Chapter 5
Environmental Impact of Human Activities on Water Resources and Its Characterization for Management and Planning of Natural Areas "Las Batuecas-Sierra Francia" and "Quilamas" (Salamanca, Spain)

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Abstract This paper presents a combined Strategic Environmental Assessment and Impact Characterisation procedure to analyse the importance and extent of the impact of human activities in natural spaces on water resources. In an initial phase, the different human actions (landfills, etc.) that may cause impacts, whether directly (sewage, etc.) or indirectly (leachate, etc.), are determined and the environmental impact identification map is drafted. Subsequently, thematic and interpretive mapping (Surface Water Quality, Aquifer Vulnerability to Pollution and Vulnerability to Solid Waste) is carried out to assess the effects on water resources. Finally, superimposing the Impact Identification map over the Vulnerability maps (Solid Municipal Waste, Aquifers and Surface Water Quality) provides the Impact Characterisation map, showing the absorption capacity of different sectors to facilitate the setting up of preventive and/or remedial measures by the authorities responsible.

Keywords Environmental assessment • Environmental impact • Water resources • Water quality • Aquifer vulnerability • Solid municipal waste • Salamanca Spain

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5.1 Introduction

The impact of human activities on the environment has highlighted the need to regulate these activities in a sustainable manner taking into account the absorption capacity of the natural environment. To this end, a set of environmental tools is established: Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA), to ensure rational use of natural resources, prevention and mitigation of the effects of pollution and natural hazards. This paper proposes a combined procedure using tools from the former procedure (EAE) and Impact Characterisation methods from the latter (EIA). This working method allows the management of a natural space to analyse the environmental impact on water resources of existing activities as well as those anticipated in the pre-project phase. This study was conducted in the natural environment of Las Batuecas-Sierra de Francia and Quilamas, in southern Salamanca province in the Spanish Central System (Fig. 5.1).

5.2 Methodology

The methodology used (Fig. 5.2) consisted of applying a mapping procedure with GIS techniques and quantification of environmental impact on natural factors: water, soil, air and landscape, using EIA methods: evaluation of attributes (persistence, extension, synergy, etc.) and matrices (crossing of actions and factors).

The EIA is carried out in an initial phase by identifying the different human activities (landfills, etc.) likely to cause impacts, whether directly (sewage, etc.) or indirectly (leachate, etc.), mapping the environmental impact and/or technological risks (Fig. 5.3a), whether discrete, linear, zonal or areal.

In the second phase, field sheets or checklists are drawn up where each disposal activity and point is characterised by its intrinsic (geology, geotechnical, surface hydrology, hydrogeology, topography and vegetation) and extrinsic features (type of waste, toxicity, persistence, drainage, covering, size, management, etc.) for a qualitative assessment (High-Middle-Low-Null) of the contamination risks at each site and determining which factors will be affected (water, land, air, landscape, geomorphology, active processes, and socioeconomic elements).

Finally, a series of thematic and interpretive maps was drafted to evaluate the effects of different human activities on the water resources:

1. Surface Water Quality map (Fig. 5.3b), where, on the basis of field surveys, the quality and/or degree of surface water pollution is determined through the Simplified Water Quality Index (SWQI) (de Bustamante 1989), which is a dimensionless number that allows operation with very few analytical parameters while providing guaranteed results (Cubillo 1986). This index is defined by five parameters, and its expression is: SWQI = T (A + B + C + D) where T is the river water temperature measured in °C. A is the chemical demand for oxygen

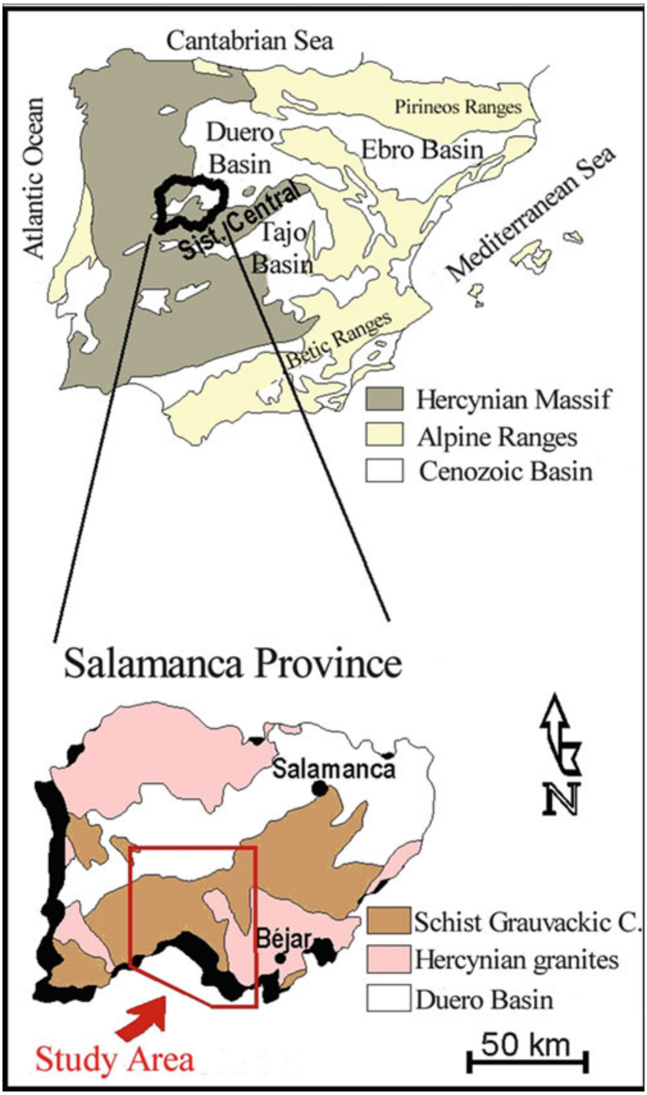

Fig. 5.1 Study area

including organic content, whether natural or otherwise. B is the material in suspension that can be separated by filtration. C is the oxygen dissolved in water. D is the electrical conductivity at 18°C; it measures the concentration of inorganic salts. The range of values of this index varies from 0 for very poor value to 100 for optimum values.

2. Map of Aquifer Vulnerability to contamination (Fig. 5.3c), drawn up from the mapping of hydrogeological units, taking into account their lithological and

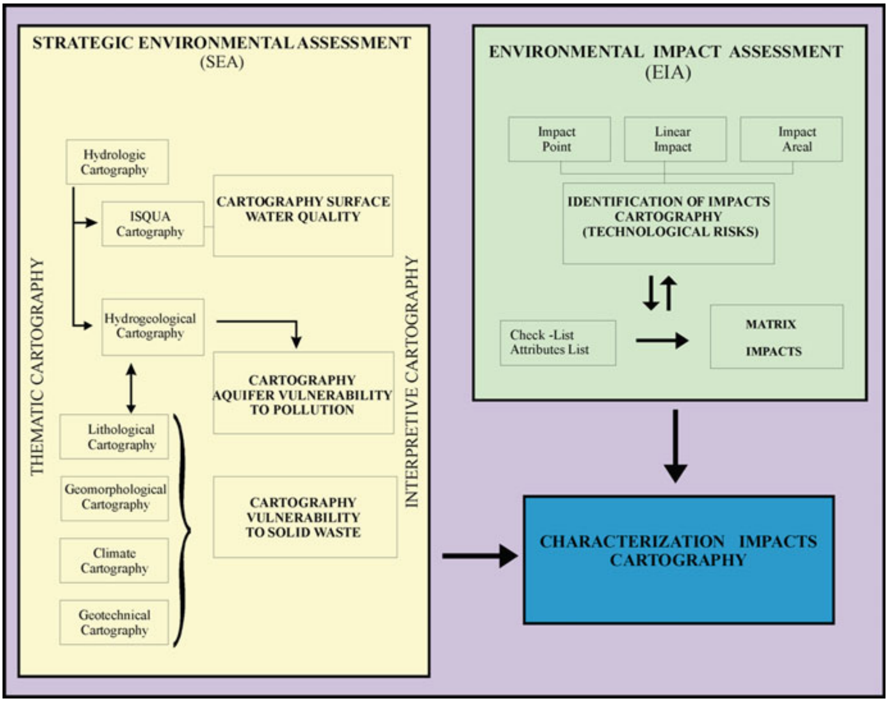

Fig. 5.2 Methodological diagram

hydraulic parameters. The GOD method was used for this purpose (Foster et al. 2003), taking into account three main factors: hydraulic containment levels (G), occurrence of overlying substrate (O) and distance to groundwater level (unconfined) or ceiling of the aquifer (confined) (D).

3. Map of Vulnerability to Solid Urban Waste – SUW – (Fig. 5.3d), obtained through GIS techniques (ArcGIS v.9) from the thematic mapping of the parameters that influence said vulnerability: lithology, surface hydrology and hydrogeology, geomorphology, climate and geotechnics. The lithological parameter takes into account the distribution of the lithology of the different sectors of the PNS (Martínez-Graña et al. 2004). Different features to be considered for the location of a landfill are taken into account: bedrock, structure (fractures and joints), surface formations (texture, compaction, etc.). The surface hydrology and hydrogeology parameter analyses these features in line with the type of permeability (K), based on the porosity (intergranular and fissure), solubility and fracturing (Martínez-Graña et al. 2004; Sanz et al. 2005). The limit values for waste disposal sites are included: non-hazardous waste landfills: K less than or equal to 1×10^{-9} m/s, and landfills for inert waste: K less than or equal to 1×10^{-7} m/s. (Williams 1998).

The geomorphological parameter helps to understand the morphological features that affect the substrate, the surface formations and the slope gradient to

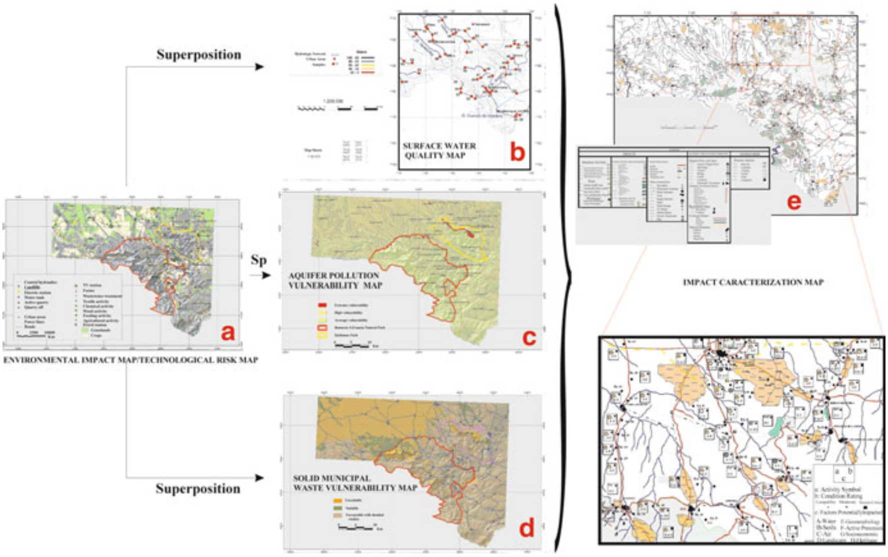

Fig. 5.3 Impact identification map (**a**) which is superimposed on the surface water quality map (**b**) aquifer pollution vulnerability map (**c**) solid municipal waste vulnerability map (**d**) obtaining the impact characterisation map (**e**) cartography details and interpretive diagram

be considered for its location (Martínez-Graña et al. 2006). This map will help to identify the active processes (risks) that determine the hazardous areas for the location of the landfill or waste treatment facility. The climate parameter analyses the rainfall distribution, as it favours the formation of leachate likely to contaminate water and soils. The Stormwater Aggressiveness map was used (Martínez-Graña et al. 2004) which was carried out based on the modified Fournier index (Fm). This mapping helps to gauge the effect of rain on the landfill and its impact on restoration (revegetation of slopes). Finally, the geotechnical parameter allows accurate planning in the operational and restoration phase of a landfill by analysing existing loan materials in the area to be used in these tasks. To do so, it is necessary to know the rippability of materials for the possibility of covering or whether it is necessary to excavate a basin to achieve a longer useful life. This variable was obtained on the basis of lithological, geomorphological and hydrological features.

5.3 Results and Conclusions

From analysing the interpretive mapping, it can be seen that the surface water quality map shows that some rivers (Alagón, etc.) present a lower water quality than their tributaries. This is due to localities dumping their urban waste water (Sotoserrano, Valero, San Miguel de Valero) as well as industrial waste (food industry, agriculture) into the channel, reducing the water quality by discharging unprocessed effluent. The lower waters corresponding to the river Yeltes present a slight decrease in quality caused by mining activities located on the plains and river terraces, creating an increase in turbidity (suspended solids) and incidence of waste typical of extraction activity (processes and machinery).

The Aquifer Vulnerability to Pollution map shows an extreme vulnerability in carbonate outcrops, where the dissolution processes of limestone and dolomite can delimit the land most vulnerable to contamination. These aquifers are extremely vulnerable to the direct and rapid spread of contaminants in fissures and cavities in carbonate rocks. In territorial land use planning, the introduction of polluting activities such as solid or liquid (urban and/or industrial) waste disposal, either on the surface or buried, should not be permitted in these sectors. Inappropriate farming practices and activities must be monitored, and the land disturbed by active or abandoned extraction activities (mining) restored. The areas with high vulnerability correspond to quaternary material, whose aquifers are highly vulnerable to the entry of pollutants from rivers, streams or direct infiltration. This pollution mainly affects free alluvial aquifers. Their ability to self-purify organic and bacteriological contamination is limited. As in the previous case, the installation of human activities likely to affect the quality of aquifers containing these quaternary formations should be closely monitored. Finally, the vulnerability is average mainly in areas where the land alternations are permeable and less permeable (detrital units) with a high capacity for bacteriological purification but low for chemical contaminants. In the second place, it may occur in impermeable igneous and metamorphic lithologies, being limited to surface water pollution and sectors of cracks and alterations.

The Vulnerability to Solid Urban Waste map shows the sectors suitable and unsuitable for landfill construction a priority, and sectors that may be favourable with detailed studies (DS), such as granite areas, to determine the saprolite thickness and degree of alteration. According to these parameters, the areas of greatest territorial acceptance of this type of human activity (landfill) are currently located near urban areas.

In second place, the Impact Identification map is superimposed on the Surface Water Quality, Aquifer Vulnerability to Pollution and Solid Waste Vulnerability maps, noting the effects and problems of different human activities in each area and their potential impact on different factors (water, soil, air, landscape, geomorphology, active processes, socioeconomic elements and heritage). The Impact Characterisation map is obtained this way, showing the absorption capacity of the different locations of human activities, the variety of types of effects (industrial, agricultural, livestock, landfills, etc.), the degree of impact (compatible, moderate, severe-critical) and the factors susceptible. The negative effects of livestock activities on soil and water resources observed are severe, compounded by a moderate degree of impact on the landscape due to the presence of electrical and communication infrastructures.

This methodology is of great interest as it provides reliable results quickly and economically, suitable for application both in rural areas with poor resources and the management of protected natural areas, constituting a useful tool to understand the state of the natural environment and in particular to analyse the impact on water quality and identify pollution sources, paving the way for further studies to identify specific problems and their solutions.

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