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GROUNDWATER CONTAMINATION FROM WASTE STORAGE WORKS

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Abstract

Groundwater is an important source of drinking water, especially for rural population. In the last years, bacteria, nitrate, organic chemicals and other pollutants existing in groundwater have increased public concern about the quality of groundwater. Groundwater provides about 22% of all freshwater withdrawals; 37% of agricultural use (mostly for irrigation); 37% of the public water supply withdrawals; 51% of all drinking water for the total population and 99% of drinking water for the rural population; 46% of domestic and commercial use; 24% of industrial and mining use. The most severe groundwater quality depreciation appeared in the rural built-up area, where the lack of minimum public facilities allows liquid waste to reach directly or indirectly into the groundwater. The paper analyzes the soil and groundwater behaviour in the presence of three of the most significant sources of groundwater contamination due to waste storage works: sewer lines, septic tanks and landfills.

Keywords: groundwater contamination, landfills, sewer lines, septic tanks, waste storage works

1. Introduction

The elevation of underground water threatens the stability and the correct exploitation of many buildings due to the influence of the pollutants into the foundation soil. Groundwater usually contains high concentrations of natural dissolved materials that affect the ground composition.

Most groundwater originates from rainfall that has entered the ground. About one-fourth of the quantity of precipitation infiltrates the soil and recharges local aquifers and the sediments that store and transport groundwater.

Shallow, permeable water table aquifers are the most susceptible to contamination, due to specific site characteristics as: distance from the contamination source to the aquifer, residence time of the water in the unsaturated area, presence of clay and organic matter in the unsaturated area, potential of a particular contaminant to decompose, amount of precipitation that affects recharge, evaporation that decreases the amount of water that moves downward to the aquifer.

The main factors influencing the transport of the pollutants in the ground are: the underground water level, the quantity of pollutants, their type, and soil bedding (Bedient et al., 1999).

The groundwater measurement consists in: measurements of the water level depending on the level fluctuation amplitude, temperature measurements in specific drillings, experimental pumping to determine the properties of the hydrogeological layer, and periodical sampling to determine the water physico-chemical characteristics (Rotaru et al., 2001).

2. Case study

Taking Romania as a case study, this research focuses on the groundwater contamination due to waste storage.

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From the point of view of pollutants, there are four types of soils (Tobolcea, 2007): (i) soils that allow pollutants accumulation; (ii) soils that allow pollutants migration; (iii) soils polluted due to natural sources; (iv) soils polluted due to human activities.

In the first case, even if the tests were performed at distance from the sewage system (100m), pollutant concentrations in the underground water are as high as in the sewage system.

In the second case, an example from Romania consists of lead traces migrated from the Roman Pipe Factory and founded in Siret Plateau, in northeaster of Roman City.

Groundwater contamination can be both natural- and human-induced. Groundwater commonly contains one or more naturally-induced chemicals, leached from soil by percolating water.

In the third case, the soil pollution was analyzed within the framework of some water drain projects realized in Iasi area, Romania, and by the mediation of some boreholes drilled in Iasi City. The presence of sulphur in weak, medium and hard soil layers was observed in the analyzed area, with great concentrations in areas like: S.C. Moldomobila S.A., S.C. Lactis S.A. and Nicolina Hospital. The values for different sulphur compounds are there up to 1200 mg/l, very high in comparison with the limits cleared up by national regulations (NTPA 002/2005) that allow maximum values of 1,0 mg/l sulphides and 600 mg/l sulphates in urban sewage systems.

The deep drillings realized by the National Hydrogeological Network in Romania investigate unknown areas from deep groundwater layers analyzing the behaviour of groundwater under natural conditions.

In the fourth case, it is obvious that groundwater pollution levels vary widely by location and depend on local industry and agriculture. In Romania, only desultory groundwater-quality measurements are available. These measurements reveal that groundwater is highly polluted in some areas, especially with nitrates, phosphates, pesticides, heavy metals and organic pollutants, the concentrations exceeding the admissible concentration limits specified by STAS 1342-9: Siret corridor on the downstream Roman-upstream Adjud stretch; Bistrita corridor downstream of Piatra Neamt; Trotus corridor on the downstream Oneşti - upstream Adjud stretch; Sitna depression - downstream of Botosani; Bahlui corridor downstream of Podu Iloaiei; Prut corridor downstream of Ungheni; eastern Covurlui Plain; lower Siret Plain; the eastern half of southern Dobrogea; lower Danube Plain; northern Baragan Plain; Ialomita corridor on the Urziceni-Tandarei corridor; piedmountaneous Ploiesti Plain; mountain and under-mountain depression areas drained by Olt-Ciuc, Brasov, Fagaras and Cibin; Crasna corridor; middle area of the Banat Plain; Mures corridor on the Reghin – Ludus stretch; Tarnava Mare corridor downstream of Sighisoara as well as Somes lower plain.

Contaminants enter groundwater from more than 30 different sources related to human activities. Some of these sources are: inadequate irrigation systems generating increased piezometric levels in Bailesti, Romanati and Baragan plains (2-15 m) and southern Dobrogea (3-10 m); excessive catchment of water generating decreases of the piezometric level of groundwater in Bucharest – "Fratesti Layers" (20–50 m); mining area drying generating in Rovinari over 80 m decreases of the piezometric level; products used in agriculture such as fertilizers (NH_4, NO_2, NO_3, phosphates) or pesticides in factories as AZOMURES Targu Mures, ARCHIM Arad, DOLJCHIM Craiova, OLTCHIM Ramnicu Valcea, AZOCHIM Roznov; products resulting from industrial processes contaminating areas around large industrial platforms such as Victoria, Fagaras, Codlea, Tohanu Vechi, Zarnesti, Bod, Isalnita, Craiova; oil products and phenol compounds due to Petrobrazi, Astra and Petrotel Ploiesti refineries; domestic products contaminating areas around important cities like Pitesti, Oradea, Bucharest, Cluj, Suceava; sewage.

Some man-made activities influence the water quality: landfill solid waste disposal, liquid waste disposal basins, septic waste infiltration systems, gasoline service stations, underground storage tanks, many industrial activities, urban storm-water infiltration (Fitts, 2002).

The common sources of human-induced groundwater contamination are: waste disposals, agricultural activities, and saline water intrusion.

Waste disposal can be made by: septic systems, landfills, waste-injection wells, and direct application of stabilized wastes to the land (Sharma and Lewis, 1994).

The most important sources of groundwater contamination in Romania are associated with the storage of liquid and solid wastes caused by (i) sewer lines, (ii) septic systems and the country's many legal and illegal (iii) waste landfills with an inadequate protection against pollutant leakage.

The organic substances resulting from waste disposal frequently existing in groundwater are: trichloroethylene (TCE), chloroform, benzene, pentachlorophenol, tetrachloroethylene (PCE), creosote, phenolic compounds, l,l,l-trichloroethane, toluene, xylene (Fetter, 1999).

In Romania, 3% of rural citizens are connected to sewage system, 11% have individual (septic) system, 15% have access to central drinking water system.

2.1. Sewer lines

In Romania approximately 20% of population uses storm water systems combined with sanitary sewer systems and 46% of population uses separate systems, especially in urban areas. When leaking sewer lines are located underground below the biologically active layer, the sewage can enter groundwater directly.

Sewer leaks can occur from tree root invasion, soil slippage, seismic activity, loss of foundation due to washout, flooding and sewage back up, among other events.

In Romania, the loss of foundation due to washout is among the top dangers for a foundation. Underground rivers move the soil under the building and put stress on the foundation. The amount of water in the soil is also a damaging factor. In an area where heavy rainfall is followed by a dry season, such as in much of the northeaster of Romania, the amount of water in the soil varies. As moisture evaporates, the soil contracts; as moisture seeps into the soil, it will expand.

2.2. Septic systems

Where no sewer system exists, such as in rural areas, to store and process wastes are used septic systems. But approximately one-third of existing septic systems contaminate aquifers because improper operation.

The typical sources of waste water entering a septic system are: toilets (approximately 38%), laundry (25%), baths (22%) and sinks (15%). These systems are sources of bacteria, viruses, nitrate, phosphorus, chloride and organic substances.

Making a septic system, the important factors for environment are: the quality of water receiver, the chemical characteristics of the groundwater, the materials used for pipes and work quality.

Contamination of water from septic systems occurs under various conditions: poor placement of septic leach fields, bad percolation system, high density placement of tanks, and construction or maintenance practices. Additionally, there are soil properties, subsurface geology, climate and vegetation which may affect the quality and quantity of waste water (Fig.1).

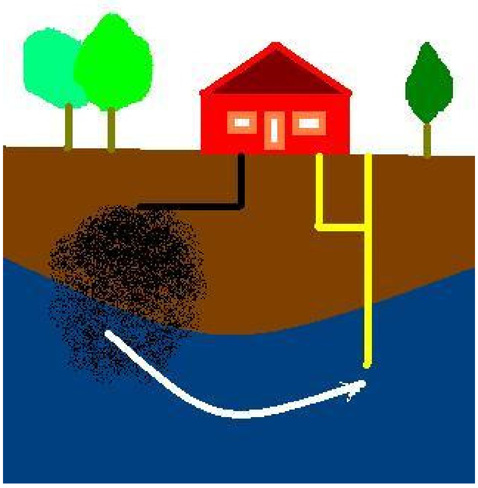

Fig. 1. Contaminated groundwater from septic systems

Septic systems must be located below the building and where the water will not come to surface or cause slope instability. The steep slopes cause effluent to surface. Large areas in Moldavia region, Romania, are steeper than 20%, being subjected to natural landslides. These soils represent thin deposits of loess, a fine-grain wind deposited sandy, silty, clayey soil with a low dry density, which has clay cementation that makes it strong and stable when dry. However, this soil is highly compressible due to its low density and unstable when wet. It becomes wet naturally resulting in landslides when moisture contents are higher than 18%. Buildings may also cause the soil to become wet or saturated resulting in large settlements under applied loads and loss of bearing capacity.

Septic systems are ones of the largest sources of pollution. A septic system consists of a septic tank (a container made of concrete, fibre-glass, or polyethylene), a distribution box, and a drain field. Wastewater flows into the tank, where it is held for a time to allow suspended solids to separate out. The heavier solids sink to the bottom of the tank and are partially decomposed by microbes forming a layer of sludge. The lighter materials (grease, oil, fat, digested solids or small food particles), float on the surface to form a layer of scum. The partially clarified wastewater between the layers of scum and sludge flows to the distribution box, which distributes it through the drain field (a network of perforated pipes laid in gravel-filled beds). Wastewater flows out of the pipes, through the gravel, and into the surrounding soil (Zheng and Bennett, 2002).

The leach field must have a certain separation from the water table to prevent contamination. Likewise layers of impermeable soil must be a certain depth below the leach field.

2.3. Landfills

Landfills represent an important threat to groundwater contamination. A landfill is a site for the disposal of waste materials by burial, the oldest form and the most common method of waste treatment.

Some hazardous waste materials are deposited in landfills and underlying groundwater may become contaminated. Most household waste is buried in landfills. Wastes deposited at industrial landfills include traces of metals, acids, volatile organic compounds and pesticides, which may cause local contamination.

3. Results and discussion

Among geological risks, the groundwater pollution is an induced one. The risk evaluation and management involves four stages (Bocanegra et al., 2003; Vrba and Zaporozec, 1994): (i) prediction, (ii) prevention, (iii) monitoring, and (iv) mitigation, as follows:

(i) The prediction of the future behaviour of the system means diagnosis of the current situation measuring the most important parameters: water resources, stream discharge, aquifer recharge, area affected by waste disposal, volume of urban waste produced, total population lacking sanitary services, untreated waste, polluting industries, fertilisers and pesticides used.

(ii) Monitoring determinates the main parameters in a given time to measure groundwater quality (Scharp et al., 1997): unsaturated thickness, area affected by waste disposal, chemical and bacteriological pollution, heavy metals in water and sediment, persons affected by hydric diseases.

(iii, iv) Prevention works with mitigation. These stages are planned and executed to avoid the contamination risk. Mitigation consists of actions taken to attenuate or eliminate alteration processes or the contamination of groundwater. Mitigation measures during design phase and afterwards are: materials chosen according to soil aggressiveness, proper work execution, and sewers monitoring during performing (El-Kadi, 1995).

In order to work properly, a septic system must accomplish some parameters.

Soil permeability must ensure proper treatment of system effluent (Rotaru and Raileanu, 2004). The water carrying capacity of the soil must be measured before the design of the septic system using a percolation test.

In general, groundwater flow is slow and depends on the permeability of the subsurface materials and on the hydraulic gradient. Soils with percolation rates slower than 20 min/cm make the septic systems unsuitable. Soils with rapid percolation rate (high permeability) are incapable to absorb effluent from the leach field. As result, alternative systems may be design.

Many environmental factors (rainfall, soil moisture, temperature, pH, organic material in the soil) influence the movement of contaminants from the septic system through the soil to groundwater.

There are two important conditions to be kept: minimum horizontal setback distances from buildings and drinking water wells, and minimum vertical setback distances from impermeable soil layers and water table.

The geotechnical features of the foundation soil presenting wastewater assume the possibility of groundwater and foundation ground pollution (Rotaru and Raileanu, 2004).

The analysis developed in Iasi area, Romania, at 2.00 m deep is presented in Table 1. Iasi City, in northeastern of Romania, is the second city of the country, with more then 350,000 inhabitants.

Iasi soils are commonly plastic clay at 2.00 m deep without foundation ground pollution, with a clay fraction between 61% and 82% and with geotechnical features as in Table 2. Drained loamy soils are proper for septic systems.

Soil characteristics and topography must be taken into account in designing the septic system, especially the drain field, located in relatively flat areas to ensure uniform effluent flow. The lower the soil permeability, the larger the drain field required. The infiltration capacity of the soil is reduced when the soil is already compacted and dry. The knowledge of the groundwater influences to the foundation soil allows the comparison of the initial properties of the foundation soil with those after its pollution.

Proper maintenance of septic system is important to prevent contamination: annually inspection to verify the internal structures and to monitor the scum level; wastewater from basement pumps and the surface runoff from roofs must not be discharged into the system; pumping out every two to five years depending on the tank size, wastewater volume, and types of solids entering the system, because the concentration of solids entering the drain field can reduce soil permeability and cause the drain field to fail. Trees should not be planted over the drain field because the roots can enter the perforated piping.

Remedial methods include: excavation and offsite removal, excavation and onsite treatment, groundwater "pump and treat", bioremediation, in-situ treatment (Rotaru, 2004).

For landfills the environmental protection should focus on: contaminated water, control water from precipitation entering into the landfill body, prevent groundwater entering into landfill waste, prevent lateral dissipation of the medium, gas control, stability insurance, hazards minimization, relation with local landscape (Nicholson et al., 1983).

Table 1. Geotechnical features in Iasi area, Romania, at 2.00m deep, for soils presenting wastewater

Geotechnical features	*Symbol*	*U.M.*	*Value*	*Observation*
Moisture content	w	%	33.70	
Plasticity Index	I_P	%	32.04	high plasticity
Consistency Index	I_C		0.62	
Natural unit weight	γ_{med}	g/cm^3	1.83	
Porosity	p	%	49.84	
Void ratio	e	%	1.02	
Degree of saturation	S_R		1.89	saturated
Oedometric modulus	M_{2-3}	daN/cm^2	83.29	
Specific settlement	ε_2	cm/m	4.57	very compressive
Angle of internal friction	$Ø$	degree	18	
Cohesion	c		0.4	

Table 2. Geotechnical features in Iasi area, Romania, at 2.00m deep, for soils without pollution

Geotechnical features	*Symbol*	*U.M.*	*Value*
Natural unit weight	γ_{med}	g/cm^3	1.67 – 1.69
Dry unit weight	γ_d	g/cm^3	1.23 – 1.35
Porosity	p	%	53.1 – 55.6
Degree of saturation	S_R		0.701 – 0.984

4. Conclusions

In many regions of Romania the groundwater quality is in critical condition. As a result of environmental pollution, 7 million hectares of agricultural land are affected by erosion, especially in the southern part of the country. For this reason, within the water quality management policy, measures to prevent the quality degradation of the water resources should be a priority (Miller and Scalf, 1974).

If groundwater contamination is identified on a site, and if contaminant concentrations are found above regulatory limits, remedial activities or feasibility studies must be done just to keep a site in compliance. Such activities vary with the contaminant, medium contaminated, and surrounding environmental factors.

Assessment of the groundwater contamination is difficult. Groundwater moves very slowly, and it may be years after remedial actions are taken before improvements in water quality are obtained. For this reason, the enhancement of the quality of the groundwater requires a long-term commitment.

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