the size of the field. One sample is only enough for small fields up to 3 ha (though it should be taken from 20 to 30 random spots in the field), but for any size of field uniformity of soil and culture should be taken into account. With this, we provide for a uniform and representative sample.

- To minimize the chance of mineral N fertilizer leaching through the soil, we apply it in smaller rations: at seeding up to 60 kg/ha, and with additional rations only up to 80 kg/ha, but the total limit specified for different zones also should not be violated.

- Another good practice is to use a "fertilizing window," which is a small plot in the field where we apply less fertilizer than elsewhere. As plants use nitrogen, plants in the "window" will show signs of deficiency sooner, and additional fertilization can be planned accordingly. But if plants in the "window" grow fine, we know additional rations are not necessary.

- It is a good idea to cover at least 25% of nitrogen needs by either animal manures or by the use of legumes, green manures, or other cover crops, as nitrogen in these forms usually releases over longer periods.

- Manure or compost needs to be stored in dedicated sealed areas to prevent leaching.

- If possible, use of slow-release nitrogen fertilizers is encouraged.

- Application of fertilizer with implements that work it into the ground is preferential, to minimize both odor and volatilization, but also to get it close to the roots sooner.

Another work on fertilizing is the "Guidelines for realization of water protection claims in regards to nitrates from agricultural sources" [17] written in 2016, with updates from 2017. This is a very farmer-focused publication, written in a question-and-answer form, and is intended to explain legislation claims in a clear and easy-to-understand manner. Farmers are becoming more and more knowledgeable and eager for education, but long and complicated legislation pieces are not very easy nor enjoyable to read. Guidelines are not focused only on water protection areas, but rather include the good practices from legislation concerning the whole Slovenia. In many points, this is similar to the previous work, but at some it goes into more practical details, that farmers are interested in, like for example: "What is the animal-based equivalent of the yearly maximum of nitrogen

Farm animal	Yearly N content in manure (kg N)
Cattle	
Calves up to 6 months	10.5
Young cattle from 6 months to 1 year	21
Young cattle from 1 to 2 years	42
Cattle older than 2 years	70
Sheep	
Lambs (included in ewes content)	0.0
Ewes older than 1 year	10.5
Rams older than 1 year	10.5
Goats	
Baby goats (included in does content)	0.0
Does older than 1 year	10.5
Bucks older than 1 year	10.5
Horses	
Foals up to 1 year	30
Ponies	30
Horses older than 1 year	60
Donkeys and crossbreeds	30
Pigs	
Piglets (included in sows content)	0.0
Young pigs up to 30 kg	3.2
Pigs from 30 to 110 kg	11.2
Boars	27.2
Sows	25.6
Poultry	
Laying hens	0.420
Young hens	0.136
Broilers	0.170
Turkeys	1.700

Table 3.
Average yearly nitrogen yield from animal manure by species [17].

input (170 kg N/ha)?" A table with average yearly nitrogen yield for different species manure as well as a calculation example is included. Part of the table values is presented in **Table 3**. If farm animals produce more than 170 kg of nitrogen per hectare, excess manure should not be used on the farm, but sold or disposed elsewhere to prevent overloading of soil with nutrients.

Apart from this, other tips are included, for example, formulas to calculate:

- Nitrogen content in different ratio NPK fertilizers;
- Land inclination for purposes of surface water protection from erosion to streams;

- Size of storage area for manures depending on animal numbers on a farm;
- Nitrogen content in part of yield that is often times incorporated back into the soil (like straw) and acts as a nitrogen source when done so.

Manual also offers clarifications of legislation, like "Is it allowed to temporarily store manure on frozen ground?" (Yes), "Is anyone allowed to make a fertilizing plan?" (Yes, as long as he knows how to do it), "Is there a specific type of fertilizing implement supposed to be used?" (No, but those that incorporate the fertilizer into the ground are preferable), etc.

Moving from the topic of fertilizer pollution into the plant protection products territory, we have another recent (2017) manual on use of phytopharmaceutical substances in water protection areas [18]. At the beginning of the document, the author makes a very important statement about what it means to cause pollution: "Advances in measuring technology have made detection of plant protection products very sensible." Author gives us the following example: "When filling a spraying implement, a farmer drops the lid of a pesticide bottle, and it ends up in the nearby stream. Even if it only had a couple drops of pesticide on it, this can still be detected up to 40 km away in drought season, and even exceed the threshold values. If even such small mistakes or carelessness of a single user can be detected, it is not hard to imagine how important it is that every single user knows the principles of good agricultural practices, or his deeds can give bad results for whole area. The thinking in terms of 'this drop can't make any difference' or 'nobody will see me if I do it' is not helpful, as detection of pesticide in waters must, by law, be sanctioned by restrictive measures of some sort in the area of concern. This of course inflicts all the farmers in the area, not just the polluter."

In the manual, there is a good explanation of what is going on in the soil that is subject to leaching, but practical considerations are also included. Attached is the list of pesticides that are not acceptable or should only be used every couple years in water protection zones because of their chemophysical properties when in contact with soil (unacceptable active substances are bromacil, propaklor, triklorpyr, terbutryn, piloram, haloxyfop, terbacil, hexazinone, norflurazon, heptachlor, terbumeton). Just as with crop rotations, pesticide rotations should also be considered to minimize constant exposure to the same active substance, but also to allow for less frequent use of more dangerous pesticides in favor of using a similar but less hazardous active substance.

Another important topic is preparation of spraying mixture and dealing with its residuals after use. Care should be taken to prepare the right amount, a certified sprayer with good nozzles should be used (as discussed in the theory chapter), and a water-tight system for cleaning the sprayer should be used afterward. There is no urgent need to buy expensive devices, the author gives farmers an easy, cheap, and effective solution: If using a dedicated commercial cleaning system is not an option, smaller farmers can also create an improvised pool out of durable foil with a small quantity of soil in it—the soil works as a reactive substance in which, under sunlight, pesticide is decomposed. Another option is to empty the sprayer into the manure lagoon, where active substances also get decomposed quickly, especially with small quantities that remain after use. A big part of the document deals with surface drift into streams though, which is not our point if interest here.

6. Perspectives and improvements for future

Several projects on the topic of groundwater protection were recently concluded or are still in progress. Some of them are briefly described in the next lines.

"SI-MUR-AT" project [16, 17], dealing with ecological and sustainable agriculture in accordance to a contemporary water management is an interregional between Austria and Slovenia. The project is still underway, but one of the interesting interim propositions was to prepare a wholesome regulation on topic of proper cleaning of spraying equipment which is not set by Slovenian law yet. A good recommendation is also to give more emphasis to conservation management of soils, which in other countries shows promising results in terms of better soil properties. Also, just as crop rotation plans are mandatory for integrated or organic agriculture, plant protection products rotation plans would also be a good idea to have in order to gain a better view of the actual farming practices.

Another project, funded by Slovenian research fund and titled "Possibilities of farming in water protection areas" [19], offered some valuable insight into possible improvements of current state. Its aim was to discover measures to improve groundwater quality, and the final propositions were the following:

- Identification of the severely vulnerable aquifers and additional funding for farmers in these areas;

- GPS devices should be mounted onto fertilizing equipment in order to have a better control overfertilization in these areas;

- Redundant liquid manures should be composted in biogas plants or wastewater treatment plants to prevent overfertilization of vulnerable areas;

- Funding for building of small biogas plants, transportation of manure into them, and additional funding for farmers, willing to implement these measures.

"UraViVo" project [20], aimed to improve land management regime in order to improve groundwater quality, is another project that is still underway. Three most interesting goals are to develop and test a new formulation of fertilizer made from pig manure to minimize leaching possibilities, test a deficit irrigation practice to save water and minimize leaching possibilities and to use nitrate-polluted groundwater for fertigation in order to reduce nitrate concentration. Use of modeling to test more long-term results is also planned.

Workshops and lectures on topic of groundwater protection are also organized frequently by Chamber of Agriculture and Forestry of Slovenia's regional offices and also other institutions to extend the knowledge and make it available to farmers and interested public.

In the end though, even if scientists and researchers figure out good ways and effective measures, it is still on the legislators to legalize them, and on farmers or industry to implement them. Without the interest in implementation, even a very effective measure is not effective, as nobody implements it. Subsidies and funding seem to help in this regard significantly though.

7. Conclusions

Groundwater in Slovenia, as well as in many places across the globe, is the main source of drinking water. With the rapid increase in use of mineral nitrogen fertilizers and different agricultural as well as industrial chemicals in the past century, many of these substances found their way into groundwater. Slovenia as a European Union member formed its legislation based on Water Framework Directive and its recommendations.

Slovenia is not a big country, but it features very diverse terrain and climate. The main reservoirs of groundwater are located under alluvial plains, which are also centers of agricultural production. When speaking of groundwater pollution, leaching is generally the cause of it, especially on shallow sandy soils. Slovenia is no exception, as depth to groundwater is sometimes only 1–2 m. Apart from soil type, climate and land use also contribute to leaching, but land use is the only factor we can consciously change. To influence better use of land, legislation and guidelines are written.

Main pieces of groundwater-related legislation in Slovenia are the Waters Act and the Decree on groundwater status. They define rules for management of waters, vulnerable areas, threshold values, etc. Decree on the protection of waters against pollution caused by nitrates from agricultural sources, plant protection products act, and decree on the management of sewage sludge from the urban waste water treatment plants are also connected to groundwater protection in terms of definition of limitations, conditions of use, etc.

Many different guidelines were written in recent and past years to help realize the legislation expectations. They contain different instructions, good agricultural practices, lists of promising measures, as well as also very straightforward clarifications of legislation in Q&A form. In terms of the future perspectives, several projects driven by Slovenian research and education institutions are also presented in the work, and their efforts explained.

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