O 23. DETERMINATION OF PRIORITY CLASSES IN WATER PROTECTION ZONES OF LECHTINGEN AREA BY GIS

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ABSTRACT: Water protection zones are mainly established for protecting different types of water sources such as surface water, coastal water, and groundwater. Many European countries use these areas to evaluate the potential contamination risk encountered by the water sources. Germany has described three different water protection zones changing with respect to the types of water sources. Zone I covers the immediate water catchment area within a radius of at least 10 meters. Zone II covers the area of zone I and distance which has been reached by the contaminant up to 50 days. Zone III is more comprehensive than others. It covers the area from Zone II to the very edge of the catchment area of the water source. Determination of priority classes in water sources is important to evaluate the risk of contamination. In this study, priority classes for nitrate leaching, which is dangerous for health if it is found higher levels in a drinking water source, in the water protection zones found in Lechtingen area of Osnabrück, Germany was determined with geographic information system (GIS). The data of nitrate leaching risk, land use, and water protection zones in that area were used to make evaluation about priority classes. As a result, almost 40% percent of the area found as a high priority against nitrate leaching.

Keywords*: Water protection zones, nitrate leaching, priority classes, GIS, water sources.*

1. INTRODUCTION

Water is the most important life source of human being, so the protection of water sources is a great issue. There are different types of water sources present all over the world such as surface water, groundwater, and ocean water. For drinking purposes mainly groundwater and surface water are used. Especially in developing countries groundwater is preferred water source because of the less requirement of treatment and better bacteriological quality (Appel & Postma, 2005). Groundwater is defined as water in the underground between cracks and other spaces in the soil. It mainly moves between geological formations and stored in the rocks and sand. These structures mainly called aquifers which has different properties with respect to its confined or not (Fitts, 2002; Usul, 2012). Groundwater provides drinking water requirement of 51% of United States (U.S.) population and 99% of the rural population. It is also used for agricultural purposes. In U.S. 64% of groundwater is used for irrigation purposes to growth of crops. It is also an important source for some industrial activities. It can be used for recharge to wetlands, rivers, and lakes (The Groundwater Foundation, 2020). The other important source of drinking water is surface water which is defined as water in river, lake, spring, and pond. These waters are naturally recreated by precipitation and lost with evaporation, the discharge to the oceans, groundwater recharge and evapotranspiration (Ohe et al., 2004). Groundwater and surface waters behave like reservoirs to feed each other.

Ocean waters are the biggest water source in the world. However, while it is not appropriate for drinking purposes, there are several other benefits of oceans such as sea plants and animals farming in coastal waters, fishing in offshore waters and huge carbon sequestration (Srinivasan & Leben, 2004). Owing to the huge benefits of water sources, it is important to protect them from contamination. For that reason, water protection zones were developed.

1.1. Water Protection Zones

Water protection zones are mainly established for protecting different types of water. Many European countries use these areas to evaluate the potential contamination risk encountered by the water sources.

The main federal law of Germans about water protection is Federal Water Act (Wasserhaushaltsgesetz, WHG, in German). The purpose of this act is providing a good status of all water bodies by 2027. This offers the elimination of pollutant concentrations in water bodies and protection of aquatic life (BMU, 2020). There are also several legislations present in Germany to provide

the sufficient protection of groundwater. These legislations are used for maintaining the quality of groundwater sources (Schleyer et al., 1992).

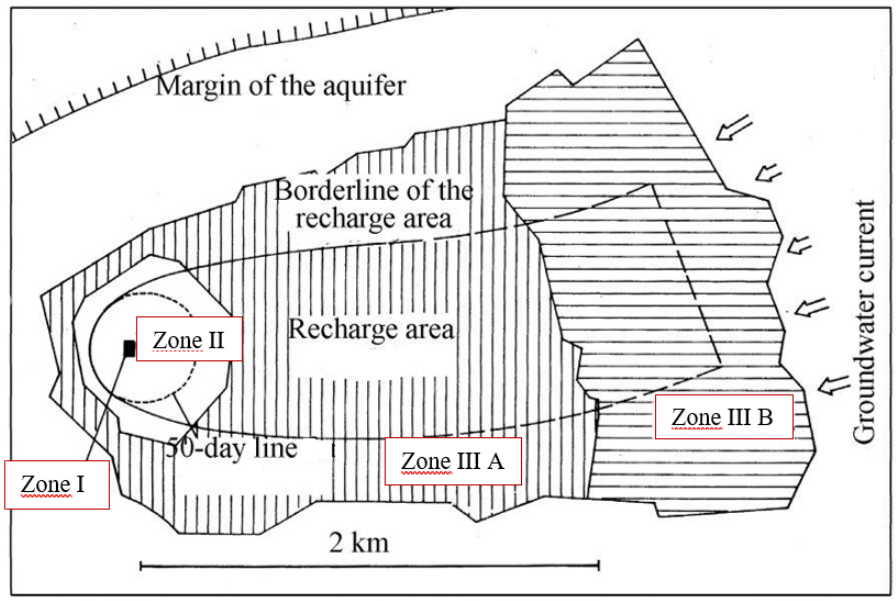

Figure 1. Groundwater protection zones for a well with respect to German legislations (Zhu & Balke, 2008)

In Figure 1, boundaries of groundwater protection zones for a well are given. In this figure the water protection zone has divided into three different zones. These are protection zone I (remedial action zone), protection zone II (attenuation zone) and protection zone III (well field management zone). Zone I mainly provide protection to the direct vicinity of a well. German legislations indicate the distance of 10 m from all sides of water source. Zone II protect water source against pollutants such as chemicals and microorganisms which are harmful for human body. Because the elimination of these kind of microorganisms takes 50 days, Zone II covers the distance of contamination from the water body up to 50 days. Zone III protects water source against radioactive pollutants and chemicals (Zhu et al., 2007). This protection affected by adsorption, decay and dilution with seepage water can be supplied by extension of boundaries of the zone over the hydrological and hydrogeological recharge area of a well. This zone includes two subdivisions called Zone III A and Zone III B, if the longitudinal axis of the recharge area is more than 2 km (Zhu & Balke, 2008). The boundaries of these zones are very important to protect water sources against pollution. there are several pollutants which can create risk on water bodies. In this work, the nitrate pollution risk on the groundwater wells was evaluated with priority classes by the help of geographical information systems (GIS), which is one of the most useful tool for creating evaluation systems and models using different types of data.. Nitrate leaching can have a direct impact on water quality because nitrate is very mobile and easily leaches with water. High levels of nitrates can be toxic to newborns, causing anoxia, or internal suffocation. The health standard limit of nitrate is determined as 10 ppm nitrate-N.

1.2. Priority Classes

Priority classes for groundwater protection may be developed to evaluate potential pollution risk on groundwater sources. It is a simple evaluation system. The urgency level of the sites is determined by the priority classes (Jobstmann, 2009). In the study of Jobstmann, three priority classes were defined. Class I represents the highest risk on the water body and the rapid spread of contaminants while class III represents the low contamination risk and limited spread of contamination (Jobstmann, 2009). In this study according to the land use of the area, the water protection zone type and pollution risk data, evaluation system of Priority Classes was developed. Different from Jobstmann evaluation system, the risk of contamination increases with priority class number in this work.

2. MATERIAL AND METHOD

2.1. Study Area

Lechtingen area is found in the Wallenhorst district of Osnabrück, located at Lower Saxony of Germany. It is situated in the Wiehengebirge, approximately 10 km north of Osnabrück. In Figure 2 the map of Lechtingen area was given.

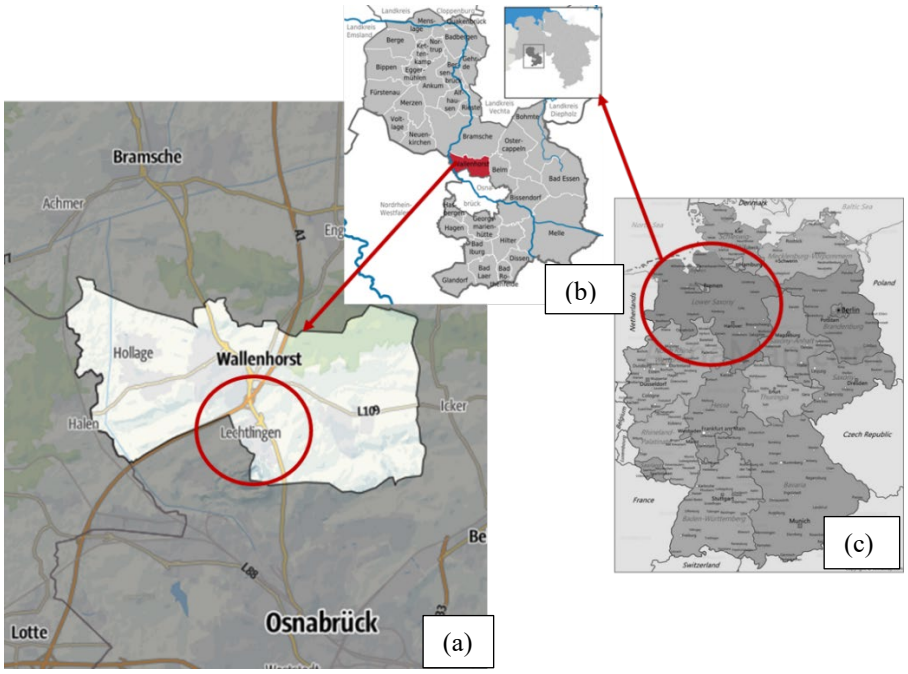

Figure 2. (a) Map of Lecthingen, (b) map of Osnabrück, (c) map of Germany (Anonymous, 2020 a; Anonymous, 2020 b; Anonymous, 2020 c)

In this study, the priority classes within water protection zones was determined. To make this evaluation, topographic map of the area is required. Topographic maps mainly used as a base map in GIS. In Figure 3 topographic map with a scale of 1:25000 was showed. In this map the boundaries of water protection zones of this area were seen also (Amtsblatt, 2000). There are two types of zones determined such as Zone II and Zone III with respect to the three groundwater wells found in the area.

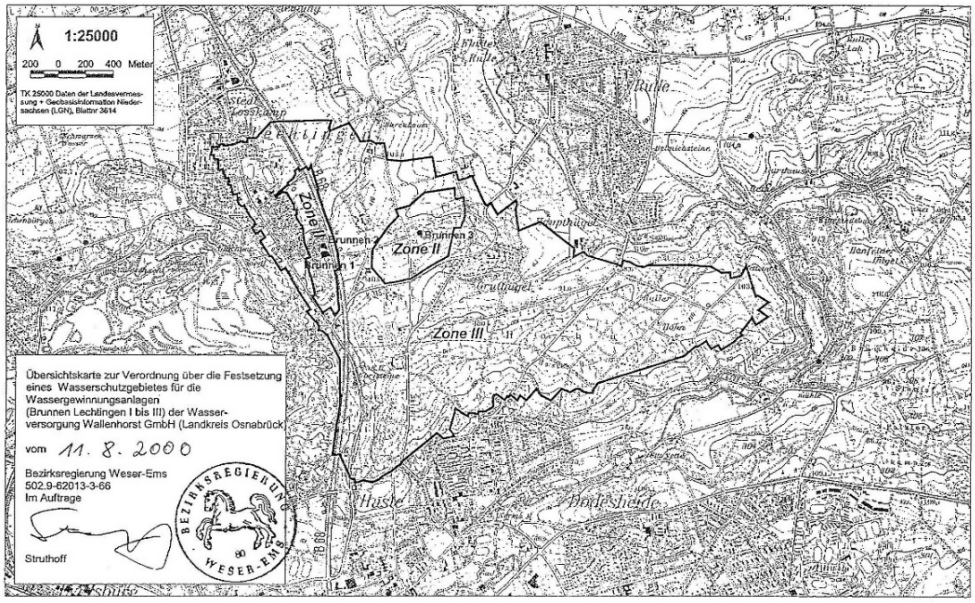

Figure 3. Topographic map of the area with water protection zones' boundaries (Amtsblatt, 2000)

2.2. Georeferencing and Digitization of Water Protection Zone Map

The topographic map of Protection Zone II and III of Lechtingen area was first projected to arrange it with the world coordinate system. This operation is necessary if the map will be used together with other maps. Germany mainly uses Gauss-Krüger-System in all maps. Scanned maps are images which must be rotated, shifted, and scaled to fit to maps in world coordinates. Georeferencing tool of ArcGIS is used to make this operation. There are two different operations is possible. One uses exact world coordinates of some ground reference points on the image and by entering the coordinates directly to the system. The other one needs already georeferenced map to identify different control points between image and map. In this study, already georeferenced topographic map of Wallenhorst was used as a base map for georeferencing the map of Lechtingen area by using different ground control points in the image and on the map.

Then, the water protection zones were digitized by creating polygons. This operation provides the digitize new information within the selected boundaries. Arctoolbox was used for this operation. Data management tools, feature class, create feature class steps were followed, respectively. As a geometry type, polygon was selected. By editing operation, the boundaries were selected, and digitization of water protection zones was completed in the new layer.

2.3. Preparation of Land Use and Nitrate Leaching Risk Maps

Land use map of the water protection zones was prepared with respect to the land usage information (Geozentrum Hannover, 2016) of the area by using joins and relates operation. With this operation it is possible to join different information about the area into the attribute table. The steps include load of table, joining tables to the attribute table of the map and using common key fields. Finally, the symbology was created according to the soil types by using legend editor.

Similarly, nitrate leaching risk map was created by joining operation. Nitrate leaching risk is mainly affected from soil properties, the plant types, seepage water rate. In this study previously determined nitrate leaching risk data was used (Ayturan & Dursun, 2020). The table including the information of nitrate leaching risk was joined into the attribute table and distributed on the water protection zones of Lechtingen area. New symbology was created with different colors.

2.4. Evaluation Criteria for Priority Classes

Determination criteria for priority classes with respect to land use, water protection zone and nitrate leaching risk data was developed as seen in Table 1. These criteria were established according to the soil properties of land uses along with nitrate leaching risk and water protection zone type. Grass lands mainly includes dark and deep soils which has full of nutrients in upper layers and appropriate for the growth of different types of roots (UCMP, 2020). Forest soils are similar with the grassland because they are also nutrient rich with help of the organic matter recycling and offer a good environment for the deeply rooted trees (Boyle, 2005). However, because of the usage of arable lands for agricultural purposes the nutrient levels are not stable and soil quality may be affected negatively especially from crop farming (Adeyolanu et al., 2015). As a result of soil properties of land use types, the evaluation criteria were developed. While the priority of a grassland and forest was determined as 4 against high nitrate leaching risk and zone II, the priority of an arable land was determined as 5.

Table 1. Evaluation criteria for priority classes

Land Use	Nitrate Leaching Risk	Water Protection Zones	Priority Class
Grassland	Very Low	III	**1**
Grassland	Very Low	II	**2**
Grassland	Medium	III	**2**
Grassland	Medium	II	**3**
Grassland	High	III	**3**
Grassland	High	II	**4**
Arable land	Very Low	III	**2**
Arable land	Very Low	II	**3**
Arable land	Medium	III	**3**

Arable land	Medium	II	**4**
Arable land	High	III	**4**
Arable land	High	II	**5**
Forest	Very Low	III	**1**
Forest	Very Low	II	**2**
Forest	Medium	III	**2**
Forest	Medium	II	**3**
Forest	High	III	**3**
Forest	High	II	**4**

2.5. Preparation of Priority Classes Map

Land use map, nitrate leaching map and water protection zone map was overlaid. Overlay operation in Arctoolbox was used to create intersection between water protection zones and the other maps. Then priority class in the water protection zone was developed in the attribute table by creating new field. By the help of query builder, the evaluation criteria were applied on the new column of the table. Finally, the symbology editor was used distribute the priority classes on water protection zones of Lecthingen with different colors. Moreover, the percentages of priority classes in the map was determined by summarizing the attribute data and counting the numbers.

3. RESULTS

3.1. Land Use

In Figure 4 the land use map of water protection zones is given. According to this map, the main soil types in that area are grassland, forest, and arable land.

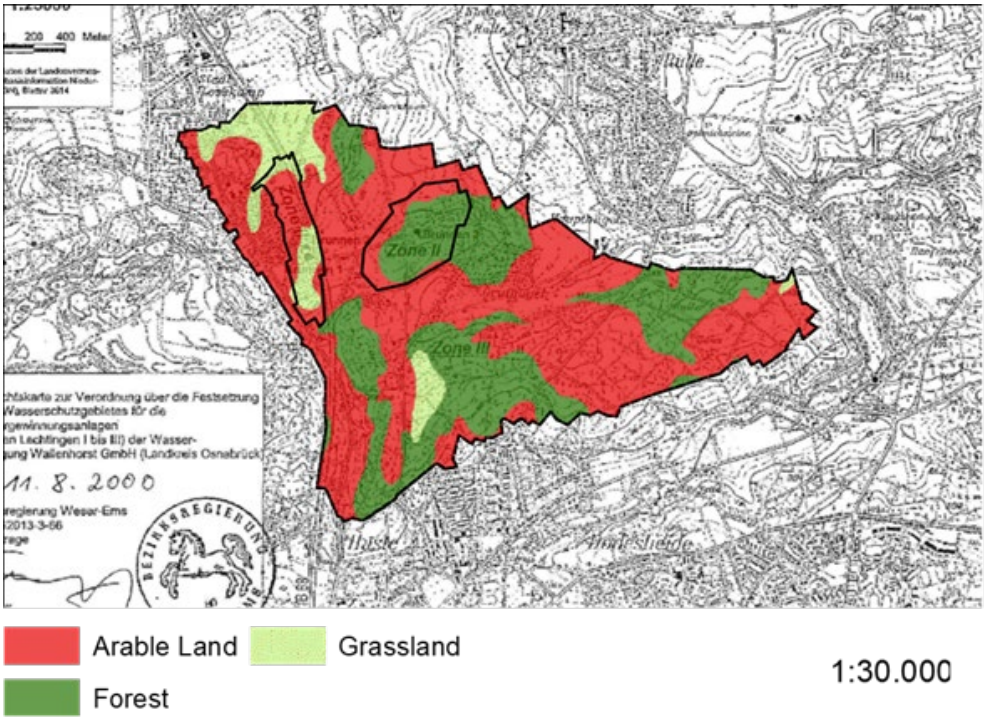

Figure 4. Land use map of water protection zones in Lecthingen

3.2. Nitrate Leaching Risk

In Figure 5 nitrate leaching risk map of water protection zones is given. The risk of nitrate leaching was found high in the most part of the area according to this map.

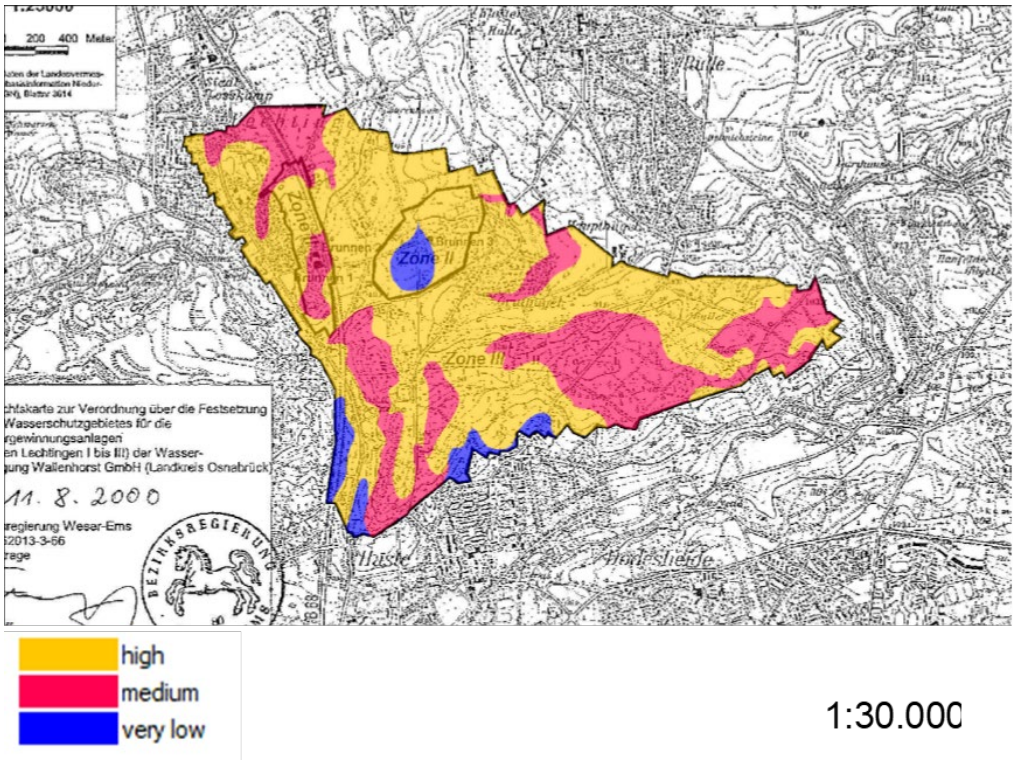

Figure 5. Nitrate leaching risk map of water protection zones in Lecthingen

3.3. Priority Classes

Priority classes map of water protection zones is given in the Figure 6. The map shows that there are some areas which are priority of 5 against the nitrate leaching risk, and they are found in the Zone II. Moreover, the most part of the map includes areas of 4 priority which means these areas are under the high of risk nitrate leaching. The rest of the map includes areas which are priority of 2 and 3.

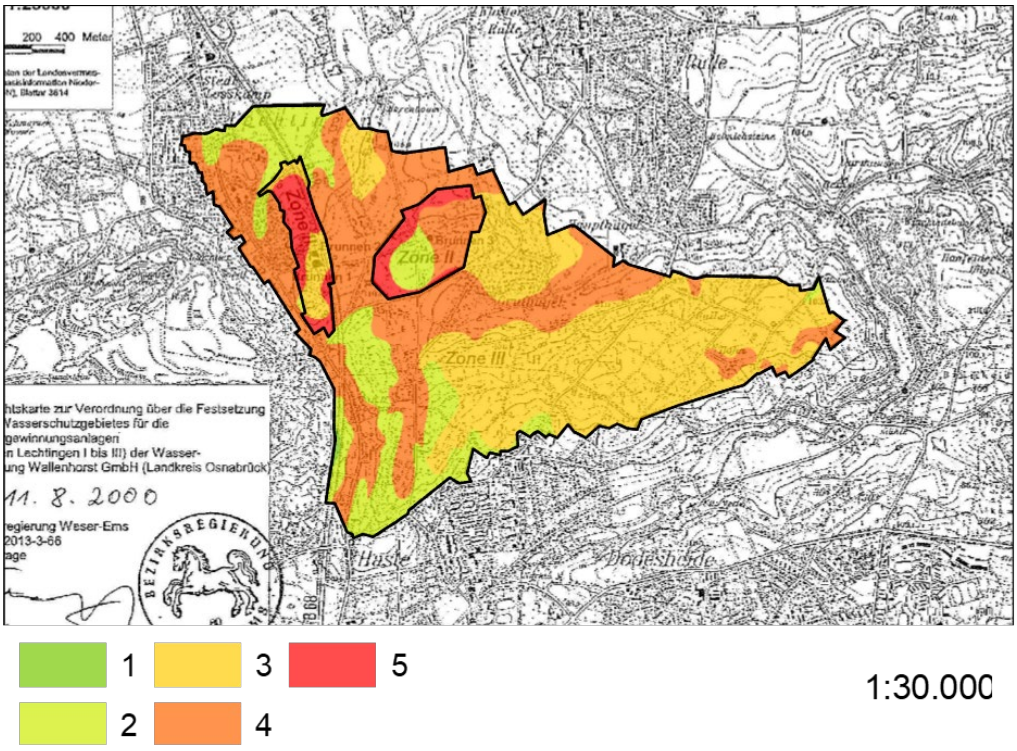

Figure 6. Priority classes map of water protection zones in Lecthingen

In Figure 7 the percentages of priority classes distributed over the map is given. 39% of the water protection zones of the area was found 4 of priority classes against nitrate leaching risk. The percentages of priority classes of 2 and 3 are similar with each other. 7% of the area was found 5 of priority classes.

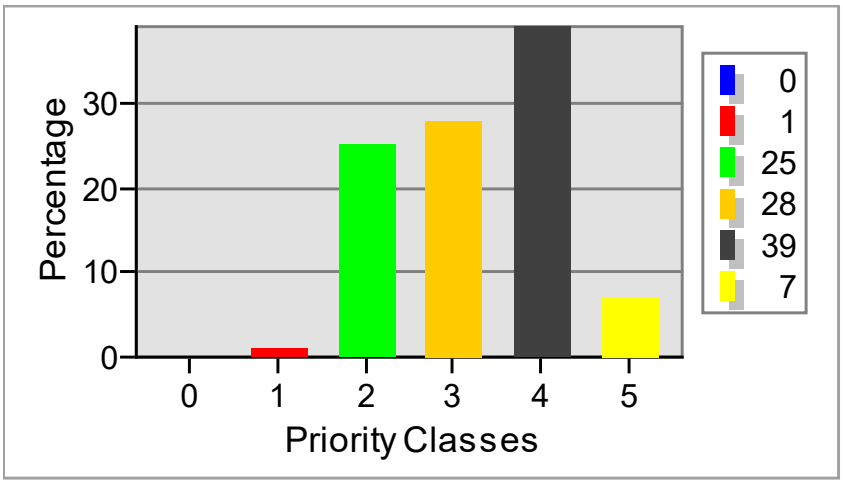

Figure 7. Percentages of priority classes distributed over water protection zones

4. CONCLUSION

Water protection zones are so important to protect water sources. The contamination risk of groundwater wells in Lecthingen area against nitrate leaching was evaluated in this work. In the 39% of the water protection zone, the risk of nitrate leaching was found priority classes of 4. 7% of the zones was evaluated as 5 in priority. These results show that a big part of this area is susceptible to be contaminated with the nitrate pollution. Some preventive precautions may be taken in this area to reduce the risk. Moreover, the nitrate levels of the wells should be measured continuously before usage. Especially infants and baby animals should be protected.

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