Liubov Orlova

GROUNDWATER PROTECTION IN RUSSIA, FINLAND AND EU

GROUNDWATER PROTECTION IN RUSSIA, FINLAND AND EU

Liubov Orlova
Bachelor's thesis
Spring 2015
Civil Engineering
Oulu University of Applied Sciences

ABSTRACT

Oulu University of Applied Sciences
Civil engineering

Author: Liubov Orlova
Title of Bachelor's thesis: Groundwater protection in Russia, Finland and EU
Supervisor: Riitta Kamula
Term and year of completion: Spring 2015 Number of pages: 51

ABSTRACT

Groundwater is a major source of fresh drinking water. Since groundwater is unevenly distributed, it is quite a strong effect on the problem of shortage of drinking water in some states. However, the importance of groundwater as the primary source of drinking water varies within countries, depending on the amount and quality of groundwater, and conditions of its use and geographic characteristics of the state.

This thesis describes characteristics of groundwater in the territory of Russia, Finland and throughout the European Union, the estimation of the operating reserves, as well as typing groundwater deposits, and their classification.

The mechanisms and techniques aimed to protect groundwater have increased their interest due to increased contamination of groundwater in the terms of legal regulation in the use and protection of groundwater. The general requirements for protection of groundwater bodies are given in this thesis, regarding termination of preventing pollution and groundwater depletion in Russia, Finland and EU.

Basic methods used in this thesis are the method of analysis and synthesis, the method of following from general to specific, and logical-technical method. Literature has been the main way to study the problem of groundwater.

Keywords: groundwater, characteristics of groundwater, protection technology, legislative, administrative

CONTENTS

1. INTRODUCTION 5

2. GROUNDWATER DEPOSITS..... 6

2.1 Groundwater deposits in Europenian part of Russia..... 12

2.2 Groundwater deposits in Finland 17

2.3 Groundwate deposits in Europe 20

3. LEGISLATIVE MEASURES IN GROUNDWATER PROTECTION..... 25

3.1 Legislative measures in groundwater protection in Russia..... 25

3.2 Implementation in EU and Finland..... 27

4. GROUNDWATER PROTECTION AND POLLUTION REMEDIATION TECHNOLOGY 31

4.1 Groundwater protection methods..... 33

4.2 Groundwater pollution remediation technology 41

5. DISCUSSION AND CONCLUSIONS 45

REFERENCES 48

1. INTRODUCTION

The term of groundwater is usually referred to as subsurface water that is situated under the water table in soil and to as geological formations that are fully saturated. Groundwater is more than just a resource. It is an important part of the natural environment. It is part of hydrological cycle. An understanding of its role in this cycle is crucial in regard of watershed and an environmental contamination. (Freezer et al, 1979)

More than two billion people depend on groundwater for their everyday needs. A large number of industries as well as agriculture in the world and irrigation depend on groundwater. A huge urban population with a high need of water can use groundwater only if the aquifer has promising storage and transmission properties. On the other hand, poorly populated areas have limited demand in groundwater because the water supply can be found in weak aquifers. At the European level, groundwater is an important economic source. According to a report made for the European Commission, about 75% of the population in Europe rely on groundwater for domestic use. (Bhattacharya et al, 2008)

Groundwater also plays a key role in keeping wet ecosystems sustainable and in providing a suitable environment for human settlements. To achieve the most benefits from the groundwater resources, significant efforts have to be made to explore the aquifer systems and to optimize its sustainable exploitation. However, attention is required as well for controlling a wide range of problems related to groundwater. Rapid growth of population in urban areas has led to increased exploitation of groundwater for domestic purposes. It is possible to predict already now that high dependence on groundwater will increase within next decades due to the limitations on the availability of surface water and its continuous degradation in terms of quality. Increased demand of groundwater during past decades has led to water scarcity. It is important to improve and develop strategies to optimize groundwater resource management and water supply management. (Bhattacharya et al, 2008)

2. GROUNDWATER DEPOSITS

Circulation of water between the land water, atmosphere, and land is called *the hydrologic cycle* (Figure 2.1). Groundwater systems recharge by precipitation, in the form of rainfall or snowmelt. Groundwater discharges into surface waters, the ocean and by evaporation gets back into the atmosphere. (Freezer et al, 1979)

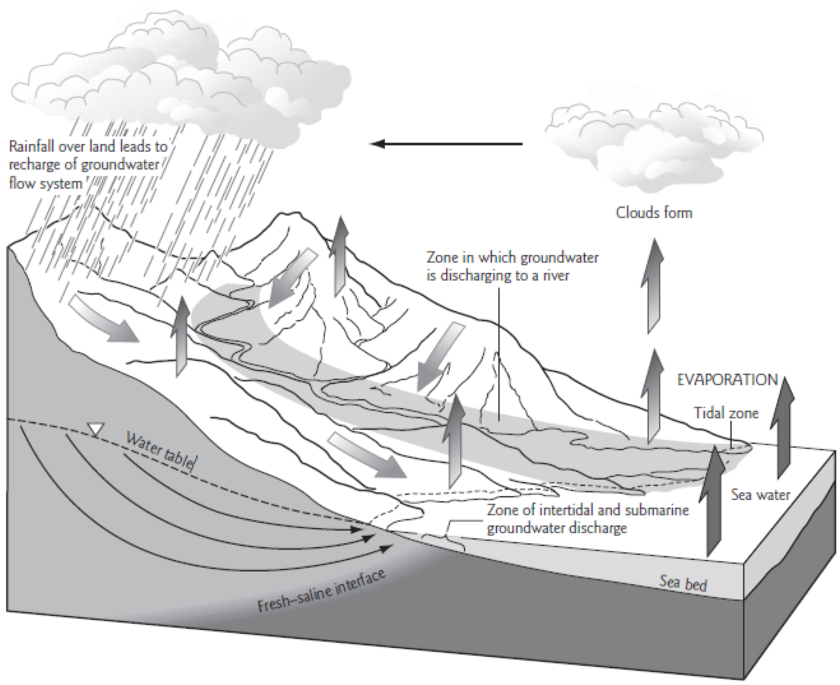

Figure 2.1. The hydrological cycle presents the importance of groundwater (Younger, 2007)

Deposits

All rocks near the Earth's surface are formed as both solids and pores (Figure 2.2). Water–bearing rocks consist either of consolidated or unconsolidated deposits. The unconsolidated deposits are underlain by consolidated deposits. Its material is a result of the disintegration of consolidated deposits. Most unconsolidated deposits consist of particles of rocks or minerals that differ in size from fractions of a millimeter (for example clay size) to several meters (for example boulders). Unconsolidated deposits include clay, silt, sand and gravel; an important group includes fragments of shells of marine organisms. Consolidated rocks consist of minerals particles of different size and shapes that have been fused by heat and pressure or chemical reaction into a solid mass. Such rocks are referred to as a bedrock. Consolidated sedimentary rocks include limestone, dolomite, shale, siltstone, sandstone, and conglomerate, igneous rocks include granite and basalt. (Heath, 1983)

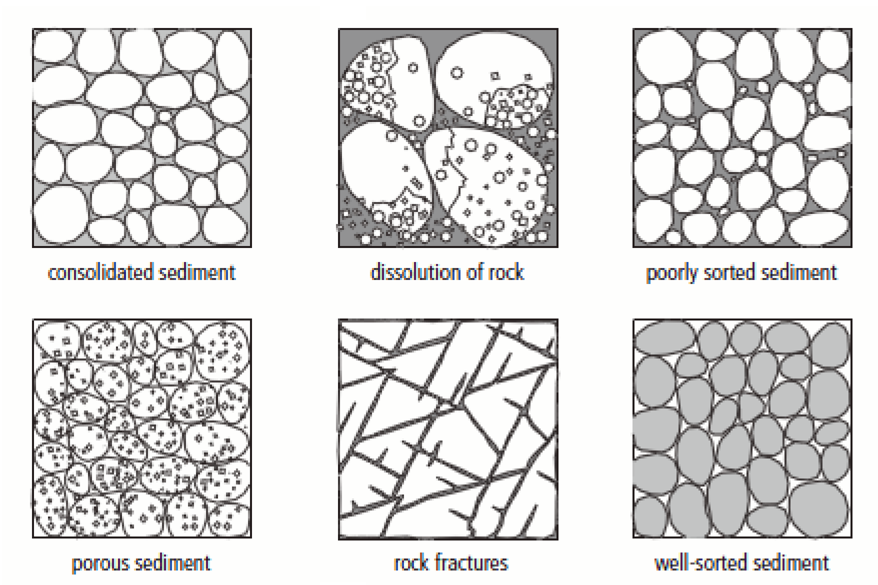

Figure 2.2. Type of pore spaces in sediments and rocks (Harter, 2003)

Rocks have two different types of pores: those that were formed at the same time as the rocks and are referred to as *primary openings*, and pores that were formed after rocks were formed are referred to as *secondary openings.* (Heath, 1983)

All water that underlies the land surface can be referred to as underground water. Underground water appears in two different zones: *unsaturated zone*, which contains both water and air, and underlies below the land surface, and *saturated zone*, where all connected openings or pores are full of water. In the unsaturated zone, moisture is moving downward to the water table to recharge the groundwater. The water table can be very close to the surface (less than one meter) or very deep (tens of meters). In other words, the water table is the level in the saturated zone where the hydraulic pressure equal to atmospheric pressure and is characterized by the water level. Water in the saturated zone is groundwater that is available to support wells and springs. Recharge into the unsaturated zone occurs by percolation of water from land surface through the saturated zone. (Heath, 1983)

A geological formation from which large amounts of groundwater can be pumped for all kind of needs (domestic, municipal, agricultural) is referred to as *an aquifer*. Sometimes aquifers can be vertically separated from each other by geological formations that let through small amount of water or no water to flow in or out. Such formations that act as a water barrier is called as an *aquitard*. If the water barrier is almost impermeable, clay for example, and it forms flow barrier between aquifers, is known as an *aquiclude*. (Harter, 2003)

Aquifers can be of two main types: *unconfined* and *confined* (Figure 2.3). An unconfined aquifer does not have an overlying aquitard. Vertical recharge of an unconfined aquifer is not limited, it occurs by rainwater or irrigation and moves downward (Harter, 2003). Water only partly fills an aquifer. Often aquifers are also referred to as water-table aquifers. The water table can move freely up and down, depending on how much water is deposited there. Wells open to unconfined aquifers are called as water-table wells. The level of water in these wells indicates the position of water table in surrounding aquifer (Heath, 1983).

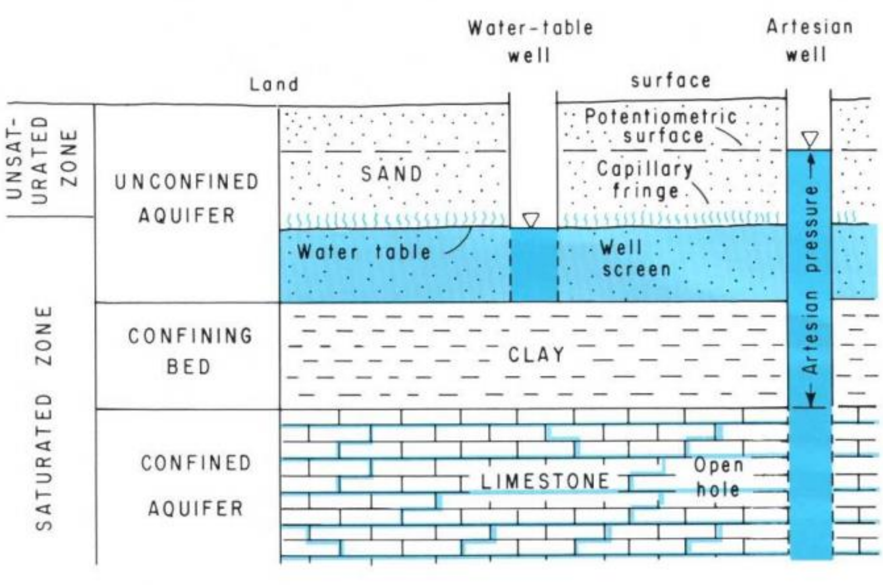

Figure 2.3.Shematic cross-section of groundwater deposits (Heath, 1983)

A confined aquifer is overlying by confining bed. The water table can be higher than the top of the aquifer. Water completely fills an aquifer, and is pressurized. Such aquifers are referred to as *artesian aquifers*. Water level in wells is higher than the top of a confined aquifer. Moreover, if the water level in artesian well stands above the land surface, the well is known as a *flowing artesian well*. (Heath, 1983)

Groundwater movement, recharge and discharge areas

Groundwater moves from higher height to lower height and from a point of higher pressure to a point of lower pressure. The movement of groundwater is very slow, from a few centimeters to a few meters per day, depending on the groundwater formations, i.e. sand, gravel or highly fractured bedrock. Hydraulic head is the driving force behind the groundwater movement. Groundwater always moves in the downward directions of the hydraulic head gradient or down-slope. (Harter, 2003)

Water enters groundwater systems in recharge area and moves through it to a discharge area. Recharge areas infiltrate a huge amount of water into the surface water (Figure 2.4).

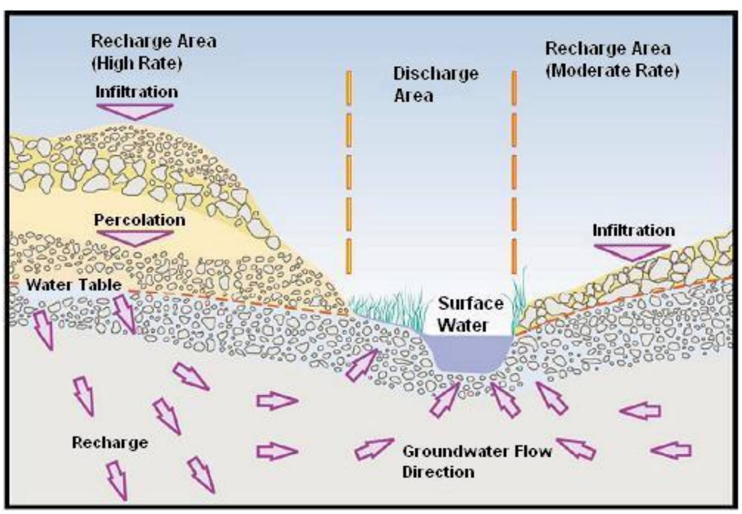

Figure 2.4. Groundwater flow (Ministry of Agriculture, Food and Rural affairs, 2006)

Recharge varies from year to year depending on the amount of precipitation, its seasonal distribution, land use, air temperature and other factors. Groundwater recharge occurs during late fall, winter, early spring in countries with warm climate. Discharge areas includes flows of springs, seepage of water into stream channels or wetlands. It also includes evaporation from the upper part of the land. Recharge appears during and after precipitation periods. Discharge is a continuous process. It lasts until the moment when groundwater head is above the level at which discharge occurs. The identification of recharge areas is highly important because of the expanding use of the land surfaces for the waste disposal. (Heath, 1983)

Natural groundwater quality and its chemical components

The chemical and biochemical components define the suitability of groundwater for industrial, agricultural and domestic use. Dissolved components in the groundwater provide the information about its geologic history, its influence on the soil or rocks through which it has passed, and the presence of hidden ore deposits. Agriculture, industrial and domestic wastes can be stored or disposed on or beneath the land surface. This can cause a great hazard, consequences of which depend on the chemical and microbiological processes in the groundwater zone. (Freezer et al, 1979)

In USA groundwater is categorized based on dissolved components. Water that contains a significant amount of mineral components is not suitable for certain uses. Water that contains less than 500 ml/l of dissolved particles is generally suitable for domestic and other industrial use. Water with more than 1,000 mg/l of dissolved particles has specific taste, and in many cases is not suitable for use. Table 1 presents the groundwater classification system based on total dissolved components applied in USA. (Driscoll, 1987)

Table 1. Groundwater classification based on total dissolved components which is used in USA (Driscoll, 1987)

Category	**Total dissolved components (mg/l)**
Fresh water	0 – 1,000
Brackish water	1,000 – 10,000
Saline water	10,000 – 100,000
Brine water	More than 100,000

Moving through the hydrologic cycle, water interacts with atmosphere, soils, and subsurface geologic formations. This affects its chemical and component concentrations. Table 2 divides important mineral components in the groundwater into major, minor and trace components. (Canter et al, 1987)

Table 2. Classification of dissolved inorganic components in groundwater applied in USA. (Canter et al, 1987)

Major components (greater than 5 mg/l)	
Bicarbonate Calcium Chlorine Magnesium	Silicon Sodium Sulfate Carbonic acid
Minor components (0.01 – 10.0 mg/l)	
Boron Carbonate Fluoride Iron	Nitrate Potassium Strontium
Trace components (less than 0.1 mg/l)	
Aluminum Antimony Arsenic Barium Beryllium Bismuth Bromide Cadmium Cerium Cesium	Molybdenum Nickel Niobium Phosphate Platinum Radium Rubidium Ruthenium Scandium Selenium
Trace components (less than 0.1 mg/l)	
Chromium, Cobalt , Copper, Gallium, Germanium, Gold, Indium, Iodide, Lanthanum, Lead, Lithium, Manganese	Silver, Thallium, Thorium, Tin, Titanium, Tungsten, Uranium, Vanadium, Ytterbium, Yttrium, Zinc, Zirconium

It has become common for concentrations of the dissolved inorganic components to be affected by man's activity. In some cases influences from human activities can cause certain consequences. Because of that, the elements listed in Table 2 as a minor can become as contaminants at concentration levels that are significantly higher than normal levels shown in this table. (Freezer et al, 1979)

In many areas groundwater can be used without any treatment, in other areas it is necessary to remove color or hardness (hardness reflects the calcium and magnesium content, and it states the equivalent amount of calcium carbonate). Chlorination is used to provide protection against pathogenic microorganisms. Water from some aquifer is not suitable for use due its salinity or presence of naturally appearing substances such as arsenic or radionuclides. (Canter et al, 1987)

2.1 GROUNDWATER DEPOSITS IN EUROPENIAN PART OF RUSSIA

Groundwater is an important natural resource. Its evaluation has to be presented under certain standards. In the former Soviet Union, groundwater has been generally considered as a part of other natural resources such as oil and gas. Groundwater classifications were developed to evaluate groundwater resources for drinking, industrial, mining and domestic use. The description of groundwater resources to a specific category is made by regional hydrogeological organizations and has to be confirmed by The State Commission on Evaluation of Natural Resources. (Green et al, no year of publication)

Deposits

The largest region of stratal water is the Eastern European area of Russian Federation. It is confined to the shield of the Russian platform, which consists mainly of terrigenous, cretaceous, and halogenic Palaeozoic formations. Formations are of a general thickness of 4 km. Deposits have been divided by Russian hydro-geologists into a Baltic-Ural, Northern Caspian, Donetsk, Dnieper, Pripet, and L'vov- Volynskii complexes of artesian basins (Zektser et al, 2004). The central European part of Russian Federation is occupied by the Moscow artesian basin; the thickness of the sedimentary cover is 5 km. The zone of fresh water in the Moscow basin is several hundred meters thick. The high flow rate is in a layer of karst rock (Pinneker, 1983).

The groundwater runoff generation is observed within Valdai, Middle Russian and other uplands, where groundwater flow is confined to karstified Devonian and Carboniferous limestone, and upper Cretaceous marl and chalk strata. Cretaceous and Quaternary sandy and clayey deposits are observed for insignificant groundwater resources. The discharge value is 1-1.5 l/s.km^2. The north and west areas of the basin are covered by fluvioglacial and alluvials sands, which contain much groundwater. The discharge is 3-5 l/s.km^2. (Zektser et al, 2004)

Timan and Ural fissure water systems form the northeastern boundary of the Eastern European Russian artesian region. The Ural hydrogeological area extends from north to south for 3 km. It has a difficult geological structure and characterized by a sharp alteration of groundwater flow. Groundwater is formed in fractured and fracture-karst deposits. The discharge values of groundwater are 10-15 l/s.km^2, and runoff/precipitation ratio of groundwater ranges from 10 to 40%. The Timan hydrogeological platform is located in Paleozoic carbonaceous and terigenous deposits. The average groundwater discharge is 0,1-5 l/s.km, depending on deposits. (Zektser et al, 2004)

In the area of the Saint Petersburg and the Baltic artesian basins, groundwater occurs in intensively karstfied limestones of the Silurian-Ordovician plateau; discharge is 3-5 l/s.km^2. In south, Devonian carbonaceous, sandy and clayey, groundwater discharge reaches 1-1.5 l/s.km^2. The water resources increase where they are hydraulically connected with overlying sandy glacial and lacustrine-alluvial aquifers. In the southwestern Baltic basin, Quaternary glacial deposits make the main contribution to groundwater. The groundwater discharge values range from 1.5-3 to 5-10 l/s.km^2. (Zektser et al, 2004)

The most favorable conditions for groundwater resources in Voronezh hydrogeological region are observed in its northern and northwestern parts. In Don and Oskol river basins, main groundwater resources are confined to Devonian and Carboniferous limestone as well as to Cretaceous sand, marl, and chalk strata. The groundwater discharge is up to 3 l/s.km^2. (Zektser et al, 2004)

In the Pripyat-Dnepr-Donets artesian basin, groundwater runoff depreciates from north-west to southeast. The discharge has decreased from 3 to 0.1 l/s.km^2 due to the climate and the replacement of highly permeable fluvioglacial sand. (Zektser et al, 2004)

Quality of groundwater

Groundwater pollution caused by the influence of various anthropogenic factors in areas which are not related to the use of natural resources, is different in intensity and scale. Within the period of

2000-2012 on the territory of the Russian Federation, 2641 zones of groundwater contaminations were discovered, 47 contamination areas were first found, and pollutions were confirmed on 755 sectors that were previously identified. Particularly strong contamination of groundwater was observed near industrial receivers, municipal and agricultural waste products. Groundwater contaminations are characterized by high intensity of pollution. All-round pollutions have been verified in the areas of industrial and urban agglomerations (Figure 2.5). All the identified pollutants, both organic and inorganic, that have been observed in groundwater originate from industrial type of contamination. Pesticides and nitrogen compounds are the primary sources of pollution from agricultural activities, nitrogen compounds, iron, manganese, chlorine, and phenols are identified from municipal type of contamination. In industrial areas, the concentration of pollutants in groundwater dominates in range of 10 – 100 of maximum permission concentrations (MPC). The maximum values can reach up to 1000 of MPC and even more. (Center of state monitoring of natural resources, 2007)

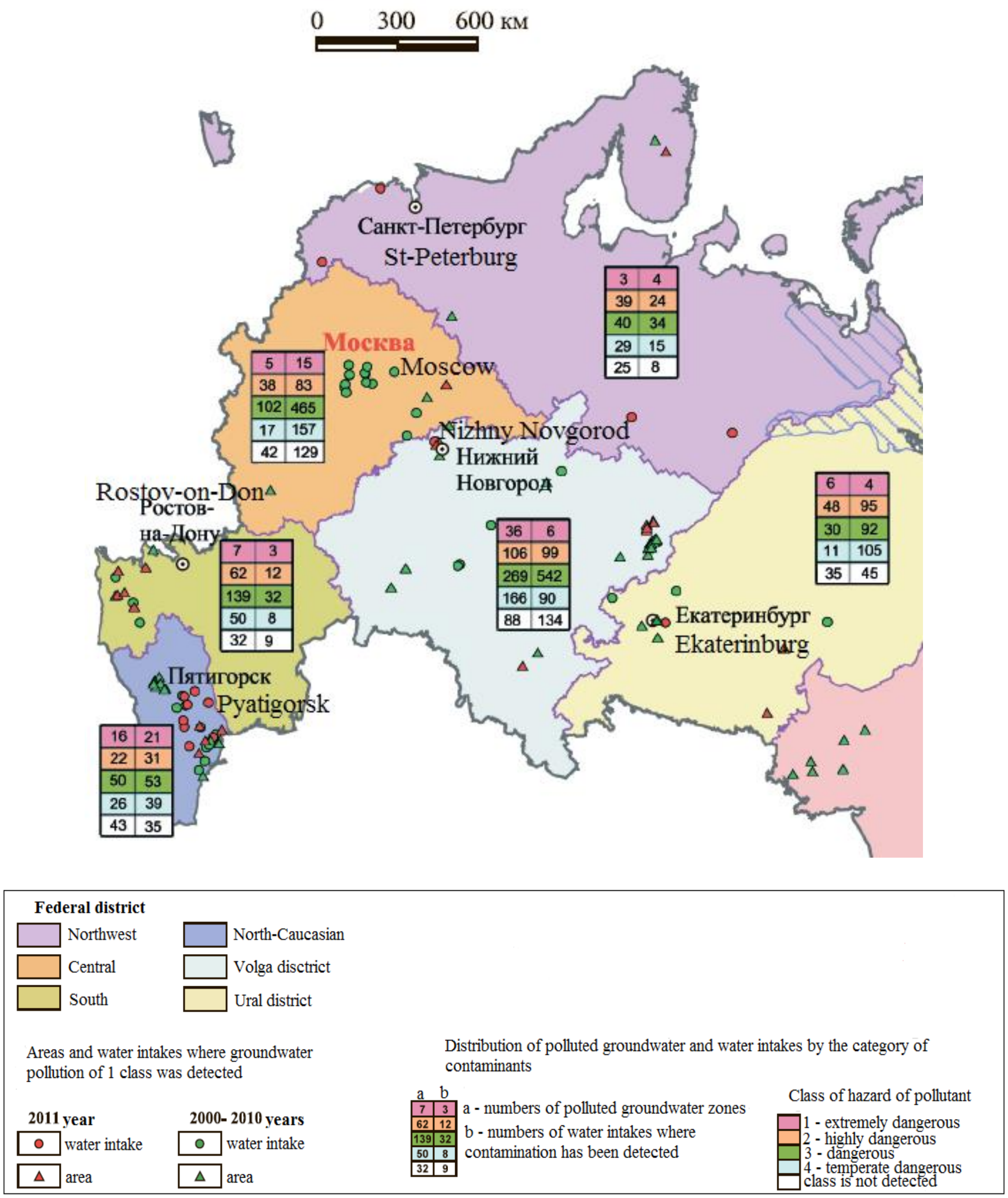

Figure 2.5. Pollution of groundwater on the European part of Russia (Center of state monitoring of natural resources, 2007)

Intensive development of agriculture has became a main reason of the pollution of groundwater in the European part of Russia (Figure 2.6-2.7). MPC of contaminants that are established in the central part of RF: chlorides - 350 mg/l; of sulfate - 500 mg/l, an iron (F) - 0,3 mg/l, manganese (Mn) – 0,1 mg/l, fluorine (F) – 1,2 mg/l. Figures 2.6-2.7 represent a heightened concentration of contaminations, detected on the territory of RF. (Zektser, 2001)

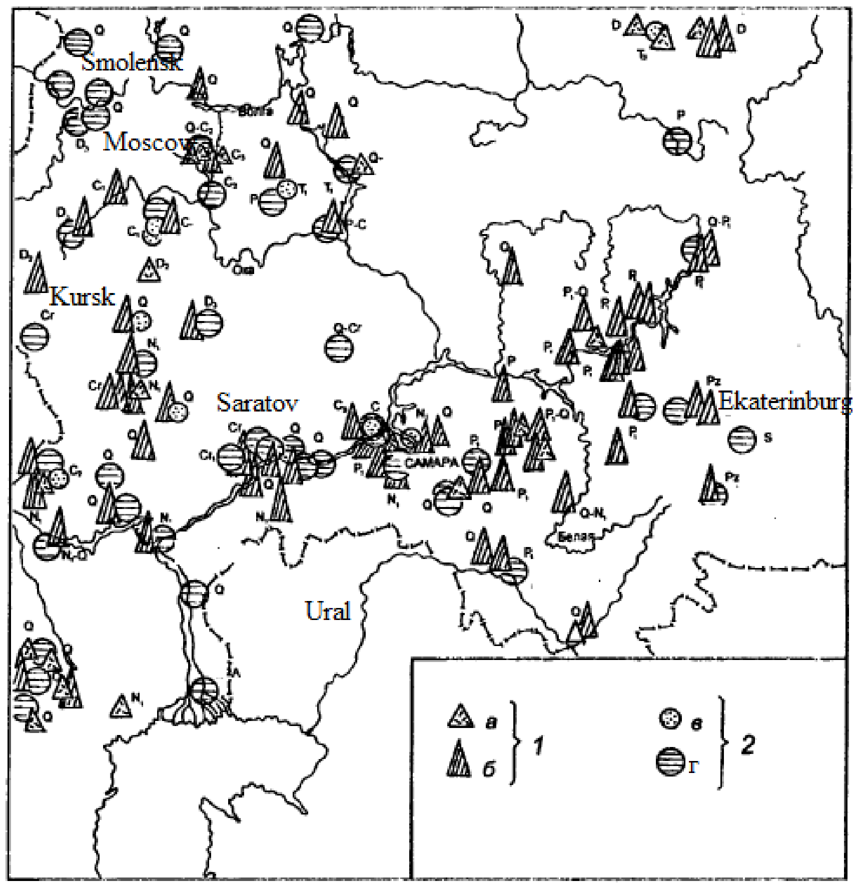

Figure 2.6. Heightened concentrations of pollutants (concentrations of 1: a – a chloride is up to 500mg/l, б – a chloride is more that 500mg/l; 2: в – a sulfate is up to 700 mg/l, г - – a sulfate is more than 700 mg/l) (Zektser, 2001)

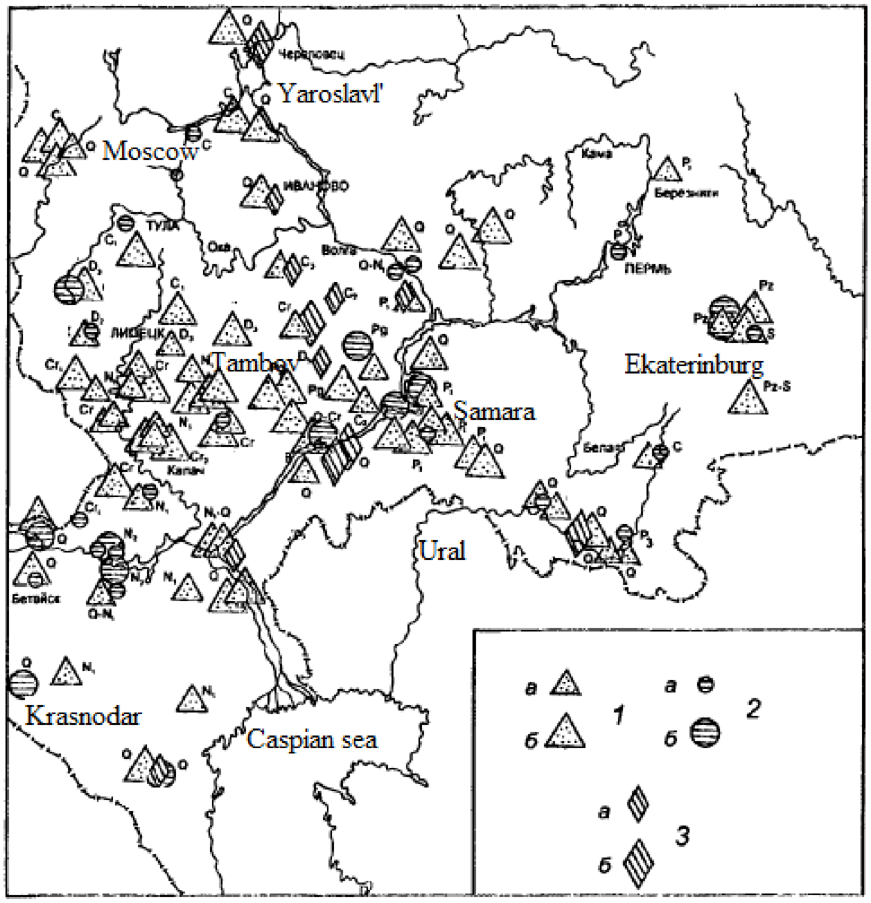

Figure 2.7. Heightened concentrations of pollutants (1: a – an iron (Fe) is up to 2 mg/l, б – an iron (Fe) is more that 2mg/l; 2: a – a manganese (Mn) is up to 72 mg/l, б - – a manganese (Mn) is more than 2 mg/l; 3: a – a fluorine (F) is up to 3mg/l, б - a fluorine (F) is more than 3 mg/l. (Zektser, 2001)

The total consumption of groundwater on the territory of RF in 2012 was 27.0 million m^3/day, including production – 22.2 million m^3/day, extraction[2] – 4.8 million m^3/day. The maximum amount of groundwater was extracted within Moscow – 6.5 million m^3/day. (Center of state monitoring of natural resources, 2007)

2.2 GROUNDWATER DEPOSITS IN FINLAND

The geological history of Finland generally explains the distribution of water resources and has had an impact on the quality of ground and surface waters. The oldest formations in Finland are

Precambrian bedrocks and the youngest glacial formations are found in the country. The Finnish aquifers contain glaciofluvial deposits such as eskers and an ice-marginal formations. The glaciofluvial aquifers are unconfined, long, narrow, and are combined of sand and gravel formations. (Katko et al, 2004)

The groundwater flow gradient is low, and flow velocity and permeability are high. The groundwater level is about 2 to 4 m below the surface. In the northern Finland, unconfined esker aquifers are found next to the surface water bodies such as lakes, ponds, rivers and wetlands. Due to the climate conditions in different parts of Finland (Figure 2.8), groundwater level fluctuations can be divided into four various types. (Okkonen, 2011)

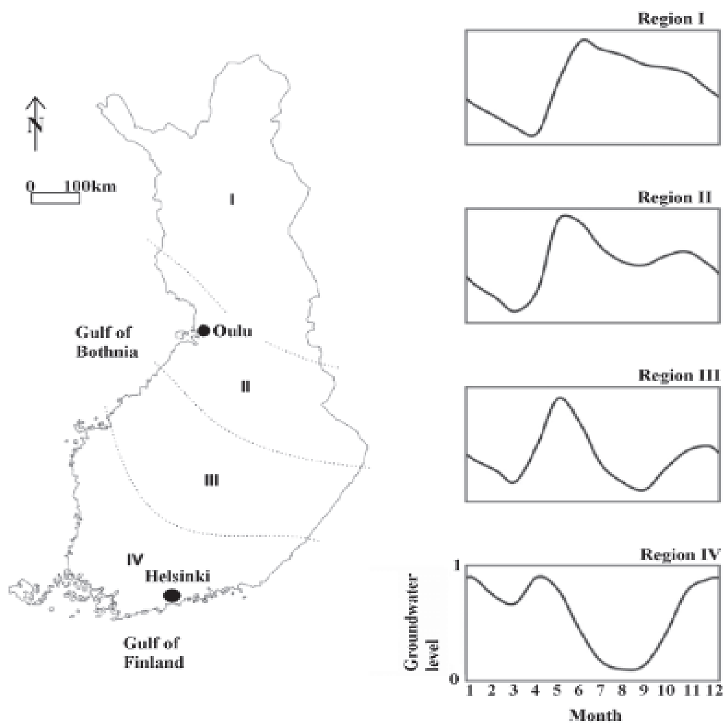

Figure 2.8. Current groundwater fluctuations in northern (region I), central (regions II and III) and southern Finland (region IV) (Okkonen, 2011)

In the northern Finland (region I), the groundwater level fluctuation occurs due to spring snowmelt. In the esker aquifers, the groundwater chemistry may also change over time and usually responds to precipitation and snowmelt with the concentration of minimum value in spring and autumn, and the concentration of maximum value in winter and summer. In regions II to IV, the annual maximum occurs in the spring due to snowmelt and at the end of the year due to increased precipitation and lower evaporation. (Okkonen, 2011)

Another classification divides groundwater of Finland into three classes according to their priority: (I) groundwater areas important for water supply, (II) groundwater areas suitable for water supply, (III) other groundwater areas. Aquifers occur primary in classes I and II (Figure 2.9).

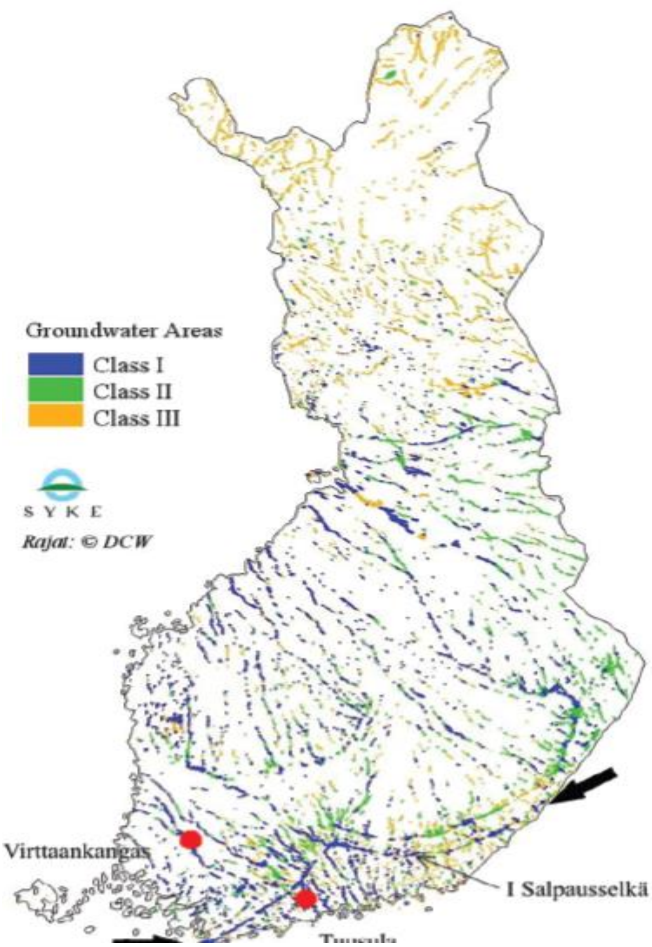

Figure 2.9. The classified groundwater areas (Lavapuro et al, 2008)

Groundwater in Finland is usually of good quality. In general, groundwater is slightly acidic due to the bedrock, with a mean of pH of 6.5. The amount of dissolved components is low, nitrate concentrations are low, less than 0.5 mg 1^{-1} (the max allowable in drinking water is 50 mg 1^{-1}, according to the Finnish Ministry of Social Affairs and Health). In some areas, in south-west of Finland, groundwater is threatened by increasing nitrate levels due to agriculture. The concentrations of NO_3 in groundwater are between 0-1 mg l^{-1}. On the western coast concentrations of iron and manganese are quite high. In eastern, western and southern Finland, there are high concentrations of sulfide ores. The geology and rock types of formations cause radon. Groundwater supplied by municipal waterworks is extracted mainly from gravel and sand formations (Lavapuro et al, 2008). In the past, it was observed that the use of salt for de-icing of roads increases the salt content of groundwater in some areas. High chlorine concentration raises corrosion of pipes and water tanks. Concentrations of the sodium chlorine have exceed the value of 25 mg l^{-1} in some zones. In south-eastern Finland, salt has had to be removed from groundwater, in central Finland the location of water supply wells has had to be moved (Katko et al, 2004).

2.3 GROUNDWATER DEPOSITS IN EUROPE

EU members have defined groundwater bodies in the national implementation of the Water Framework Directive as management units that may include one or several aquifers or even a part of an aquifer. EU members have used different classification criteria, based on water abstraction in some countries, and based on hydraulic properties in other countries. (Wendland et al, 2007)

Sand and gravels

A sand and gravel aquifer types are productive due to their thickness and high water permeability under unconfined or confined conditions, which demonstrate intergranular porosity. Glacial sand and gravel deposits, and fluviatile deposits as subtypes, are marked out on the map in figure 2.10 according to groundwater residence time (groundwater residence time is the time which water spends in the groundwater portion of the hydrologic cycle). The aquifers are similar in quartz minerals, but have differences in groundwater composition. Dutch, Danish and German aquifers of glacial sand and gravel deposits subtype show the behavior of reduced aquifers due to the concentrations range of O_2, Fe(II), Mn(II), No_3: O_2 and No_3 concentrations < 1 mg/l, Fe(II) > 0.2 mg/l and Mn(II) > 0.05 mg/l. Glacial sand and gravel deposits monitored in the Netherlands have low concentrations of Ca and HCO_3. German and Danish groundwater deposits also belong to the same subtype category. French and German groundwater from fluviatile deposits show high concentrations of O_2 and NO_3 with low concentrations of Fe(II) and Mn(II). There are similar type of groundwater deposits in Belgium and Netherlands show reduced aquifer conditions. (Wendland et al, 2007)

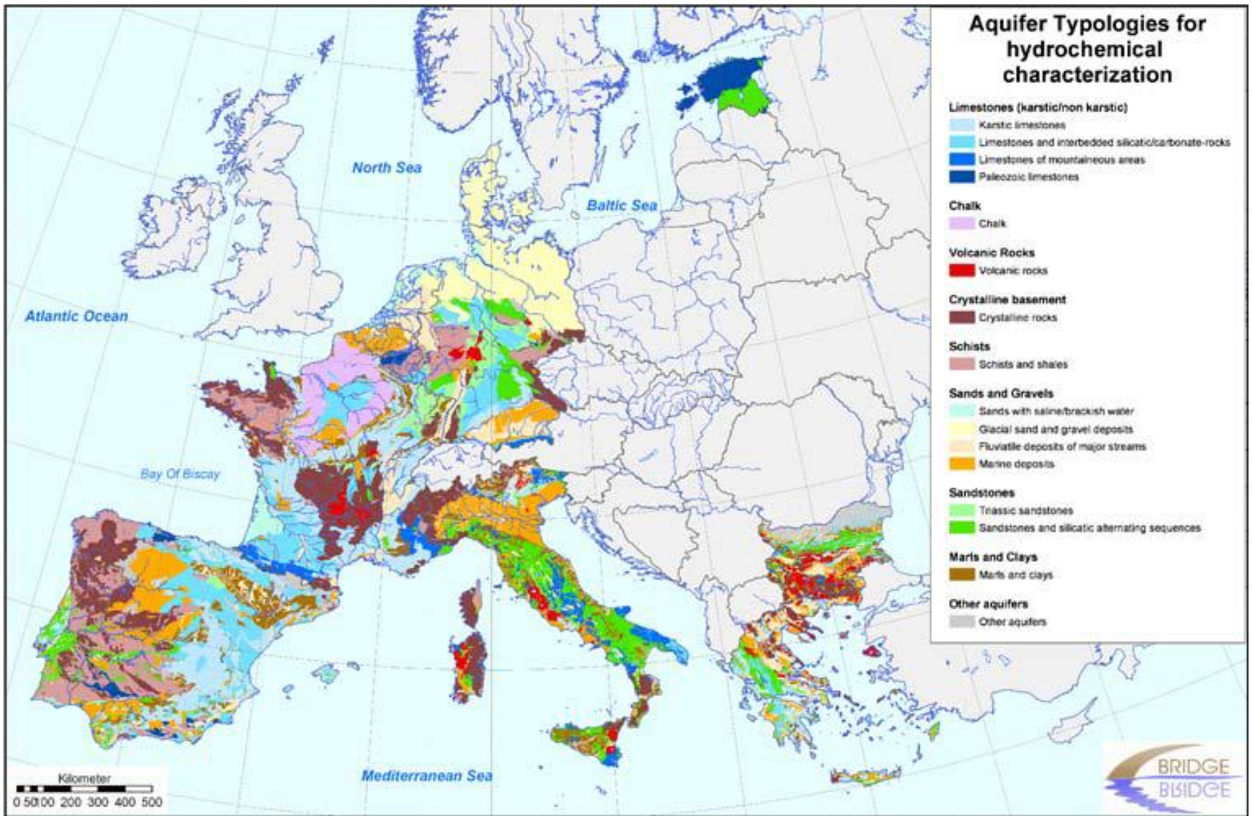

Figure 2.10. Example of aquifer typologies for hydro-chemical characterization in Europe (Wendland et al, 2007)

Limestone and crystalline rocks

The main groundwater compositions in the aquifer types across Europe are *limestone* and *crystalline rocks*. Limestone and dolomite deposits dominate, as well as clayey and gypsiferous formations that occur to smaller coverage. Carbonate rocks are impermeable. Cementation and compaction processes affect the deposits in a way that they change their porosity and permeability. Rocks are vertically and horizontally fractured providing openings for storage and transmission of water. (Wendland et al, 2007)

The aquifer type of crystalline rocks includes magmatic and metamorphic rocks (German and France). Water movement in these rocks at shallow depth depends on fissures within the weathered horizon and at deeper depth on joints and fractures. Limestone and carbonate rocks have high concentrations of Ca (66-122 mg/l), HCO_3 (323-439 mg/l), Na (8-10 mg/l), K (2-5 mg/l). Due to high portion of dolomites in the limestone and carbonate rocks, German aquifer shows higher magnesium contents ($P_{50} > 30$ mg Mg/l) compared to other aquifers. Limestone and carbonate rock aquifer in Bulgarian groundwater illustrate high values for Na (122 mg/l), K (11.5 mg/l), SO_4 (118 mg/l), Fe(II) (0.93 mg/l). The groundwater structure in crystalline rock aquifer is different from the groundwater structure in limestone and carbonate rock aquifers in regards to mineral concentrations. Water is in contact with a small surface in crystalline rocks due to the fast water movement. Water in crystalline rock aquifer contains a small amount of dissolved components, and it is threatened by acidification due to silicatic rocks. (Wendland et al, 2007)

Different indicators have been used to identify the pressure on groundwater quality related to nitrates, pesticides, groundwater abstraction and human intervention in the hydrological cycle. The usage of nitrogen fertilizer in agriculture have been increasing in most Western European countries since 1992. Pesticides have an impact on Europe's groundwater as well. In some areas the extend of groundwater intake exceeds the recharge rate, which means over-exploitation. Figure 2.11 summaries the information on the state of Europe's groundwater at the aquifer level. (European Environment Agency, 1999)

Determinand concentration (annual mean)	Total number of regions/areas	Number of groundwater regions/areas where none	>0% to <25%	≥25% to <50%	≥50% of the sampling sites exceed the respective determinand concentration
Nitrate					
>50 mg NO_3/l	96	20	64	7	5
>25 mg NO_3/l	96	9	37	37	13
Chloride					
>250 mg/l	89	45	37	2	5
>100 mg/l	89	29	39	11	10
pH-value					
≤ 5.5	87	70	13	3	1
≤ 6.5	87	52	26	3	6
> 8.5	87	65	20	2	0
Alkalinity					
≤ 1 mval/l	55	26	17	7	5
≤ 4 mval/l	55	5	19	5	26
electrical conductivity					
>2000 µS/cm	79	42	33	3	1
>1000 µS/cm	79	25	32	13	9

The number of groundwater regions/areas where defined percentages of sampling sites exceed the given concentrations of selected determinands.

Figure 2.11. State of groundwater in Europe at the aquifer level (European Environment Agency, 1999)

Nitrate is a large problem across Europe, however some countries such as Iceland, Finland, Norway and Sweden have shown good results with low nitrate concentrations. According to the Drinking Water Directive, the maximum permissible concentration for the regional level of NO_3 is 50 mg/l. Significant problems with *chlorine* are found in Cyprus, Denmark, Estonia, Germany, Greece, Latvia, the Republic of Moldova, The Netherlands, Poland, Portugal, etc. Most of these areas are located near the coast line. Salt water is the main reason for the high concentrations of chlorine in these groundwater. *Acidification* is shown with a pH of ≤ 5.5. It occurs commonly in Northern European countries due to long-distance transportation. *Chlorinated hydrocarbons* are widely located in groundwater in Western European countries, while hydrocarbons and mineral oils causes serious problems in Eastern European countries. Chlorinated hydrocarbons comes out from old landfills, contaminated industrial sites and industrial activities. The pollution of groundwater with heavy metals is also detected in some countries. It is caused mainly by leaching from dumping sites, mining activities and industrial discharges. *Over-exploitation* of the groundwater is a significant problem in many European countries, especially in Eastern Europe. The majority of the groundwater areas have been over-exploited since the 1980s. The main reason of groundwater over-exploitation is intensive water abstraction for public and industrial supply. Mining activities, irrigation at the same time with naturally occurring dry periods are the reasons for lowering of groundwater table. (Environment Agency, 1999)

3. LEGISLATIVE MEASURES IN GROUNDWATER PROTECTION

Protection and appropriate water management of quality of groundwater resources have become a significant public problem within the last decades. Many groundwater quality management programs are being developed within federal agencies, state and local governments, and private sectors. (Canter et al, 1987)

3.1 LEGISLATIVE MEASURES IN GROUNDWATER PROTECTION IN RUSSIA

Complex use and protection of water resources determine the fundamental basis of the water resources of Russia. The major intention of the water legislation is to control relation in the use and protection of water units. The main role in the protection of water resources is the public verification of surface and groundwater in their restoration and protection. Water users are provided with all important information of the state monitoring and accounting data. The protection of water resources from depletion and pollution by harmful substances provides a set of measures: 1) the development of relevant legislation; 2) organization of monitoring of water bodies; 3) the protection of surface and groundwater, including treatment of industrial and domestic waste water; 4) preparation of water used for drinking and household purposes; 5) state control for the use and protection of water resources. (Znosok, 2010)

Water legislation in Russian Federation (RF) contains the Water Code, adopted to federal laws and regulations, and other normative legal acts. The licensing of water use plays an important role in the protection of water resources. The Water Code regulates licensing, as well as Russian Federation Government Resolution "On approval of rules, provided for the use of water bodies in the public domain, is establishing water use limits, issuing licenses for water us". (Znosok, 2010)

Water code of RF adopted by State Duma, on June 3th, 2006 replaced the Water Code of RF dated 16.11.1995 № 167 Federal law. It has conceptually changed the water use legislation of the country. The key difference of the new Water Code is the state of main principles of water legislation. It establishes to organize Basin Councils which will develop guidelines in the fields of use and protection of water objects. Basin Council includes representatives of the federal executive bodies, local governments, representatives of water consumers, non-governments associations and other stakeholders. Legal regulation of water relations such as rules of use of water objects, which are located on the municipal territory for general usage, can be done by local governments. (Seliverstova, 2008)

Basin Councils develop principles of citizen participation, public associations for solving problems concerning the rights for water objects, regulations of water relations in borders of basin district. In spite the fact that the legislation of RF can provide free water management, the use of water bodies is implemented with a fee. (Seliverstova, 2008)

The Russian legislation uses classification "water object" which is identified as a natural or artificial water reservoir, a waterway or other object which have forms and qualities of water mode such as: time changing of levels, flow rate, and water volume. The concept of "water object" is abstract and covers all range of water reservoirs of RF: seas, channels, bays, rivers, lakes, ponds, water storage basins, groundwater (springs, Geysers), glaciers, groundwater basins, aquifers. (Seliverstova, 2008)

The Water Code of RF provides the basic principles in the management of water objects. It provides the economic support for the protection of water objects. It means that payments for the use of water objects include expenses of protection. The new Water Code has developed the institute of contract of water management instead of licensing for water bodies, which states that water management contract provides responsibilities between parties with respect to the water objects. Administrative responsibility is the most common and widely used type of liability for water use and protection. (Seliverstova, 2008)

The Government has determined state monitoring of water objects in order to guarantee rational water use and implementations of the Water Code. Thus, it provides regular monitoring of qualitative and quantitative indicators of surface water and groundwater; collection, storage and processing of data; assessments, forecasting changes in the water objects and transfer of relevant information to government authorities and its subjects. The Ministry of Natural Resources, Federal Service of Hydrometeorology and Environmental Monitoring execute the state monitoring. (Znosok, 2010)

3.2 IMPLEMENTATION IN EU AND FINLAND

A big growth has been made in water protection in Europe, and in single member states. The European Union (EU) has established The Water Framework Directive (2000/60/EC) to prevent and control groundwater pollution and deterioration. The Water Framework Directive (2006/118/EC), adopted in October 2000, arranges measures that should prevent and control groundwater pollution, known as a “daughter Directive” to Water Framework Directive (WFD). In 2013, it had replaced the Directive 80/68/EEC on the protection of groundwater against pollution caused by dangerous substances. (Europa, 2007)

The WFD protects clean water across Europe. The Directive establishes new methods for water management based on river basins, natural geographical and hydrological units, and sets special deadlines for the member states to protect water ecosystem. The Directive takes into account surface water, transitional, coastal water and groundwater. The WFD has specified good status of groundwater in terms of quantity and chemical condition to be achieved by 2015 year. It includes the Nitrate Directive, which implements measures to protect surface and groundwater from nitrogen-based pollutants, coming from fertilizers in agriculture. Member states use monitoring data and scientific knowledge to analyze underground geology to define individual groundwater bodies. Detected water bodies are a significant step in managing and protecting of groundwater. (WISE, 2008)

According to the WFD, the member states are required to:

- Classify groundwater by evaluating the pressure and impact of human activity on the quality with a view to define groundwater bodies which will not achieve WFD objectives,
- Put in order a register of protected areas within each river basin district which directly depends on water,
- Establish groundwater monitoring networks based on a classification analysis to provide a summary of the chemical and quantitative status of groundwater,
- Establish the river basin management plan (RBMP) which includes a summary of the impact of human activity on groundwater status, demonstration on map forms from monitoring results, a summary of the economic analysis of water use, summary of protection programs, control of remediation measures,
- Include principles of cost recovery for water services,

- Set up a program of measures to achieve the WFD objects by the end of 2009. The program must include control of groundwater extraction, control of artificial recharge. It has to be reviewed and updated by 2015 and every six years thereafter. (European Commission, 2015)

The concept of groundwater protection is fully included into the basic measures of the WFD (Figure 3.1).

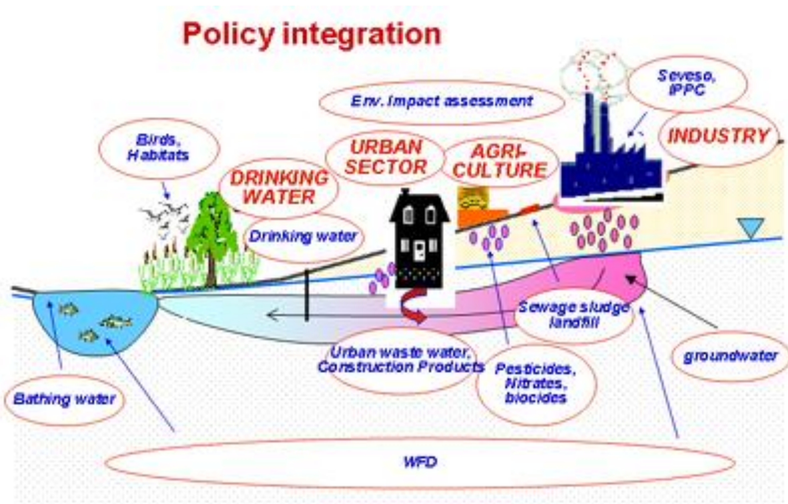

Figure 3.1. Integration of different pieces of legislation instruments (European Commission, 2015)

Different legislation instruments are directly connected to the WFD and meant to prevent or limit contaminations catching groundwater. The main aspects are the following:

- The Nitrates Directive (96/676/EEC) is aimed to decrease and prevent nitrates contamination of groundwater,
- The Urban Wastewater Treatment Directive (91/414/EEC) is aimed to protect the environment from the discharge of urban waste water from industrial sectors,
- The Plant Protection Product Directive (91/414/EEC), states the use and control of commercial plant protection products within EU,

- The Biocides Directive (98/8/EC), works with biological products such as pesticides, herbicides, and fungicides,
- The Integrated Pollution Prevention and Control (IPPC) Directive (96/61/EC) is aimed to prevent air, water or soil pollution, etc. (European Commission, 2015)

Implementation in Finland

While the WFD gives a common basis for water management, member states apply it to local conditions. The goal of water protection in Finland is to achieve good surface and groundwater quality by 2015. It includes:

- decrease causes of eutrophication,
- decrease risks of hazard substances,
- protect groundwater,
- preserve water ecosystem,
- restore of water bodies.

All water bodies as well as water ecosystems must be protected from harm caused by pollution. The Government has also established a framework for the protection of groundwater. The Ministry of the Environment arranges objectives for water protection, develops water protection legislation to reduce hazard impact on water bodies. (Ministry of the Environment, 2014)

The Finnish government has made several RBMPs. The plans contain information on the condition of water bodies, factors affecting them and measures which will restore inland and coastal waters to good conditions by 2015. Each RBMP is reviewed every six years. The organization of river basin management is covered by:

- the Act on Water Resources Management (1299/2004),
- the Decree on Water Resources Management (1040/2006),
- the Decree on Water Resources Management (1303/2004)

Legislation established to prevent pollution of water bodies came into force in 2000, it involves:

- Environment Protection Act (86/200),
- Environment Protection Decree (169/2000),

- Decree on Substances Dangerous and Harmful to the Aquatic Environment (1022/2006) (Ministry of the Environment, 2014)

Structure of the Administrative organizations and water monitoring

The Finnish Environment Institute is a controller of the programs, manager of the database and the reporting center. The Finnish Environment Institute is a supervisor for the Centres for Economic Development, Transport and the Environment (ELY centres) and gives guidance to them. The ELY centres implement maintenance, reconstruction, take samples and are relatively responsible for the chemical analyses. The major tasks of the institutions are to identify changes in groundwater quality and infiltration water that are caused by anthropogenic impact, to collect basic data, and to provide necessary data for research purpose.

The Finnish monitoring network is a national network which provides information on changes in groundwater table and climate changes, it helps to estimate and predict drought periods.

Monitoring of groundwater quality is implemented by 50 groundwater sampling sites across the country. Most of the sampling sites are situated in the springs; others are in tubes and wells. There are 20 sampling sites located in porous media aquifers, and the rest are in other aquifers. The stations are mostly set in natural state, where groundwater quality has not been affected by local environmental impacts. The stations are located in different climatic zones and different soil type regions, the size of exanimated area is in the range of 0,2 to 3 km^2. In order to identify groundwater quality, 30 detectors are made six times a year.

The monitoring of groundwater quantity involves 54 groundwater observation stations with 550 observations points across the country. The conditions for the groundwater monitoring quantity stations are the same as for the groundwater monitoring quantity stations. The sampling sites detect the water level 26 times a year. (European Environment Agency, 2011)

4. GROUNDWATER PROTECTION AND REMEDIATION TECHNOLOGY

Environmental pollution and contamination are becoming a common problem in the world. Many rural and urban areas of the industrialized world have been affected by large-scale pollution, resulting in losses of human, material and financial resources. In many American, European and Asiatic countries, a colossal amount of money is spent for research to prevent and control widespread contaminations. Volumes of these contaminations are produced yearly through natural and anthropogenic activities such as industrial activities, agricultural practices and waste disposal systems. These contaminations may be physical, chemical, biochemical, biological or microbiological in nature. (Lucier et al, 1989)

The natural processes and anthropogenic activities that generate contaminations are many and varied. These contaminations by the hydrological cycle reach the groundwater systems and pollute them. Through the circulation of water within the hydrological cycle, pollutants (Figure 4.1) on the ground surface moves through the soil zone into the aquifer horizons and damage drinkable water supplies. (Lucier et al, 1989)

Figure 4.1. Hazard posing threat to groundwater quality (EA, 2013)

Let us consider the main aspects of pollutions in order to get general conception of the hazard that can occur. According to Lucier (1989), it is possible to define contaminations into two main sources. They are point sources and distributed sources. The point sources come from areas of known and defined boundaries. The pollution load can be controlled at the point of input before they can spread into the surrounding environment. Point sources include sewage lagoons, industrial wasters, landfills/garbage dumps, liquids spills (oil, chemical, etc.), mining, saline lakes and deposits. The distributed sources are those in which the pollutants are spread through a large area of hydrogeological environment. The distributed source is very widespread and pollutants may be introduced from various sources and directions. Spreading is increased by wind, rain and snowfall through atmospheric circulation and precipitation. The boundary conditions for pollutants are difficult to define. The sources include acid-alkaline rain, floods, erosion, agricultural fertilizer, generated agricultural wastes, sea spray, etc. Acid rain is a major distributed source of pollutions. Waste products in urban areas are transported away by runoff. Wind, wave action, seaspray or saltwater intrusions are also major distributed sources of pollution.

Various environmental problems can appear as a result of groundwater contamination. The main is the potential contamination of surface water (Figure 4.2). Proper understanding of sources and types of pollutants and their genesis and hydrodynamics would help to determine appropriate control and protection measures (Lucier et al, 1989). It is also generally accepted that not all groundwater resources must be protected. To protect all groundwater resources at the same level would be economically unstable and unrealistic in terms of management and control (Vrba et al, 1991).

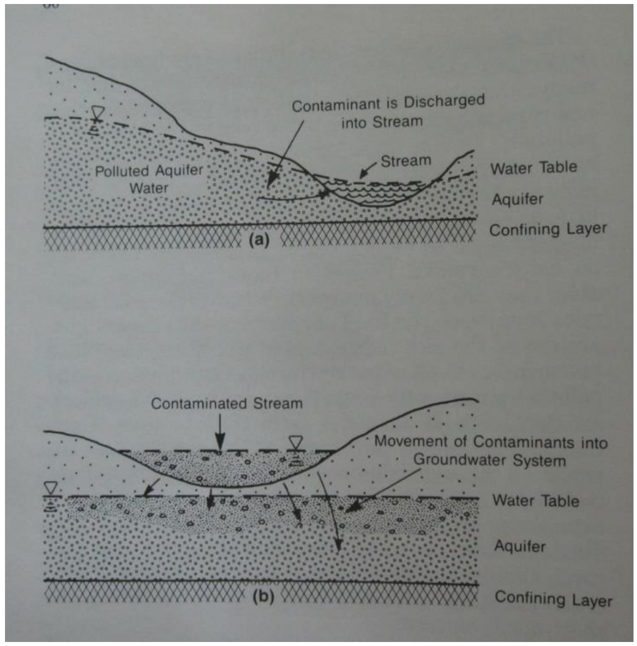

Figure 4.2. A schematic diagram showing the potential of contamination of (a) surface water when an aquifer is polluted and (b) contamination of groundwater when the surface water is polluted (Lucier et al, 1989)

4.1 GROUNDWATER PROTECTION METHODS

Groundwater protection must be planned and controlled collectively, taking into account social, economic and environmental aspects. It is not an isolated action but a long-term and multivariate program. Protection of groundwater contains researches, mapping, monitoring, modeling and analysis of the changes and processes in the groundwater system. A protection strategy needs to correspond with the components of hydrological cycle, land-use planning and other natural resources. (Vrba, et al, 1991)

According to J.Vbra (1991), there are two categories of groundwater protection management: *general protection and comprehensive protection*. The criteria for general protection are established for national and regional water management plants. It is based on the assumption that all groundwater resources are referred to as for drinking purposes. The strategy is based on good knowledge of the parameters of the saturated and unsaturated zones of groundwater system and its vulnerability. It also includes assessment of existing and potential pollution sources, analysis of the data taken from quality monitoring networks. Comprehensive groundwater protection coordinates with public water supplies. It requires cooperation with national, regional and local water authorities, waterworks organizations and land users; realization of technical, institutional, legislative and control measures and regulations in protected areas. (Vrba et al, 1991)

Source protection zones

The groundwater resources utilized for public drinking water supplies are protected by protection zones, usually including two or three levels of protection. The main purpose of the protection zones is to protect drinking water wells from pollution and provide the population with water, which meets the standards for drinking water. The techniques and methods used for the groundwater protection zones depend primarily on the permeability of the aquifer (porous, fissured, karstic), complexity and vulnerability, properties and thickness of the unsaturated zones, quantities, properties of potential pollutants and their distance from the wells of wellfield. (Vrba, et al, 1991)

A system of zoning of the recharge area is most needed and this approach has been adopted in Europe as well as in the United States. As presented in figure 4.3 and table 3, the zoning system includes several zones. The first zone is based on a delay time of 60 days from any point below the water table in order to protect against pathogenic bacteria, viruses and hazard chemicals. Table 1 describes land-use restrictions applied in each areas. (Hiscock, 2005)

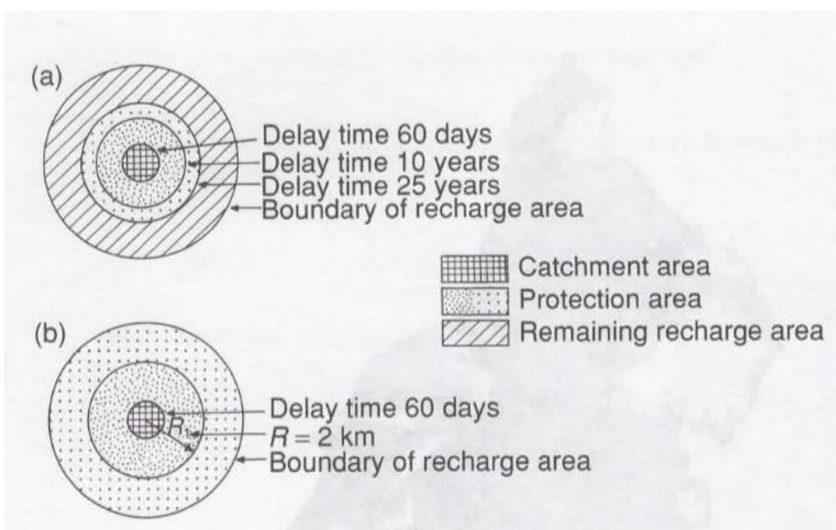

Figure 4.3. Example of groundwater source protection zones, (a) a porous, permeable aquifer and (b) a fissured, karstic aquifer (Hiscock, 2005)

Table 3. Land-use restrictions for the source protection zones shown in Fig.14 (Hiscock, 2005)

Catchment area	Protection area	Remaining recharge area
60 days and ≥30 m	10- and 25-years delay-time or 2 km	
Protection against pathogenic bacteria, viruses and against chemical pollution sources	Protection against hardly degradable chemicals	Soil and groundwater protection rules
Only activities in relation to water supply are admissible	The following are not admissible: Transport and storage of dangerous goods Industrial sites Waste disposal sites Building military activities Intensive agricultural and cattle breeding Quarrying Waste water disposal	

The first zone is usually extended 30-150 m from an individual borehole. The delay-time in the second zone is at least 10 years in order to continue water supply in the event of heavy pollution occasion and to prevent public health risk. Protection in the next zone of 25 years is necessary. The 10- and 25-years protection zones cover about 800 m and 1200 m from borehole. (Hiscock, 2005)

The Environmental Agency in EU and other countries has established source protection zones (SPZs). These SPZs are applied to public water supplies, and private water supplies, as well as bottle water, and commercial food and drink production (Figure 4.4). The shape and size of the SPZs are determined by hydrogeological characteristics and direction of groundwater flow around each source. (Hiscock, 2005)

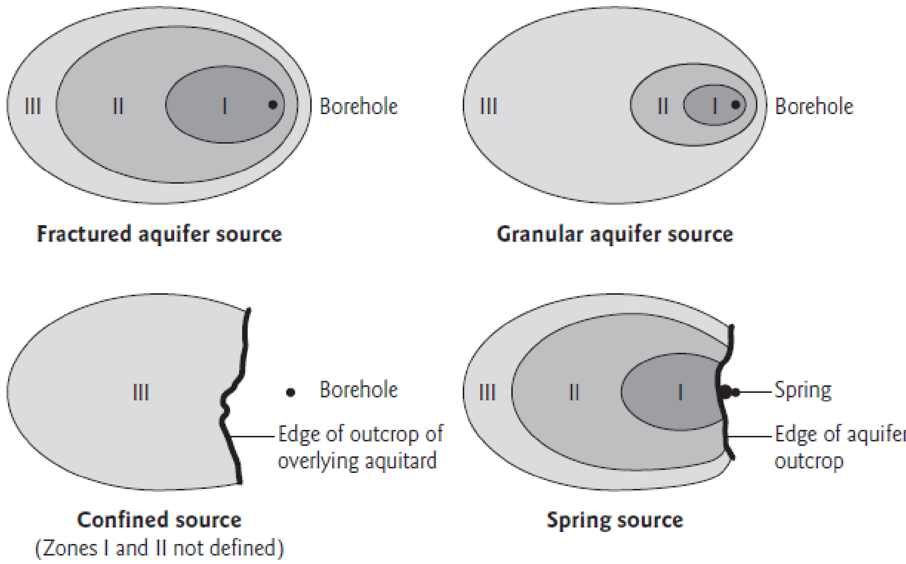

Figure 4.4. Source protection zones: schematic plans of the anticipated layout of the inner (I), intermediate (II), and entire (III) source protection zones anticipated in a range of hydrogeological settings (Younger, 2007)

The first zone, or the inner protection zone, is located immediately nearby the groundwater source. It is designed to protect against the impact of human activity. The area extends to a 50-day travel time from any point below the water table to the source and a minimum 50-metres radius from the source. The second zone, or the outer protection zone, extends to a 400-day travel time, and is designed to provide delay and dilution of slowly degrading pollutants. The third zone, or the source catchment, is the remaining catchment area of groundwater source and it is defined as the area which is needed to support intake from long-term annual groundwater recharge. This zone vary from tens to a few thousands of meters depending on the volume of groundwater abstraction and the amount of recharge. (Hiscock, 2005)

Groundwater vulnerability, maps of vulnerability

Appropriate assessment of groundwater resources vulnerability prevents their alteration and pollution. Groundwater vulnerability assessment must be combined with plans to support planning, policy and strategy of groundwater resource protection and quality management. The concept of groundwater vulnerability is based on the assumption that the geological environment may provide some level of protection to groundwater against the natural and human impact. The idea of vulnerability of groundwater protection to contaminants by means of maps is aimed to show that protection provided by the natural environment varies at different locations and that it would be helpful to identify areas on the maps, where protection measures are most needed. The fundamental understanding of groundwater vulnerability is that some land areas easily contribute to groundwater contamination, and thus are more vulnerable, and others are not. (Zekster et al, 2004)

The principal characteristics used in the assessment of the groundwater vulnerability are the time of travel of infiltrating water and contaminants, the relative quantity of contaminants that can reach the groundwater, and the damping capacity of the contaminants of the geological materials through which water and contaminants infiltrate, which refer to the recharge, soil, properties, and the characteristics of the unsaturated and saturated zone. (Geological Survey of Ireland, 2015)

This approach has been used by the Environmental Agency in Europe and in England and Wales to make vulnerability maps presenting vulnerability classes regulated by overlay of soils and hydrogeological information (Figure 4.5:)

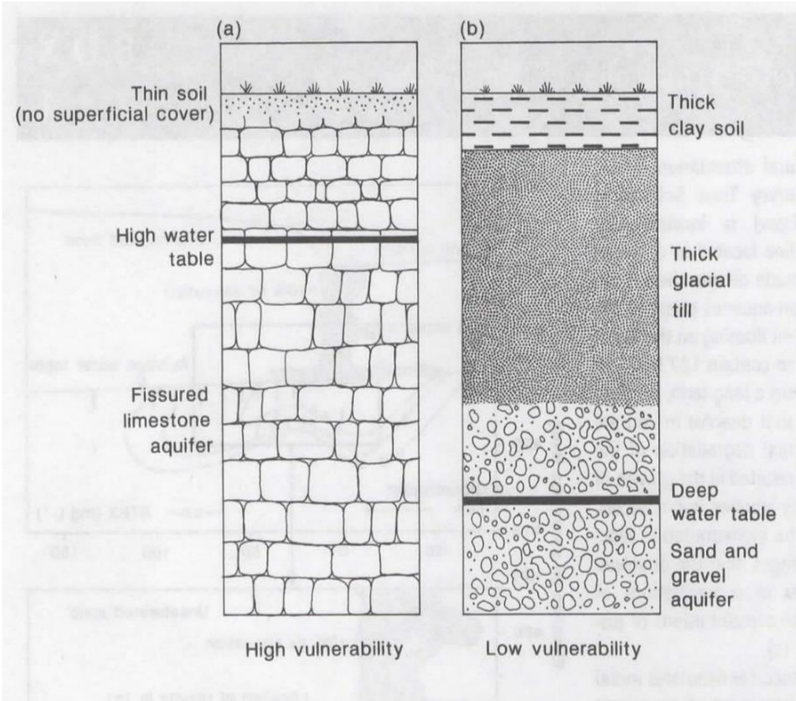

Figure 4.5. Groundwater vulnerability: (a) the unconfined, fissured limestone aquifer with a permeable soil cover and high water table (thin unsaturated zone) has a high vulnerability; (b) the sand and gravel aquifer with overlying law permeability soil and glacial cover has a low vulnerability (Hiscock, 2005)

Groundwater vulnerability map express more or less a subjective view of the capacity of the subsurface environment to protect groundwater, typically in terms of water quality. The contents of the map must meet the requirements of map users. The main goal of the vulnerability map is a subdivision of an area into several units, showing differential potential for a specific purpose and use (Geological Survey of Ireland, 2015). Four groundwater vulnerability categories are used on the maps – extreme (E), high (H), moderate (M), and low (L) (Figure 4.6).

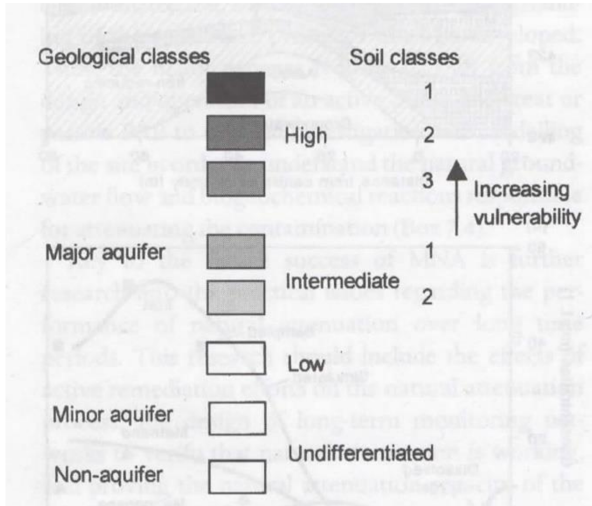

Figure 4.6. Vulnerability classification schemes (Hiscock, 2005)

There are two approaches to vulnerability mapping: natural and specific (Geological Survey of Ireland, 2015). The natural vulnerability map is used to evaluate the natural vulnerability of groundwater, without context to a specific contaminant (Figure 4.7), and the specific vulnerability map is used to evaluate the impact of a specific contaminant on groundwater system. (Figure 4.8).

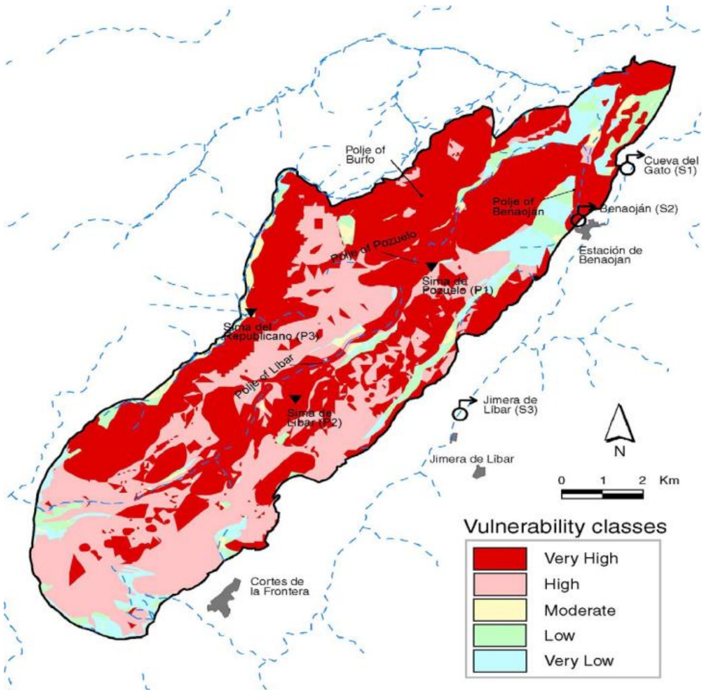

Figure 4.7. Natural vulnerability map by example of Spain territory (Andreo et al, 2005)

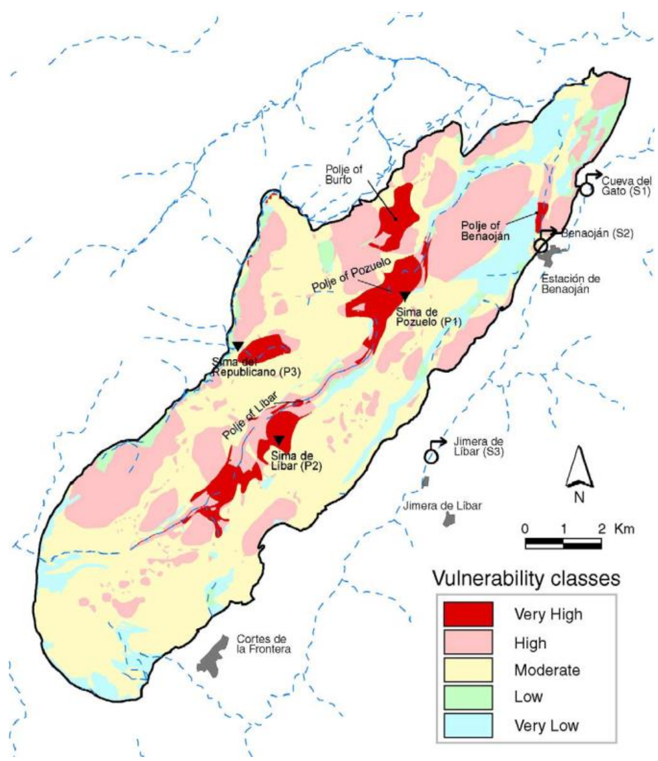

Figure 4.8. Specific vulnerability map for aromatic hydrocarbons contamination by example of Spain (Andreo et al, 2005)

Vulnerability maps provide a regional picture which demonstrates the actual threat to the groundwater resources at a local scale. The real vulnerability can be recognized with confidence of supporting, site-specific investigations. Thereby, vulnerability maps can help to achieve water quality objectives by influencing land-use management. (Hiscock, 2005)

4.2 GROUNDWATER POLLUTION REMEDIATION TECHNOLOGY

The remediation of groundwater can be implemented through attempt at a total clean-up of a contaminated aquifer or the containment of groundwater pollution source. In some cases such as in areas of low risk of human or environmental contact to contaminants the aquifer can be left for the recovery through natural reduction processes. (Hiscock, 2005)

Typical remediation techniques apply pump-and-treat methods. This method has shown to be less successful with respect to the clean-up of pools of trapped organic pollutants. Latest technologies include soil vapour extraction, air sparging and bioremediation for the improved removal of organic contaminants. Passive techniques such as permeable reactive barriers (PRB) are increasing interest. PRB provide an innovative, cost-effective and low-maintenance solution for the clean-up technologies of contaminated land and groundwater. (Hiscock, 2005)

Pump-and-treat

The standard pump-and-treat method is used for the clean-up of groundwater contaminated with dissolved chemicals like industrial solvents, metals, fuel, and oil. Pump-and-treat method includes pumping of groundwater from wells to an above-ground treatment system which removes the contaminants (Figure 4.9). In some cases the systems are used to contain the polluted plume. Containment of the plume is aimed to keep it from spreading contaminated water by pumping it toward the wells. Pumping keeps contaminates from reaching drinking water wells, wetlands, etc. (EPA, 2012)

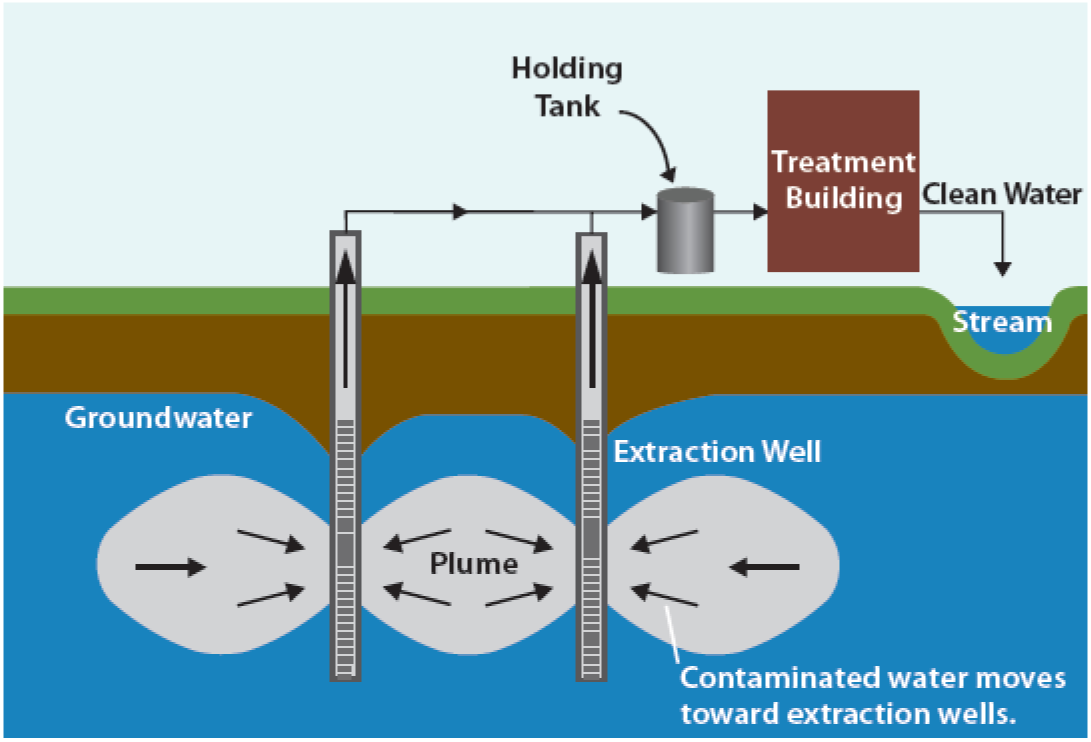

Figure 4.9. Pump-and-treat method with two extraction wells (EPA, 2012)

Pump-and-treat method can include installing one or more wells in order to extract contaminated water. Groundwater is pumped from these wells either directly into a treatment system or into a holding tank until the time when treatment can be done. Usually treatment systems consist of one clean-up method. However, sometimes it requires several methods if groundwater contains different types of contaminants or high concentrations of a single contaminant. (EPA, 2012)

After the groundwater quality has reached regulatory standards, it can be discharged for disposal or further use. It can be pumped back into the ground or into a nearby stream, or it can be distributed for irrigation of soil and plants. Treated water may be discharged also to public sewer systems for further treatment. Pump-and-treat method can last from a few years to several decades depending on the concentrations of contaminants, size of the plume, and groundwater flow. (EPA, 2012)

Permeable reactive barriers

A permeable reactive barrier (PRB) is a wall created below the ground surface to clean-up contaminated groundwater. PRB is made by digging a long and narrow channel in the path of contaminated water. The channel is filled with a reactive material, such as iron, limestone, carbon, etc. The material of the wall catches the harmful substances or makes them less harmful. Typically the wall can be no deeper than 50 meters. Groundwater can easily flow through the wall. The reactive material used to build up the wall depends on the types of contaminants in groundwater. The material of the wall can also be mixed with sand that makes groundwater flow more easily through it (EPA, 2012). In order to help contaminated groundwater to flow toward the wall, the funnel or side walls filled with an impermeable materials such as clay are built (Figure 4.10-4.11).

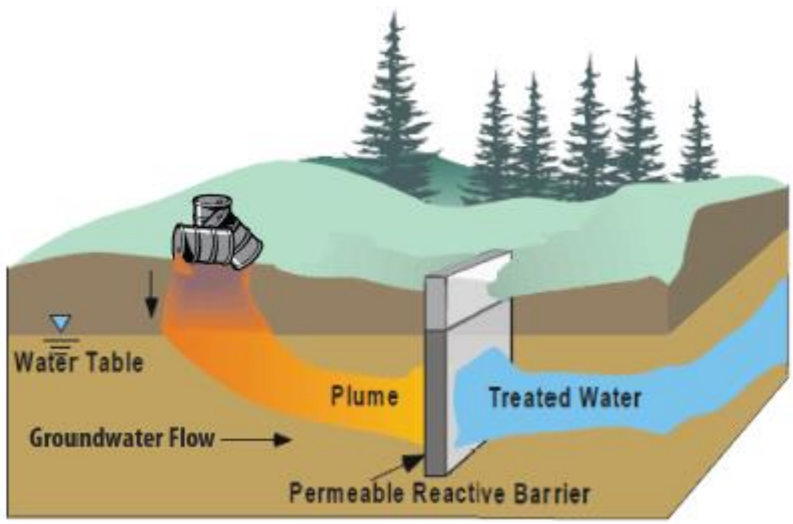

Figure 4.10. Example of permeable reactive barrier (EPA, 2012)

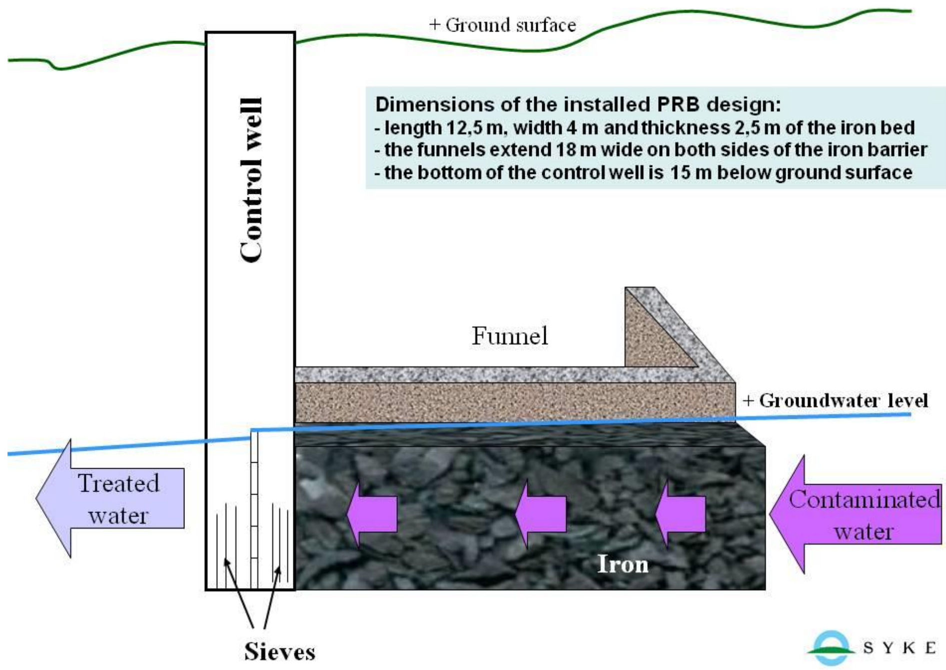

Figure 4.11. Example of permeable reactive barrier with funnel (SYKE, 2013)

Depending on the reactive material, contaminants are removed for example through different processes:

- contaminants sorb to the surface of the reactive material,
- metals dissolved in groundwater precipitate,
- contaminants react with the reactive material to form less harmful substances,
- contaminants are biodegraded by microbes in the PRB (EPA, 2012)

PRBs may take years to clean up contaminated groundwater. The process depends on the source of dissolved contaminants, groundwater flow, properties of dissolved contaminants. After reactive materials are filled with the harmful substances or treatment product, it becomes less effective and may be excavated for disposal or replaced with new material. (EPA, 2012)

PRB is applicable under most hydrogeological and geochemical conditions. It is a cost-effective and sustainable treatment solution. PRB is a passive technology, which does not require external source of energy or regular maintenance. The costs in the long-term treatment in PRB method are lower than in the pump-and-treat methods. (SYKE, 2013)

5. DISCUSSION AND CONCLUSIONS

For years everyone took water for granted. Few persons worried that water resources have limits, that they could be contaminated, or that the pressure of the increasing population would create physical and chemical stress on these resources. However, since 1960's, an awareness of the weakness of these resources has developed throughout the world. (Fletcher, 1986)

Groundwater has become a natural resource for national and international importance within the last several decades. It has received high attention due to increasing use of groundwater, heighten pollution problems, new legislative programs and management strategies. Groundwater pollution problems can be considered in terms of resource extraction, and natural and man-made pollution. Resource extraction may cause groundwater depletion, salt water invasion, and land subsidence. Groundwater quality must be considered in terms of potential groundwater use. Natural geological conditions can be a reason for poor groundwater quality due to inorganics and metals, for example such as chlorides, sulfates, hardness, iron, and manganese. Categories of man-made pollution are enormous, and are receiving an attention as a result of legal requirements and special programs (Canter et al, 1987). Groundwater is harder to clean than surface water, and once it becomes contaminated the consequences will last for decades. Society can spend large sums of money and time to determine what the problems are and to develop potential solutions (Fletcher, 1986).

The use of groundwater for drinking purposes is often preferred because of its good microbial quality in its natural state. Nevertheless, according to the World Health Organization (WHO) water-related disease is one of the major health concerns in the world. It is one of the reason of high level of mortality in the developing countries. Disease from poor water quality and poor water protection affects all nations. Water-related diseases still continue to occur in both developed and developing countries. They lead to loss of life, loss of economic costs both for individuals and communities. The improvement of water quality control strategies can deliver significant health achievements for the population. (World Health Organization, 2006)

In accordance with national statistics, consumption of groundwater varies in different countries of Europe (Figure 5.1):

Country	Proportion	Country	Proportion
Austria	99%	Bulgaria	60%
Denmark	98%	Finland	57%
Hungary	95%	France	56%
Switzerland	83%	Greece	50%
Portugal	80%	Sweden	49%
Slovak Republic	80%	Czech Republic	43%
Italy	80%	United Kingdom	28%
Germany	72%	Spain	21%
Netherlands	68%	Norway	13%

Figure 5.1. Proportion of groundwater for drinking purposes in Europe (World Health Organization, 2006)

Despite the fact that the quality of groundwater is usually good, it still may be contaminated if the measures at the point of abstraction are not implemented and well maintained. Groundwater may become contaminated during withdrawal, transport and household storage as well. Because of hazardous chemicals and pesticides which accumulate over time groundwater source may become unusable. (World Health Organization, 2006)

Nowadays there are many technologies which are being used for groundwater protection and remediation. However, scale, impact and sometimes the lack of possible clean-up technologies for some chemical pollutants in groundwater means that they should be considered in priority for preventative and remediation strategies. (World Health Organization, 2006)

Groundwater has a high socioeconomic value. The natural groundwater quality makes its use valuable in industry as well. The advantages of groundwater emphasize the need for its protection. The costs of implementing measures such as protection plans and strategies should be taken into consideration, as well as the costs of not protecting groundwater and wise groundwater use in order that balanced decisions on groundwater protection to be made. (World Health Organization, 2006)

In my opinion in both Russian Federation and European Union the importance of groundwater is implemented at a high level and different protection measures have taken into account.

European Environmental Agency has established guidelines for all European countries on the protection of groundwater bodies. The Water Framework Directive organize necessary measures in groundwater protection which have to be taken in to account by all EU Member States. It contains measures related not only to groundwater but it also covers water management for surface water, transitional, and coastal water. In addition to the WFD, different legislation guidelines are used to control water quality such as: the Nitrate Directive, The Urban Wastewater Treatment Directive, The plant Protection Products Directive etc. The main aim of the all directives is to protect water ecosystem and to achieve good surface and groundwater quality by 2015.

In Russian Federation water legislation contains the Water Code. The Water Code states to establish the Basin Councils which are responsible for the developing of guidelines for use and protection of water bodies. Instead of practice of licensing for use of water objects, the Government has established contracts for water management. Control and monitoring for water objects are implemented by The Ministry of Natural Resources, Federal Service of Hydrometeorology and Environmental Monitoring.

Quality of groundwater in Europe and Russian Federation is usually found under different kind of pressures. Nitrates, pesticides, groundwater abstraction and over-exploitation, and human intervention are the most common of them. Groundwater contaminations are most commonly observed near industrial receivers, municipal and agricultural sites.

The most important and most commonly used protection method is source protection zones (SPZs) which usually includes two or tree levels of protection. The techniques of the method depend on the aquifer and on properties of potential contaminants. The approach has been adopted both in RF and EU. At the same time with SPZs, the vulnerability mapping is another protection technology used for groundwater protection. The vulnerability maps are used to show the capacity of subsurface environment to protect groundwater in terms of water quality. Maps demonstrate regional situation in regards to actual threats to groundwater.

The groundwater pollution remediation technologies apply pump-and-treat and permeable reactive barriers (P-RB). Pump-and-treat method has shown to be less effective compared to PRB which provide a cost-effective and low-maintenance solution for clean-up technologies of groundwater.

REFERENCES

Andreo B, Goldscheider N, Vadillo I, Vıas J, Neukum C, Sinreich M , Jimenez P, Brechenmacher J, Carrasco F, Hötzl H, Perles P, Zwahlen F, 2005, Fast groundwater protection, First application of a Pan-European Approach to vulnerability, hazard and risk mapping in the Sierra de Libar)Southern Spain), Science of the Total Environment 357 (2006) 54-73

Bhattacharya P, Ramanathan AL, Mukherjee A, Bundschuh J, et al, 2008, Groundwater for sustainable development: problems , perspectives and challenges, Taylor & -francis Group, London, UK

Canter L, Knox R, 1987, Groundwater pollution control, USA, Lewis publishers

Canter L, Knox R & Fairchild D, 1987, Groundwater quality protection, Michigan: Lewis Publisher

Center of state monitoring of natural resources 2007, Pollution of groundwater, date of retrieval 17.09.20013, http://www.geomonitoring.ru/ , in Russian

Driscoll, F.G., 1987, Groundwater and wells, Second edition, Minnesota: Johnson Division

Europa, Summaries of EU legislation, Protection of groundwater against pollution, date of retrieval 11.03.2013, http://europa.eu/legislation_summaries/environment/water_protection_management/l28139_en.htm, in Englis

European Commission, 2015 Groundwater in the Water Framework Directive, date of retrieval 1.02.2015

http://ec.europa.eu/environment/water/water-framework/groundwater/framework.htm, in English

European Environment Agency, Finland, date of retrieval 03.05.2014

http://www.eea.europa.eu/publications/92-9167-032-4/page006.html , in English

Fletcher, G, 1986, Groundwater and wells, Second edition, Minnesota, published by Johnson Division

Freezer, R.A. & Cherry, J.A., 1979 Groundwater, USA

Geological Survey of Ireland, Protection Schemes Guidelines, date of retrieval 10.02.2015

http://www.gsi.ie/Programmes/Groundwater/Projects/Protection+Schemes+Guidelines.htm#categories, in English

Green B., Boronina A., Connelly R., Prorosed groundwater classification scheme, SRK Consulting (UK) Limited

Harter T, 2003, Basic concepts of groundwater hydrology, California: University of California & Division of Agriculture and Natural Resources, Publication 8083, 2

Heath R, 1983, Basis ground-water hydrology: U.S. Geological Survey Water-supply paper 2220, Virginia

Hiscock K, 2005, Hydrogeology. Principles and Practice, School of Environmental Sciences, UK

Katko T, Lipponen M, Rönkä E, 2004, Groundwater use and policy in community water supply in Finland, Hydrogeology Journal (2006) 14:69-78, Springer-Verlag 2004, published online :28 May 2004

Lavapuro M, Lipponen A, Artimo A, Katko T, 2008, Groundwater sustainability indicators: Testing with Finnish data, BOREAL ENVIRONMENTAL RESEARCH 13: 381-402, Helsinki, 2008

Lucier G & Hook G, U.S. Department of Health and Human, Public Health Service, National Institute of Health: Environmental Health Perspectives, volume 83, November 1989

Ministry of the Environment, Legislation on the protection of water and the sea, date of retrieval 03.05.2014 http://www.ym.fi/en-US/Nature/Legislation/Legislation_on_the_protection_of_water_and_the_sea , in English

Ministry of the Environment, Surface water and groundwater, date of retrieval 3.05.2014

http://www.ym.fi/en-US/Nature/Surface_waters_and_groundwaters , in English

Ministry of Agriculture, Food and rural affairs (Ontario), 2006, Understanding Groundwater, date of retrieval 03.05.2013, http://www.omafra.gov.on.ca/english/environment/facts/06-111.htm

Okkonen J, 2011, Groundwater and its response to climate variability and change in cold snow dominated regions in Finland: methods and estimations, Oulu: University of Oulu, Faculty of Technology, Department of Process and Environment, Juvenes Print Tampere 2011

Pinneker, E.V., 1983, General hydrogeology, GEOLOGICAL JOURNAL, vol. 19, 299-308 (1984), translated from Russian by Howard, D.E. & Harvey, J.

Scheidleder A, Grath J, Winkler G, Stärk U, Koreimann C, Gmeiner C, Nixon S, Casillas J, Gravesen P, Leonard J, Elvira M, 1999, Groundwater quality and quantity in Europe, EEA, Copenhagen, 1999, final editing: Nixon S

Seliverstova M 2008, Current Russian Water Legislation, date of retrieval 12.03.2012

http://wldb.ilec.or.jp/data/ilec/wlc12/K%20-%20LegalRegulatory%20Measures/K-3.pdf , In English

SYKE, 2013, Remediation of contaminated groundwater using permeable reactive barriers (RESET), http://www.syke.fi/en-US/Research__Development/Research_and_development_projects/Projects/Remediation_of_contaminated_groundwater_using_permeable_reactive_barriers_RESET, date of retrieval 25.02.2015, in English

EPA (United States Environmental Protection Agency), 2012, A citizen's guide to pump-and-treat, date of retrieval 24.02.2015, http://www.clu-in.org/download/citizens/a_citizens_guide_to_pump_and_treat.pdf

EPA (United States Environmental Protection Agency), 2012, A citizen's guide to Permeable Reactive Barriers, date of retrieval 24.02.2015, http://www.cluin.org/download/Citizens/a_citizens_guide_to_permeable_reactive_barriers.pdf

Vrba J, Gun J, 2004, The world's groundwater resources: *Contribution to chapter 4 of WWDR-2 (Draft)*, Utrecht: International Groundwater Resources Assessment Centre, Report Nr IP 2004-1

Vrba, J., Aldwell, C., Alfoldi, L., Andersen, L., Hanh, J., Kaden, S., Miller, J. & Waegeningh, H., 1991, Integrated land-use planning and groundwater protection in rural areas, Paris: UNESCO

Wendland F, Blum A, Coetsiers M, Gorova R, Griffioen J, Grima J, Hinsby K, Kunkel R, Marandi A, Melo T, Panagopoulos A, Pauwels H, Ruisi M, Traversa P, Vermooten J, Walraevens K, 207, European aquifer typology a practical framework for an overview of major groundwater composition at European scale, original article, Springer-Verlag 2007

World Health Organization, 2006, Protecting Groundwater for Health: Managing the Quality of Drinking-water Sources. Edited by Schmoll O, et all, London, UK, Published by IWA Publishing

WISE, Water Note 3, date of retrieval 03.05.2014 http://ec.europa.eu/environment/water/participation/pdf/waternotes/water_note3_groundwaterrisk.pdf, in English

Younger P, 2007, Groundwater in the environment: an introduction, UK: Blackwell publishing

Zektser, I. & Everett, L., 2004, Groundwater resources of the World and their use, Paris: UNESCO 2004

Zektser, I., 2001, Groundwater as a component of the environment, Moscow: Scientific world

Znosok D 2010, Federal law and protection of water bodies, date of retrieval 05.03.2012

http://b-energy.ru/biblioteka/ekologiya-konspekt-lekcii/254-ohrana-vodnyh-resursov , in Russian