The integration of groundwater protection into land-use planning, certification and standardization of quality of urban supply systems

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Abstract

Groundwater is an essential resource for water supply. For this reason, it is necessary to integrate and harmonise efforts to protect groundwater quality with socio-economic activities and existing land-use patterns in any given region, as well as complying with the requirements of the EU Water Framework Directive. In addition, land management seeks to coordinate and harmonise policies with regional impacts. Water—as a public good and an essential resource for the development of life and the evolution of populations—needs to become one of the main pillars of management for a variety of regional policies. Therefore, water resources planning does not make sense without firstly considering forecasted land management patterns. The objective of this work is to standardize the process of managing the supply systems and prove their quality by certification. This will require guaranteeing the sustainable management and obtaining the certificate. During this long process, there may be complications that prevent achievement of the ultimate objective. For this, it is necessary to promote a standardization tool, which will value the efforts of the various agencies involved in the protection and management of groundwater used for human consumption in achieving sustainable management of water resources.

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1. Introduction

The total population of the 27 European Union countries has increased from 400 to 497 million between 1960 and 2007. Rapid population growth, socio-economic progress and development of tourism, all have led to an increase in groundwater usage and the pressures that affect their quality.

Groundwater is an important resource, especially in the Mediterranean countries where surface water cannot, by itself, meet the demands of agriculture, industry and human consumption. Southern Europe is climatically characterized as a semi-arid region where there is a significant difference in rainfall due to seasons cycle and topography.

The sustainable use of groundwater for human consumption is critical in countries of the Mediterranean area, especially during periods of drought that occur cyclically. The various models proposed for different climate change scenarios also show that these droughts will become more frequent and intense, augmenting the necessity of a smart use of groundwater. The same effect is posed to ecosystems since in the Mediterranean most of them (especially wetlands), are linked to groundwater, so any condition affecting them, both in quality and quantity, will be reflected in the quality of these ecosystems.

Europe needs a sustainable groundwater management strategy to allow its preservation and use in a more efficient way. This need for a sustainable and integrated management is reflected in current policies and legislations. The Water Framework Directive is imposing Member States of the European Union to make Water Basin Plans with the requirement of active public participation in the planning and development process thereof.

The implementation of these measures in policies with territorial impact must be accompanied by an assessment of socio-economic effects that may occur in both populations and associated ecosystems.

2. Environmental problem

Groundwater constitutes a basic resource for urban water supply in Europe. In countries such as Austria, Germany, Italy or Denmark, more than 70% of the population’s water supply comes from groundwater [1], while the vast geological diversity and consequently the hydrogeological one, along with the specific socio-economic characteristics of each country, generates different proportion of surface and groundwater usage for human consumption [2].

The protection of groundwater has become one of the high-priority environmental objectives in European policies entering into force in 2000, through the Water Framework Directive (WFD), Directive 2000/60/CE of the European Parliament and the Council [3], and more specifically in 2006 through the Directive 2006/118/CE of the European Parliament and the Council, dealing with the protection of groundwater against pollution and deterioration [4]. It promotes cooperation through coordination between the different responsible authorities, the different levels of decision making, the different social agents and society, in general, as the ultimate user. The last phase of the integration process must be the consideration of new strategies in water management policies with a positive impact on the territory.

In Article 6, the WFD requires that all water bodies used for the abstraction of water intended for human consumption providing more than an average of 10 m³ per day or serving more than 50 persons and bodies of water intended for such use are included in a register of protected areas, constituting the so-called Drinking Water Protected Areas (DWPAs). Because of these stringent requirements, in many states the majority of groundwater bodies must be considered under such protection thus covering a large part of its territory. Water intended for human consumption includes the quantity supplied to the population (both public and private), and the quantity used directly in food processing (canning). This article also includes the register of protected areas for the conservation of habitats or species.

It is important to mention that, although protected areas for drinking water must be analyzed at the level of the entire groundwater body in which they are located, this does not imply that measures to achieve the objectives of Article 7.2 must be applied to the full extent of the DWPAs. The requirements of Directive 98/83/EC, drinking water, must be met at the point where the water is supplied to the consumer.

Article 7.3 of the WFD requires that states must ensure the necessary protection of DWPAs "in order to prevent deterioration of their quality, to reduce the level of purification treatment required for the production of drinking
water”. Although avoiding the quality deterioration of water bodies does not necessarily generate a reduction in levels of purification, it is clear that this requirement indicates the high concern of the deterioration of water quality. To this end, authorities must take measures to protect water quality so that, at the point of extraction, no significant deterioration exists, that would require an increased water treatment. Each vulnerable parameter should be individually controlled. [5].

In practice, it is almost impossible, at least costly-wise, to apply the restrictive measures needed to be compliant with the requirements of Article 7.3 in all the DWPAs, at the same intensity. In order to overcome this obstacle, the WFD (Article 7.3) defines “safeguard zones”, zones where restrictions and control measures will be considered.

The safeguard zones are areas (the WFD considers establishment optional), where measures are taken in order to protect groundwater to limit quality deterioration and to reduce the level of purification treatment required for the drinking water. This approach is recommendable, especially given the size of numerous water bodies that have been defined in various states. They are therefore equivalent to "safeguard zones" in bodies of groundwater for human consumption under Article 7.3 of the WFD [6].

Restrictive measures must be applied to safeguard areas in order to protect the groundwater that is/will be used for human consumption (activities permitted cartography), and should be included in the approved measures requested by the WFD.

3. State of the art and innovation

According to the WFD (i.e. Article 7.3), safeguard zones are areas to be established as an optional method by which appropriate protective measures are applied to limit deterioration in the quality of groundwater used for human consumption and to reduce the amount of purification required. This option is strongly recommended given the extremely large dimensions of groundwater bodies in many EU member states.

Jiménez-Madrid et al. [6] propose the Groundwater Protection Zones method (GPZ method) for determining safeguard zones as a way to protect carbonate groundwater bodies used for drinking water supplies. According to this

Figure 1. Methodology for the delimitation of safeguard zones [6].
method, the first step is to establish the risk of groundwater contamination (RI index) by combining a characterization of external pressures (IP index) and an evaluation of intrinsic vulnerability to contamination (DRISTPI index). The second step is to identify existing supply points and their inputs, that is, the areas within the region that provide water used for human consumption and its zone of contribution (ZOC) of supply abstraction points. This objective is independent of other measures that may be required in other areas to comply with WFD requirements. Last, the existing protection perimeters are identified in the relevant protection zones.

Once the safeguard zones are established, the activities permitted are mapped. This process produces a dynamic instrument to be applied directly in the study area to determine where pressures can be located, thereby eliminating negative impacts on the quality of groundwater intended for human consumption.

4. Integration in urban policies

The delimitation of safeguard areas can be integrated into spatial land-use planning by mapping the allowed activities– a tool that can be directly applied in the region in question. This process sets a threshold value corresponding to a tolerable water environment value based primarily on the hydrogeological and climate characteristics of the area. An analysis of existing pressures identifies the current groundwater condition [7].

If the condition exceeds the threshold, current new activities are not allowed. When the condition is less than this threshold, different management scenarios can be created for the activities to be allowed.

This represents a management tool that accommodates different assumptions related to the implementation of new zones or changes in existing zones by evaluating the economic impact of decisions. A combination of groundwater protection with the possibility of economic activities makes this methodology an effective tool for sustainable development [8].

The proposed methodology – compared with traditional methods of groundwater protection – allows the same approach to be applied in different conditions (e.g. karst, intergranular porosity and mixed materials), which can often be present in the same groundwater body, the basic unit of WFD implementation. Similarly, planning policies are effectively integrated with resource protection. This is, therefore, a general methodology applicable across Europe and compatible with sustainable development, allowing economic activities compatible with environmental protection depending on the associated pressures and economic costs.

This tool also allows the integration of diverse aspects on different geographical and socio-economic scales, making it versatile and promoting coordination between different government and decision-making levels, in order to achieve sustainable development within the spirit of WFD guidelines (see Figure 2). This tool promotes standardization, which will enhance the efforts of the various agencies involved in the protection and management of groundwater used for human consumption to achieve sustainable management of water resources. This is an important contribution to the Common Implementation Strategy of the WFD, as well as land and water planning.

5. Certification and standardization of quality of supply systems

Water is an essential resource for urban life, and groundwater, in particular, is one of the most valuable natural resources on which many of the urban and rural areas of developing countries depend. However, according to UNESCO [10], there is currently a crisis of management of water resources worldwide. Unfortunately, excessive and uncontrolled use and continuous mismanagement have caused a decline in both quality and quantity and the associated ecosystem degradation. On the other hand, in some areas there is a water excess, due to climate changes or the cessation of pumping activities.

This action aims to promote the standardization of supply systems through the development of a quality certification standard for supply systems including protection zones and all parts and facilities of the system, from source to distribution. This also involves the enhancement of the whole process of water management and the actions of all agents involved. This action will develop a pilot program for membership administrations and entities responsible for the supply to different populations in order to implement the proposed rule to specific cases. This will need to ensure
compliance with existing regulations, the carrying out of risk analysis and elimination of appropriate management protocols from the situation of the resource itself in nature (aquifer) to the final user.

The following schema describes the outline of the procedure to be carried out to certify and standardize supply systems through the implementation of the four phases of work integrating: identification, diagnosis, development of standardization and subsequent implementation. The final definition of the process that will be evaluated for normalization will be obtained at the end of the development of the action.

![Figure 2. Methodology for the implementation of the WFD guidelines regarding groundwater for human consumption in regional policies [9].](image)

a) Identification phase
This phase will identify the different elements of the supply system from the source aquifer by conducting a detailed inventory of the following components:
- Appeal. Aquifer, groundwater level, catchment
- Deposits, surveys, well, springs, galleries and control systems.
- Safeguard zones established according to the results of actions 2, 3 and 4. Restrictions [6].
- Piping system, pipelines, pumping systems, vents, valves and control systems.
- Deposits and regulation. Deposits, pools.
- Distribution network.
- User. Population center and characteristics.

b) Diagnostic phase
A working stage of diagnosis of citations and case types has been defined; it is based on a review of the characteristics of real supply systems. A diagnosis and a definition of the shortages and problems in such cases will be made, on the following issues and typologies:
- Restrictions and aspects of the protection zone.
- Water efficiency and energy
- Control and monitoring (ISO standards, legislation, sampling protocols, laboratory certificates)
• Test Protocols
• Risk Assessment Protocols

During the diagnostic phase there will be an analysis process of each of the elements identified in the previous phase, on the real cases.

During the development of the diagnostic phase various types will be considered depending on the following casuistry:
• Quality of installations
• Protection
• Designs and optimization
• Management and efficiency
• Impacts on surrounding nature and man-made constructions
• Other risks

For the diagnostic phase some records will be designed that will be oriented towards the diagnosis and identification of system deficiencies. As a result in this diagnostic phase we will obtain a clear and comprehensive view of the problem and to deficiencies to be corrected and to address priority issues in the standardization of supply systems.

c) Standardization development phase

During the development of the standardization we will take into account the regulations for parallel reference and opinions of specific work group dedicated to standardization and management processes of groundwater for human consumption.

For carrying out this phase the following developments will be considered:
• Development of records. These records will integrate the input data, analysis and results.
• Databases. We will design specific databases and common criteria for the management of water supply systems to the population.
• Geographic Information Systems.

The result of this phase will be the writing of a draft of the standard to certify supply systems and a defined accreditation process.

d) Application phase

• The action programmed to perform this phase of implementation will be divided into different stages:
• Programs for adherence. A pilot adherence programmed of administrations and entities responsible for the supply to different towns will be developed in order to apply the proposed methodology to specific cases.
• Application tests with the following phases:
  o Global inventory. This global inventory aims to detect and highlight where problems occur or which parts of the system are sensitive to improvement according to defined objectives. It will start with a full flow chart of the process from water harvesting to consumption by the end user. This is generally performing body and energy balances to identify where inadequate management operations are being produced.
  o Selection of options. Based on the overall results of the inventory data related to the operation of the system shall be collected and sorted. Defined options must consider the side effects of the project and its profitability, feasibility, risk minimization and probability of success.
  o Specific inventory. This step is accomplished by analyzing in detail the areas for improvement in those identified as problematic in the options provided. Therefore, we will go from a theoretical option to a real one that can be put into practice.
• Feasibility Analysis. It is necessary to evaluate the technical, environmental and socio-economic feasibility of the options identified in the previous steps in order to make the best decision possible. Implementation and monitoring of viable options. Once the global inventory has been finished and minimization options have been selected, a specific inventory of each of them has been carried out, and their feasibility analysis has been made, if the result is positive, we will proceed with the implementation of these options. These are generally performing body and energy balances to identify where inadequate management operations are being produced.
Successful performance of the four stages of work will establish a protocol for sustainable management of water supply systems that will be used as reference for obtaining a quality certification standard and their management.

![Diagram](image)

Figure 3. Identification of elements in the supply system.

6. Conclusions

The methodology proposed will facilitate the integration of different environmental protection policies in all aspects related to the groundwater component of the water cycle (in urban settings). It will also significantly boost the common implementation strategy of the WFD in groundwater bodies used for human consumption.

The ultimate objective of this methodology is to standardize the process of managing the supply systems and prove their quality through a certification. This will require guaranteeing the sustainable management and obtain the certificate. During this long process, there may be complications that prevent achievement of the ultimate objective. For this, it is necessary to promote the standardization tool which will value the efforts of the various agencies involved in the protection and management of groundwater used for human consumption in achieving sustainable management of water resources.

Finally it will increase security of supply to small populations and ecosystems in particular, as a preventive tool, reducing healthcare costs, as this size populations are mostly supplied with groundwater (in Spain 70% of the towns with less than 2,000 inhabitants).
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