Status of the peninsular Spanish basins according to the quality of their bodies of water

A. Castro-Valencia\(^{(1)}\), R.M. Arce-Ruiz\(^{(2)}\), J.A. Saiz-Hernández\(^{(1)}\)

\(^{(1)}\) Department of Civil Engineering and Mining, Universidad de Sonora
+52 1 662 1940001  alejandra.castro@unison.mx

\(^{(2)}\) Department of Transport and Territory of the E.T.S.I. de Caminos, C.P., UPM

Summary – With vectorial information of the second cycle of River Basin Management Plans 2015-2021, elaborated as part of the actions of the Water Framework Directive and published by the Ministry of Ecological Transition, 5,122 bodies of surface water and 12,185 sub-basins of the Spanish peninsular territory were identified. The sub-basins were classified according to the chemical, ecological and general status of their bodies of surface water, obtaining as a result spatial distribution maps of the surface water quality by sub-basin. Based on population information published by the National Institute of Statistics, the population living in each sub-basin was determined. As results were obtained that, considering the chemical status, 65 percent of the population lives in 83 percent of the territory with a good status of its surface waters, but considering the ecological status, only 21 percent of the population, in 37 percent of the surface, it lives in sub-basins with good or very good general condition; In addition, it was found that the ecological status is the one that most affects the general status of the sub-basins and that there is a relationship between water quality status and population density.

1. Introduction – The Water Framework Directive (WFD), established in 2000, sets as its main objective to establish a framework for the protection of European surface waters, transitional waters, coastal waters and groundwater, which contributes to the supply of good surface and groundwater quality as necessary for a sustainable, balanced and equitable use of water. One of the fundamental actions to achieve it, was the identification and classification of the water masses, according to their ecological status and chemical status to maintain the good status if it is the case, or improve until reaching it.

According to the 2011 census of the National Institute of Statistics (NIS), Peninsular Spain has a population of 43,238,260 inhabitants distributed in cities or urban communities located in 15 River Basin Districts (RBDs), in which productive activities are developed that greatly condition the presence of contaminants, having been found agrochemicals such as N, NH\(_3\) and P in rivers and lakes, product of agriculture \([1], [2]\); Zn, Cd, Cu and Pb \([3]\) and As, Co, Ni, and Pb, in addition to acid discharges, due to mining activity \([4]\); Hg, Fe, Zn, Cu, Mn and drugs, which contribute urban areas \([5]\) and Cr, Zn, Sb, Hg and Cu, due to industry \([6]\), which have altered the ecological and chemical status of bodies of surface water.

As part of the actions contemplated in the WFD, the RBDs, through the Ministry of Ecological Transition (MET), have elaborated databases in which tabular attributes of variables and water quality parameters are related to vectorial maps of the bodies of water, representing stretches of rivers, lakes and coasts within the Spanish RBDs with linear and polygonal entities. With these data, studies have been made in which lengths and areas of bodies of water are analyzed \([7] - [10]\) although they give an idea of the magnitude of the problem, they do not identify a relationship between water status and the anthropogenic activity in the basins, which conditions the status of the bodies of water \([11], [12]\).

In this article, considering that each body of surface water responds to the characteristics of its slope \([13]\), that the status of the bodies of surface water depends on the use of soil in its drainage area \([5], [14]\) and that the analysis must be carried out by sub-basin \([15]\), maps of the spatial distribution of the ecological, chemical and general status of the sub-basins have been made corresponding to the same status of the body of water to which they belong and, based on the grid of 1 square kilometer of population of the census...
drawn up in 2011 by the NIS, determines the population that inhabits each one of the 12,185 sub-basins in which the Spanish peninsular territory was divided.

2. Methodology - The study site includes the RBDs of peninsular Spain, Image 1. For the analysis, vectorial information of the ecological and chemical status of 5,122 bodies of surface water of the second cycle RBMPs, published by MET [16] was used. The population information was extracted from the grid of 1 square kilometer published by Eurostat [17], which is related to the NIS indicators [18].

The process of analysis and mapping is described below:

Step 1. Assignment of ecological status to the sub-basins. It is assumed that the ecological status of the water body within the sub-basin is the same ecological status of the sub-basin. Line vector data of rivers and polygon type of lakes, waters in transition and coasts were processed with a Geographical Information System (GIS) joins attributes from one feature to another based on the spatial relationship to assign the ecological status to each sub-basin as "high", "good", "moderate", "poor", "bad" or "unknown" as it is marked by WFD Annex V-1.4.2 for bodies of water, resulting in a polygon-type vector map of sub-basins with an associated table of their ecological status, Images 2.a. and 2.b.

Step 2. Assignment of chemical status to the sub-basins. It is assumed that the chemical status of the water body within the sub-basin is the same chemical status of the sub-basin. Proceed in an analogous manner to step 1 and assign the chemical status as "good", "failing to achieve good" or "unknown" to each sub-basin as marked by Annex V-1.4.3 of WFD, Images 2c. and 2d.

Step 3. Assignment of the general status to the sub-basins. Each feature, that is, each sub-basin, in step 1 and 2 is assigned the ecological status and the chemical status, to later know the general status taking into account the scheme shown in Image 3a. If the ecological status is "high" or "good" and the chemical status "good" or "better", then the sub-basin will have a general status of "good or better", otherwise its status will be "failing to achieve good" according to Art. 2.17 of WFD for bodies of water, Image 3b.
Step 4. Calculation of the population and the surface of the sub-basins by classification. In this part the grid of a square kilometer established by Eurostat (ETRS89_LAEA grid 1km) is used and merged with the population database of the 2011 census of the NIS (Population database), to assign the population that inhabits each subbasin following the Scheme of the Image 4a. Points were created corresponding to the centroid of each square in the grid with information about its total population and then assigned to each sub-basin (Sub-basin shape type polygon) the sum of the population of all the points that coincide within it, Image 4b.

Image 3. a) Schematic diagram of assignment of the General Status to the sub-basins, taking into account the Ecological Status and Chemical Status. b) Representation of the General Status of the sub-basins in the same area of the example in Image 2.

Colour code: Good or better (blue), Failing to achieve good (red).

Image 4. a) GIS schematic diagram to assign total population to each sub-basin. b) In the example shown, the sum of the population of the 12 shaded squares is assigned, which coincides with the point of its centroid in the corresponding sub-basin.
3. Results and Discussion – From the analysis of the ecological status of sub-basins, it was obtained that only 23 percent of the population lives in a basin with "good" or "high" status that comprises 38 percent of the total area. The RBDs with the highest percentage of good or high quality are Western Cantabrian with 81 percent and Galicia Coast with 72 percent, with the same RBDs with the highest percentage of population, 67 and 58 percent respectively. The RBDs with less good ecological status are Duero, with 84
percent of its population living in 72 percent of its surface and Guadiana, with 81 percent of its population living in 82 percent of its surface, Image 5a.

The sub-basins with the best ecological status have the lowest population density, on average those that have an ecological status of "high" or "good" have a low population density of 52 and 77 inhabitants per square kilometer respectively and those that have more population density in average are those with worse ecological status, Image 6a. The sub-basins with good and high status are mostly in the right margin of the Guadalquivir, the left margin of the Ebro and distributed equally in the Mino-Sil, all of them with less than 1 inhabitants per square kilometer. On the other hand, the sub-basins with the worst ecological status have the highest population density and are found in the Llobregat river basin in Catalonia with more than 20,000 inhabitants per square kilometer and in the Genil river basin in the Guadalquivir with more than 17,000 inhabitants per square kilometer.

From the analysis of the chemical status, 65 percent of the population lives in basins of good chemical status and inhabits in the 83 percent of the total area. The RBDs that contain the largest area of chemical status "failing to achieve good" are Tinto-Odiel-Piedras, Guadalate-Barbate and Catalonia, being 79, 45 and 62 percent of its population respectively, Image 5b.

On average, sub-basins of good chemical status have 106 inhabitants per square kilometer; on the contrary, those that do not reach good chemical status have an average population density of 482 inhabitants per square kilometer, Figure 6b. In 10,083 sub-basins, the chemical status is good, but where it does not reach good condition, population densities are high, such as in the Nervión river basin in Eastern Cantabrian, where more than 32,000 inhabitants per square kilometer live. High densities are also found in the basin of the river Besós and Llobregat in Catalonia and the basin of the Genil river in the Guadalquivir.

It was found that only 21 percent of the population lives in basins of general status "good or better" that corresponds to 37 percent of the surface of peninsular Spain. The RBDs with the largest area in "good or better" status are Western Cantabrian, Galicia-Costa and Mino-Sil, with 77, 71 and 67 percent of their surface area, corresponding to 57, 54 and 40 percent of the population respectively. The RBDs that have more surface with water that did not reach the good status are Guadalquivir with 82 percent of its surface and 80 percent of its population and the Duero with 73 percent of its surface and 86 percent of its population, Image 5c.

There are 5,685 sub-basins, almost half of the total, which have a good general status and on average their population density is 67 inhabitants per square kilometer, while those that do not reach good condition have an average of 208 inhabitants per square kilometer, Image 6c. The sub-basins with better general condition are those with less population density and are located on the right riverbank of the Guadalquivir, the right riverbank of the Tajo, the left riverbank of the Duero, as well as the basins of northern Spain in general.

4. Conclusions – The study shows a clearer way to visualize the quality of surface water bodies and the sub-basins that provide them with run-off, it enables to identify the surface of the territory that houses the sources of contamination and to determine the population that interacts with the masses of water.

Most of the peninsular Spanish territory is in good chemical status and also accommodates 65 percent of the population, however, it is the ecological status, the one that determines the general condition of the sub-basins and their water bodies and also is the most difficult to restore, so only 23 percent of the population lives in sub basins with good general condition in their surface waters.

The relationship observed in the status of the sub-basins and the density of the population opens the possibility of deepening the knowledge of the relationship between the quality of water bodies and sub-basins with: the gross domestic product, the industrial development, per capita income, health and the incidence of diseases and other anthropogenic activities related to water resources.
5. References


