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Groundwater vulnerability and quality standards

title: **Wellhead protection against diffuse pollution at catchment scale**

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INTRODUCTION

Solutions such as agri-environmental measures, land management, afforestation and grasslands are used to protect underground water, especially when used for human water supply, against persistent chemical contaminants, such as nitrates and pesticides. The cost of such measures, which can be very important if considering the whole groundwater catchment area, requires having a specific and optimized approach based on the identification of areas where the actions will be the more efficient. This approach is based on the crossing of catchment area vulnerability with pollution pressures (Fig. 1).

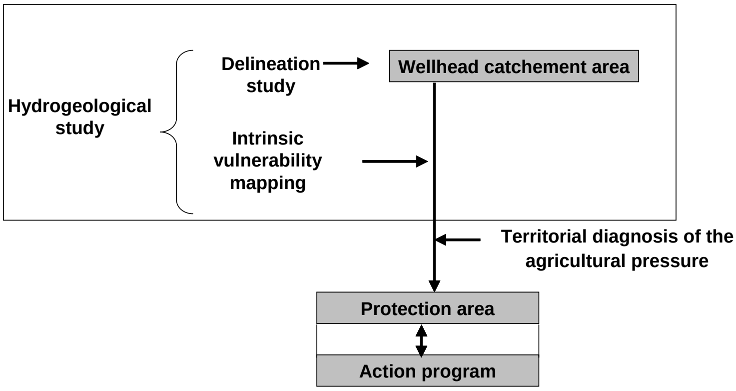

Figure 1. Approach for the protection of water well againt diffuse pollution.

METHODOLOGY

A methodology was developed by BRGM in order to delineate such protection areas and action plans according to the type of aquifers present in France : alluvial, sedimentary (karstic or non karstic), basement (Vernoux et al., 2007 ; Vernoux et al., 2008). Nevertheless, it can be applied to any type of aquifer as long as the considered aquifer was classified among three proposed types : continuous aquifer, discontinuous fractured aquifer, discontinuous karstic aquifer. The methodology consists of three steps : (i) identifying the aquifer area that supplies the groundwater source or well, (ii) defining on the ground surface the catchment zone of the well or source in question (Fig. 2), (iii) mapping the vulnerability of the catchment zone from a multicriteria analysis. The aquifer area that supplies the groundwater source or well depends on structural geology and hydrodynamic criteria. In the same way, different methods were developed for vulnerability mapping, according to the type of aquifer. The proposed methods of vulnerability mapping were adapted from existing methods (DRASTIC, RISKE and DISCO). The needed parameters for multicriteria analysis are : soil characteristics, efficient rainfall, infiltration in the overlying layers, unsaturated zone thickness, aquifer permeability and karst specific parameters (karst network development and epikarst).

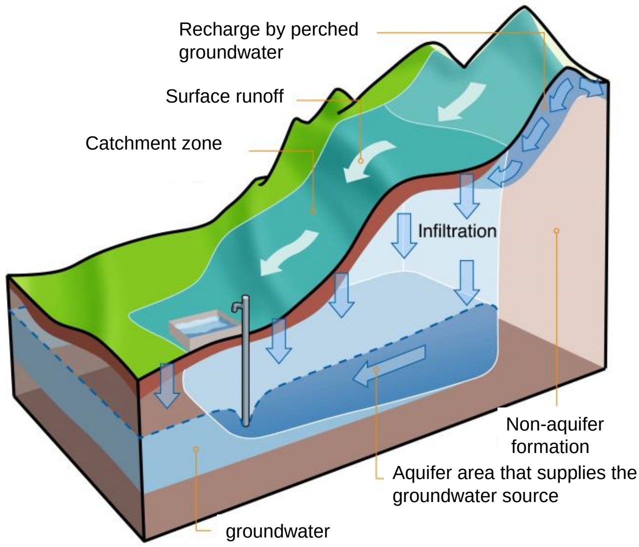

Figure 2. Schematic representation of a catchment area.

APPLICATION TO A SAND AND CHALK AQUIFER

The methodology was applied to the study of 24 wellheads located about 50 km south-west of Paris. The aim of the study was to delineate the catchment zone for each wellhead, to map aquifer vulnerability, to identify pressures and to propose action plans to reduce pollution, especially diffuse pollution (Vicelli et al., 2008). The aquifer is made up of Fontainebleau sand et cretaceous chalk that can be locally separeted by clay formations (Fig. 3). On a hydrodynamic point of of view, the two formations can be considered as a single aquifer.

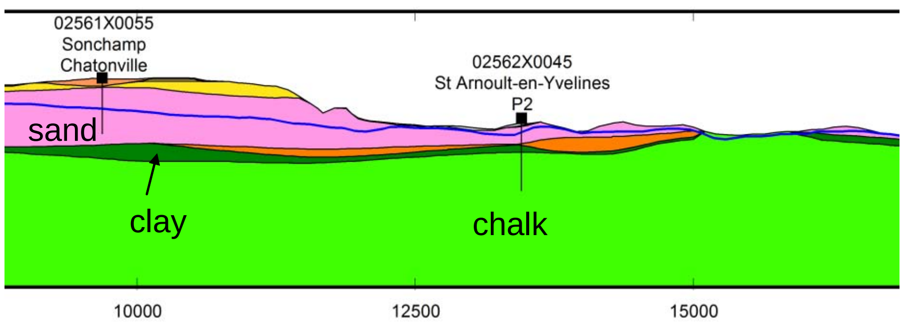

Figure 3. Hydrogeological section of the study area.

Ten catchment areas were defined from piezometric map and hydrodynamic modelling and the vulnerability was assessed from a continuous aquifer approach with (Fig. 4):

Vulnerability = $0.1 \cdot P + 0.25 \cdot S + 0.3 \cdot I + 0.2 \cdot H + 0.15 \cdot K$ (where P is efficient rainfall, S is soil, I is infiltration, H is unsaturated zone thickness and K is aquifer permeability).

One of the main parameters is infiltration (I). Typically, this parameter is estimated from precipitation, evapotranspiration and runoff (I = P - R – ETR). BRGM developed a tool named Network Persistence and Development Index (IDPR) which gives an indirect approach to infiltration (Mardhel et al., 2007). Based on the comparison between two drainage patterns (one calculated from a Digital Elevation Model (DEM) and the natural hydrological pattern), it reflects the influence of the underlying geological formations toward surface-water runoff or infiltration.

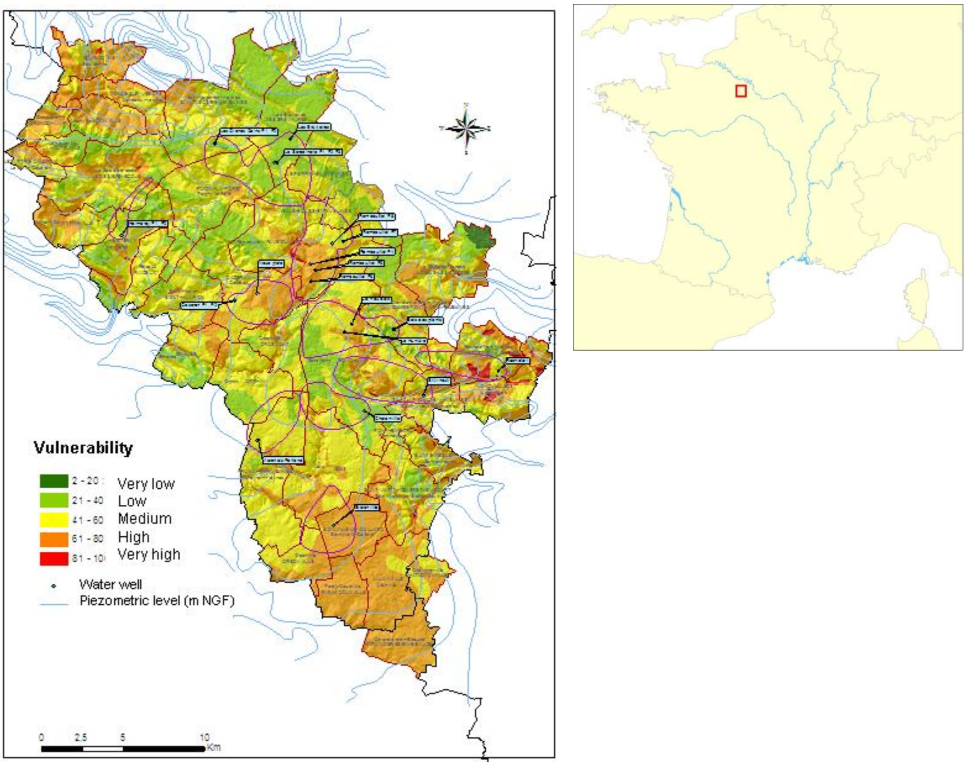

Figure 4. Catchment areas and vulnerabilty mapping.

ACTION PLANS TO REDUCE DIFFUSE POLLUTION

Action plans were developed to help deciders to efficiently adapted preventive action against contamination. The aim of the action plans is to propose realistic measures for the studied area and to suggest proportional responses to the risk. This allows giving advices which are more likely to be accepted. For instance, action plans to prevent fertilizers or plant protection products contamination take into account pedoclimatic context and farm economic viability. Realistic responses are possible by the promotion of mitigation measures already used. The dissemination of knowledge and technologies is a key-principle. The actions plans are hence established for the different types of contaminations identified (e.g. gardens, fields). Proportional responses to the risk are achievable by the description of different classes of risk (high, medium, low) for the each type of contamination. Actions plans are gathered into a set of forms which give a brief description of plans for deciders and give applicable methods and financial aspects. Forms are not standalone products but are a help during the decision-making process.

The catchment area were shared into three zones : zone with a high risk, zone with a low risk and zone with a moderated risk. Different action plans were designed to be adapted to each zone (Fig. 4). The practices modifications should be more important with a high risk. Plans of practices modifications were also designed to be adapted to the different users of pesticides and fertilizers such as the farmers or the gardeners. Plans were also designed to take into account the differences between the diffuse pollutions and the point source pollutions.

Several plans were designed to reduce contamination from field diffuse pollutions. A set of way of improvement were proposed. This set was presented by 17 specification sheets. Each sheet described a way of doing to decrease the pressures of pesticides or nitrates on groundwater. Few sheets were advised to farmers in zones with a low risk whereas the complete set of sheet was advised to farmers in a high risk zone.

Some sheets concern fertilizers and pesticides uses. For instance, new technologies and methods for calculating the nitrogen needs of crops (such as N-testers use) are a possible way for reducing nitrates transfers from the surface to groundwater. Other ones concern agricultural practices as the use of long crops successions. Long crop successions are easy ways for reducing pesticide uses since the planting of the same crop at short interval attracts specific pests. Cultivating new successions could be complicated if no advices is received from the local farm advisors. Practice improvements are not only expected from the farmers but also from the farmer's partners. Action plans point the needs for implications of all the partners (farmers, farmer advisers, municipalities) to decrease the pressures on groundwater.

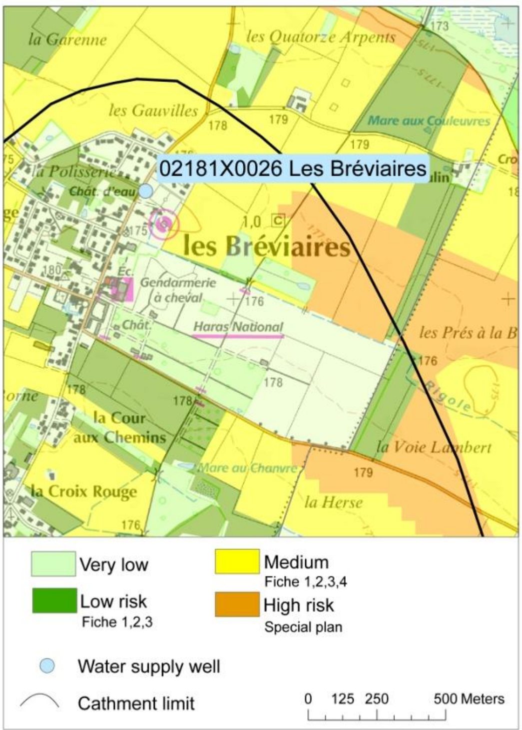

Figure 5. Use of action plan around a water supply well.

Some specification sheets concern the possibility of reducing risks by modifying the practices only on precise areas. These areas could be identified only on high risk zone by farm advisors specialized on the detection of those areas. Once the area detected, the farmers have to make important changes in their practices. To create new grassland or to convert the plots to organic farming are possibilities. The municipalities can buy these plots or exchange the risky plots with low risk ones. The farmers need to deeply modify their practices only on a reduced area. In the rest of the high risk zone, their practices are modified. In the low risk zone, their practices are little modified. Identifying different zones is a way to reduce the pressures of pesticides and nitrates on the groundwater without jeopardizing a farm future. The method could yield to economically viable modification.

Plans have to be designed to be used locally. Advices on new crops successions or on new hoeing method have to be useable on the studied area. To ensure that the advices are realistically useable, meetings with local farming advisers and farmers were realized.

CONCLUSION

The proposed approach is based on the assumption that it is very expensive, and thereby almost impossible to effectively protect against diffuse pollution the entire catchment zone of a groundwater source, especially if it is large. Rather than dispersing financial resources on the whole basin with limited expected results, it appears more appropriate to focus on sensitive areas.

The methodology is based on the intrinsic characteristics of the basin (geology, soil science, hydrodynamics, rainfall). It consists in defining as precisely as possible the catchment zone and afterwards to identify the most sensitive to the transport of pollutants to groundwater source. In a second step, the realization of a territorial diagnosis of the pressures (especially agricultural) related to vulnerability, will enable the effectiveness and efficiency of the action.

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