Groundwater in Spain: Overview and management practices

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Abstract Spain is among the most arid countries in the European Union, but has a large hydrogeologic potential with many aquifers widely distributed throughout the country. It is estimated that annual aquifer recharge in Spain is about 30% of the total water resources available in the country. Groundwater abstraction is mainly used for irrigation, and often concentrated in some intensively exploited aquifers in the Mediterranean side of the Iberian Peninsula. According to the official figures 699 groundwater bodies have been identified in Spain and 259 (38.65%) of these groundwater bodies are classified "at risk" of not achieving the environmental objectives of the WFD. Groundwater in Spain is a public domain resource since 1985. The changes introduced by the 1985 Water Act and the successive reforms were necessary to deal with the challenges resulting from the more intensive use of groundwater resources. However its implementation has encountered many difficulties which in some ways continue up to date. As all the European Member States, Spain has recently transposed the European Water Framework Directive (WFD) into Spanish law. The WFD states that groundwater abstraction should not cause a significant impact on the related surface water bodies. It also says that Member States must implement measures to prevent or limit the input of pollutants into groundwater. If these provisions are strictly enforced, many groundwater intensive developments and productive activities in Spain may have to cease. The real challenge for the technical, political and social stakeholders in the south European countries will be to find out the paths to effective implementation of WFD principles in their specific hydro-climatic and socio-economical contexts.

Key words Groundwater; Spain; semi-arid Europe; Mediterranean region; Water Framework Directive.

INTRODUCTION

Spain is a country with a large hydrogeologic potential. As other south European countries most of the water resources are used for irrigation and, very often, much of the groundwater abstraction is concentrated in a number of intensively exploited aquifers. Groundwater was

declared a public domain resource in Spain in 1985, but the real implementation of such a declaration has encountered many difficulties in practice. For several reasons, groundwater management in Spain has not been considered as a task for water management agencies and authorities. As all the European Union Member States, Spain is nowadays fully involved in the process of implementing the principles of the European Water Framework Directive (WFD). Such a process constitutes a unique opportunity to improve groundwater protection, knowledge and achieving an effective management. However, to adapt the WFD principles to the hydro-climatic and socio-economical context of a south European Mediterranean country is not an easy task. The current paper wants to summarize an overview of the hydrogeologic context and groundwater management practices in Spain. The main groundwater "facts and figures" of Spain are introduced first, mainly concerning the hydrogeologic knowledge and the groundwater use in the country. A summary of the groundwater management context is described afterwards, introducing the institutional and legal framework as well as some basic concepts related with groundwater management in Spain. Next, a section of discussion about the going-on process of WFD implementation in Spain is shown. This papers finish with a general summary and some conclusions.

GROUNDWATER FACTS AND FIGURES IN SPAIN

Traditionally, only high permeability geological formations were officially considered aquifers in Spain. Official aquifers were found in about 180,000 km^2, or one third of the country's surface area. However, WFD characterization works recognise nowadays the occurrence of many groundwater bodies in other geological formations such as igneous and metamorphic rocks of moderate permeability but with strategic importance mainly for rural population. Considering those less pervious aquifers Annual aquifer recharge in Spain has been estimated to be about 30,000 Mm^3 which amounts for 30% of the total water resources available in the country (MMA, 2000). However, the total amount of water stored in aquifers is probably two orders of magnitude higher that those yearly renewable resources (Sahuquillo et al., 2007). This fact is extremely important for countries suffering frequent droughts, because groundwater constitutes a strategic resource that allows keeping irrigation during dry periods.

Recent official papers (MMA, 2000) estimate that groundwater use in Spain increased from 2,000 Mm^3/year in 1960 up to 6,500 Mm^3/year nowadays. It is worth noting that the ratios of groundwater use can be very different depending on the regions. Groundwater becomes the main source available in the islands (Baleares and Canary islands), in the south Mediterranean part (Jucar and Segura basins) and in some continental areas such as La Mancha. Just as an example it can be illustrative to point out the fact that groundwater pumping in an individual south-Mediterranean basin (the Jucar basin) amounts for 25% of the total amount of groundwater exploited in the whole country.

Approximately 75% of groundwater abstracted is used for irrigation, which is by far the main use of groundwater. These figures are actually quite similar in most arid and semiarid countries. The dramatic increase in groundwater development in Spain has been primarily undertaken by thousands of individual farmers in different regions with very limited public involvement. Groundwater irrigates around one million hectares, which is about 30% of the total irrigated area. Increasing groundwater pumping allows farmers to guarantee their crops in drought years when surface water resources are not available. It is

known that groundwater provides 20% of all water used to irrigate 30% of the total irrigated area, which means that groundwater irrigation is significantly more efficient than surface water irrigation in Spain, as it is in many other countries (Llamas et al. 2001). The reasons that may help to explain such a higher efficiency are analysed in detail by Hernandez-Mora et al. (2007), but it could be summarized on that they are operated as a private resource, with full cost recovery by the users, in contrast to irrigations based on surface water infrastructures which use to be heavily subsidized by the Government.

On the other hand, groundwater is the source for water supply of 35% of the Spanish population (i.e. 14 millions of inhabitants). In some large cities, such as Barcelona, groundwater constitutes a key strategic resource to ensure water supply to population during dry periods. Hernandez-Mora et al. (2007) pointed out the limited use of groundwater resources in Spain for domestic purposes, in contrast with other European countries with sufficient aquifer potential. Except of Norway, which has very little aquifer potential, in 1999 Spain had the lowest percentage of groundwater used for urban supply (large cities) in Europe, about 19% according to MMA (2007). However, the amount of groundwater use is much higher in small villages than in large cities. Water supplies for villages of less than 20,000 inhabitants use approximately 70% of groundwater sources (MMA 2000). Apart from the average figures, groundwater as a source of domestic water supply is crucial in some particularly arid river basins (51% in the Andalusian Mediterranean Basins, 49% in the Canary Islands or 43% in the Júcar River Basin, and even more in the Balearic Islands). In addition, rural water supply in the humid basins of Northwester Spain relies mainly on groundwater, but it is not considered as groundwater exploitation within the official databases, because they correspond to a myriad of individual small wells and springs, out of any water exploitation inventory. However, such spread rural population can be as large as 30% of the total population in some Spanish regions such as Galicia or some areas of Asturias.

Following the implementation schedule of the European Water Framework Directive (WFD), a report with the main results of the “Initial Characterization Stage” was submitted by the Spanish Water Authorities (MMA, 2006; Lopez-Geta, 2007). According to this report, 699 groundwater bodies have been officially identified in Spain. 259 (38.65%) of these groundwater bodies are classified “at risk” for the environmental objectives of the WFD. 57 groundwater bodies (18.24%) are classified without risk (good environmental conditions) and 86 bodies (8.51%) are waiting or further evaluation to decide the environmental conditions. Figure 1 shows the map with location of the groundwater bodies and their classification according to the Initial Characterization Stage of the WFD. Of the 259 groundwater bodies at risk, 89 have been included for reasons of quantity and the rest by chemical pollution. Diffuse pollution, mainly due to high content of nitrate, is the most relevant environmental problem identified, affecting 167 groundwater bodies, and marine intrusion affects to 72 groundwater bodies (Lopez Geta, 2007). However, it is worth mentioning that these figures will increase in the near future when the results of the additional assessment of the 256 pending groundwater bodies were published. Much fewer number of groundwater bodies have been classified at risk due to point (non-diffuse) pollution by chemicals, but these figures could also increase in the future with additional assessments.

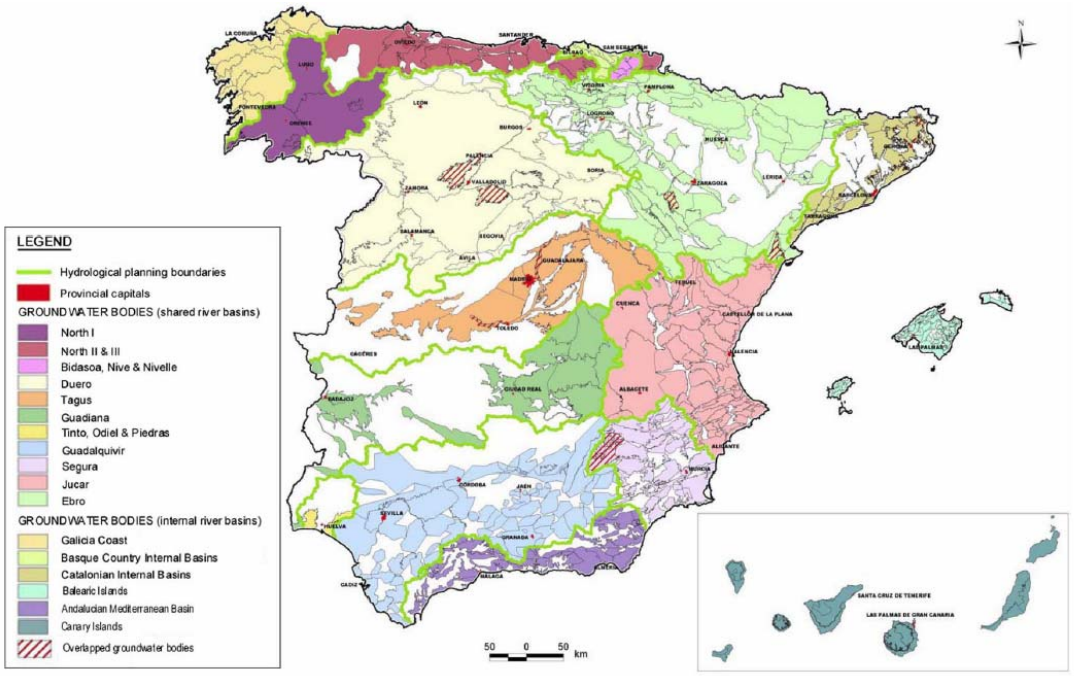

Fig. 1 Classification of groundwater bodies in Spain, according to the Initial Characterization Stage of the WFD (MMA, 2006).

GROUNDWATER MANAGEMENT IN SPAIN

Water management in Spain is based on River Basin Agencies. When a given hydrological basin is interregional, then the water management depends on the Ministry of the Environment of the Government of Spain. By the contrary, when the hydrological basin is entirely located in an Autonomous Community (regions of Spain with Autonomous Government) the water management is a full responsibility of the Regional Autonomous Government. Examples of hydrologic basins managed by regional governments can be found in Catalonia, Andalusia, the Basque Country and the Balearic and Canary islands.

The Spanish Water Act, from 1985, declared all groundwaters as a public domain resource for the first time. The new law left two to possibilities to existing groundwater owners: (a) to remain in a transient private regime until 2038 and after that becoming a public concession, or (b) to remain permanently in a private regime. Owners had a 3 year-deadline to register themselves in a Catalogue of Private Waters. According to the Water Act, new groundwater exploitations requested after 1986 must be approved by the corresponding Basin Agency and also registered in a Registry of Public Waters. However, after more than 20 years both the Catalogue and the Register are far from being completed, and the actual situation could be defined as a hydrologic chaos. Hundreds of thousands of

new wells and boreholes have been constructed since the Water Act of 1985, most of them without submitting any application for approval to the Basin Office, so actually being out of the control by the corresponding regulatory authorities. The fact is that the actual figures of groundwater exploitations in Spain are unknown for the authorities that did not allocate the needed resources to make effective the controls required by the Water Act.

A relevant novelty was that the Water Act foresees the possibility to officially declare an aquifer to be overexploited. Such a legal overexploitation can be determined based on both, quantity and quality indicators. There are 16 aquifers officially declared overexploited up to date. The Act give Basin Agencies broad powers for the management of aquifers declared overexploited. Agencies have to draw up a management plan and determine annual pumping regimes. Restrictions must apply to users in both the public and private property regimes and no new pumping permits can be granted. All users in the aquifer are required to organize themselves into Groundwater User Associations. These associations can represent the interests of the users and cooperate with Basin Agencies in the design and implementation of management plans. However, the practical implementation of these measures has not always been easy. User organizations have only been created in 5 of the 16 aquifers declared overexploited, and management plans have only been drawn up in 3 of them. In fact, the actual technical reasons for some of the aquifers that have been officially declared overexploited are not clear and have been questioned. On the contrary there are other aquifers not declared overexploited which have serious problems, in terms of both quantity and quality. It seems that sometimes the declaration (or not) of overexploitation is highly dependent on political and socio-economical factors that have nothing to do with technical and hydrogeologic evidences. It is worth commenting the quantitative imbalance between intensive groundwater exploitation and the magnitude of the environmental impacts of the intensive groundwater pumping. The assessment of the environmental impact of intensive groundwater exploitation is not as straightforward as it is often stated. As an example, the development of heavy pumping in La Mancha area (central Spain) has produced serious environmental impacts on wetlands and in the Júcar River flow. By the contrary, there are several aquifers in the semiarid South-western Spain where intensive exploitation have induced important aquifer drawdown, but their environmental impact has been relatively low (limited to some relatively small wetlands and spring flows) but, at the same time, have produced huge economic and social benefits. As was stated by Llamas and Custodio (2003), in the cases of groundwater intensive use general rules should be taken with care, since appropriate solutions are heavily site-dependent. Proactive actions are needed in order to effectively solve the problems associated to intensive use of groundwater. Sound cost and benefits assessments, stakeholder education and participation and the implementation of effective institutions for collective groundwater management are proposed as more relevant actions to be promoted. After more than 20 years from the Water Act, it becomes apparent that the legal tool provided by the possibility of official declaration of aquifer overexploitation does not provide any warranty for effective improvement of groundwater management. Proper groundwater management looks mainly a political (and social) willingness issue in combination with adequate technical advice, more than just a matter of laws.

User participation in water management has been traditionally understood in Spain as the right of irrigators to organize self-governing institutions for the management of surface water irrigation systems. However, the 1985 Act and subsequent reforms expanded the

concept of users to groundwater users and representatives of other interests and uses beyond irrigators. It established user participation quotas in the different participatory boards of the Basin Agencies: Governing Board, User Assembly, Public Works Board, Aquifer Management Boards, and Dam Management Boards. Stakeholders are also represented in the basins' planning body, known as the Water Council. There exist some examples of successful groundwater user associations and effective cooperation between users and water authorities, but they are still few (Hernandez-Mora et al., 2003). A remarkable example of success in participatory management in Spain is the Water Users Association of the Llobregat Delta. Such a Water Users Association was created in 1975, much before the Water Act, and involves irrigators, industries, water supply companies, water management agencies and other users. They have their own technical department which promotes effective monitoring and control in the aquifer, as well as active technical measures for aquifer protection and management such as artificial recharge. This successful example (previous to the current Water Act) contrasts with several unsuccessful attempts that have failed after official declaration of aquifer overexploitation (as required by the Water Act). Once again, it becomes apparent that having a good or bad law is not the most important factor to succeed in proper groundwater management practices.

Changes introduced by the 1985 Water Act and the successive reforms were positive, and necessary to deal with the challenges resulting from the more intensive use of groundwater resources. However, its implementation has encountered difficulties from which two are worth highlighting. On one hand, Basin Agencies, who lacked any experience in groundwater management, have consistently lacked sufficient human and financial resources to deal with their newly acquired responsibilities. They have also had difficulty shifting their focus from their traditional water infrastructure development and management responsibilities to their new broader water management goals. Staff at Basin Agencies has been historically dominated by civil engineers, and they have lacked expertise in other areas (economics, ecology, hydrogeology, geography, education, etc.) necessary to address their new responsibilities. The second significant difficulty is the absence of updated groundwater rights records. More than twenty years after the Water Act came into effect both the Registry of Public Waters and the Catalogue of Private Waters are still incomplete. There are not updated and reliable records of existing groundwater uses and total extraction volumes, which makes effective management difficult.

IMPLICATIONS OF THE EUROPEAN WATER FRAMEWORK DIRECTIVE

On 23 October 2000, the Directive 2000/60/EC of the European Parliament and of the Council known as the EU Water Framework Directive (WFD) was finally adopted. The WFD provides a framework for the protection, improvement and sustainable use of all water bodies in the environment across Europe, from source to sea. These water bodies include surface, underground and coastal waters. The main aims of the Directive are to protect and improve the water environment. This includes preventing the deterioration of aquatic ecosystems and, where possible, restoring ground and surface waters to achieve a "good status" by 2015. Afterwards, on 12 December 2006, the European Parliament approved a new directive (2006/118/EC), known as the "Groundwater Directive on the protection of groundwater against pollution and deterioration". This second directive explicitly reinforces those key aspects of the WFD dealing with groundwater.

According to Sahuquillo et al. (2007) two different set of actions are required in order to achieve a proper implementation of WFD: (1) technological actions, and (2) management and legal actions. In this way, the process is proceeding in parallel, from the transposition of the WFD into Spanish law, which has been recently done, to the technical work and public participatory activities being carried out by the different Basin Agencies and other water research and management institutions under the supervision and coordination of the Spanish Ministry of the Environment. From a legal standpoint, the first reform came in 2003 through Law 62/2003 of December 30th, which introduced some of the key concepts and language of the WFD into Spanish law.

As pointed out in Hernandez-Mora et al. (2007) the concept of sustainability in the WFD is mainly related to its ecological dimension. Attention to other dimensions of sustainability (social, economic, institutional, legal, political, and so on) is only secondary and the responsibility of each country. In terms of defining good ecological status for groundwater bodies, the WFD focuses primarily on water quality and pollution sources. This outlook may prove challenging to implement when dealing with groundwater in arid or semi-arid Southern Mediterranean countries, where excessive groundwater abstraction with its potential impact on water quality and stream flows and wetlands has been the primary concern. If WFD provisions are strictly enforced, many groundwater intensive developments in Spain may have to cease, while the social and economic sustainability of such a decision, and its political viability, is problematic. As pointed out by Llamas and Garrido (2007), this situation may be caused by the insufficient participation of European Mediterranean experts in the preparation of the WFD. In Spain, as in other semiarid Mediterranean countries of South Europe, about 80% of water is used for irrigation and intensive use of groundwater is a common practice. Water quality problems are also important in the Mediterranean countries indeed, but it must be taken into account that effective actions to achieve the good chemical and ecological status of the groundwater will be much more difficult to implement in the Mediterranean countries than in other central and north European humid and temperate countries. The WFD also states clearly (article 4) that Member States shall implement the measures necessary to prevent or limit the input of pollutants into groundwater and to prevent the deterioration of the status of all groundwater bodies. However, restoration of contaminated aquifers in semiarid regions can be an extremely costly, long-term and technically difficult task in practice. The real challenge for the scientific-technical, political and social stakeholders in the south European countries will be to find out the paths to achieve an effective implementation of WFD principles in their specific hydro-climatic and socio-economical context.

SUMMARY AND CONCLUSIONS

Spain is among the most arid countries in the European Union, but has a large hydrogeologic potential. Annual aquifer recharge in Spain has been estimated to be about 30,000 Mm^3 which amounts for 30% of the total water resources available. Current groundwater use in Spain amount to 6,500 Mm^3/year, mainly used for irrigation of about 1 million of hectares, which corresponds to 30% of the total irrigated surface of the country. Groundwater-based irrigation shows higher efficiency than irrigation based on surface water which uses to be heavily subsidized.

699 groundwater bodies have been identified in Spain during the “Initial

Characterization Stage" of the implementation works of the WFD. 259 (38.65%) of these groundwater bodies are classified "at risk" of not achieving the environmental objectives of the WFD. Diffuse pollution, mainly due to high content of nitrate, is the main identified environmental problem affecting 167 groundwater bodies, and marine intrusion affects to 72 groundwater bodies. Most probably, these figures will increase in the near future when the results of the additional assessment of the 256 pending groundwater bodies were published.

Groundwater in Spain is a public domain resource since 1985. The changes introduced by the 1985 Water Act and the successive reforms were necessary to deal with the challenges resulting from the more intensive use of groundwater resources. However its implementation has encountered many difficulties which in some ways continue up to date. On one hand, Basin Agencies, who lacked any experience in groundwater management, have consistently lacked sufficient human and financial resources to deal with their newly acquired responsibilities. They have also had difficulty shifting their focus from their traditional water infrastructure development and management responsibilities to their new broader water management goals.

WFD provides a framework for the protection, improvement and sustainable use of all water bodies in the environment across Europe, from source to sea. The main aims of the Directive are to protect and improve the water environment, to achieve the "good status" of all the waters by 2015. The WFD states that groundwater abstraction should not cause a significant impact on the connected surface water bodies. If this provision is strictly enforced, many groundwater intensive developments in Spain may have to cease. The real challenge for the technical, political and social stakeholders in the south European countries will be to find out appropriate paths to effective implementation of WFD principles in their specific hydro-climatic and socio-economical contexts.

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