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REVIEW OF CHLORIDE AND SULPHATE ATTENUATION IN GROUND WATER NEARBY SOLID-WASTE LANDFILL SITES

G. Venkatesan[1], **G. Swaminathan**[2]
[1]*School of Civil Engineering, SASTRA University, Thanjavur-613402, India*
Research Scholar, Department of Civil Engineering, National Institute of Technology,
Tiruchirappalli-620015, India
[2]*Department of Civil Engineering, National Institute of Technology, Tiruchirappalli-620015, India*
E-mail: [1]*gvnitt@gmail.com; gvnitt@yahoo.co.in.*

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Abstract. Ground water drawn for various purposes, such as irrigation, drinking and industrial, is constantly on the rise in areas where surface water are sources nowadays scarce due to erratic rainfall and climatic conditions. Chloride and sulphate in ground water increase due to municipal and industrial waste dumped on the ground surface. Elevated concentration of chloride (Cl^-) and sulphate (SO_4^-) in surface and ground water are common in all countries, and can serve as indicators of ground water pollution. We have to characterize the most prevalent natural and anthropogenic sources of chloride and sulphate in ground water and explore techniques that could be used to identify their source. There is an urgent need for additional solid-waste management capacity sites in many parts of developing countries. Current design, operation, closure, and post-closure activities for sanitary landfills do not guarantee sufficient public health and environmental protection of the groundwater resources near a landfill. While in the past, sanitary landfills have almost without exception contaminated ground waters in the vicinity of a landfill. Due to scarcity of hand, to many urban localities, people never mind having residents nearby a landfill site. Significant changes must be made in the approach used for landfill of metropolitan solid wastes. Chloride and sulphate may be taken as critical parameters in assessment of ground water quality.

Keywords: ground water, chloride, landfill, sulphate, waste**.**

1. Introduction

The impact of leachate on groundwater and other water resources have attracted a lot of attention worldwide because of its awesome environmental significance. Leachate migration from waste sites or landfills and the release of pollutants from sediment (under certain conditions) pose a high risk to groundwater resource if not adequately managed. Ground water is getting polluted due to various human activities such as solid-waste landfill sites arising out of municipal and industrial activities. While the temporal changes have been attributed to dilution and concentration phenomena governed by climatic factors, the spatial variations in the geochemical characteristics of groundwater appeared to be related to pollution due to effluents from the nearby industry (Pawar *et al.* l998).

Chloride ion Cl^-, sulphate ion SO_4^{-2}, nitrate ion NO_3, and carbonate ion CO_3^{-2} occur as anions in groundwater. Sulphate comes in water may be due to natural sources as well as anthropogenic sources. Vinyl chloride concentrations from monitoring-wells indicate the extent of contamination of ground water from PVC-sludge wastes.

Rain water and melted snow that infiltrated through contaminated soils and rock fractures flushed leachate into ground water aquifers.

2. Importance of chloride and sulphate

An extensive amount of chlorides is added in ground water receiving municipal waste, farm drainage, piggery wastes and sewage effluent. The sewage effluent to water sources is bound to increase the chloride concentration in ground water. Chlorides are habitually present in water in the form of sodium chloride. These impart a salty taste to water. The taste may be objectionable to several consumers. It would point towards the possibility of organic pollution of a water source. Chlorides coupled with sodium bring to bear salty taste, when its concentration is more than 250 mg/1.There is no identified authentication that chlorides constitute any human health hazard. For this reason, chlorides are generally limited to 250 mg/1 in supplies intended for public use (IS 14543:2004). In many areas of the world where water supplies are scarce, sources containing as much as 2 000 mg/1 of chloride are used for domestic purpose, once the human system becomes adopted to the water. It can also promote corrosion in concrete by extracting calcium in the form of calcite. Magnesium chlorides in water generate hydrochloric acid after heating which is also highly corrosive and create problems in boilers.

The concentration of chloride ion in the groundwater, soil water, and river water near landfills to trace

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movement of contamination in soil to see infiltrations of leachate plume from sanitary landfills into the ground. Chloride in groundwater is obtained by measuring soil water in soil cores (Mizumura 2003; Ikem *et al.* 2002). Groundwater protection schemes, supported by detailed investigations, provide hydrogeological information for landfill site selection. They are used to identify areas where landfills should normally be excluded and areas where they are less likely to pose a risk to groundwater. The groundwater protection responses outlined here require that new landfills should not generally be developed on regionally important aquifers.

Developers of landfills should have regard to both the resource potential and the vulnerability of the underlying and adjacent aquifers. The groundwater protection responses combine both of these factors in a matrix which facilitates rational decisions on the acceptability or otherwise of a landfill from a hydrogeological point of view. The risk in the direction of chloride and sulphate groundwater from a landfill of waste is mainly influenced through the nature of waste, leachate composition, the volume of leachate generated, the groundwater vulnerability; the proximity of a groundwater source, the value of the groundwater resource, the landfill design in addition to the landfill operation and management practices. In general, the pollution threat is furthermost in source protection areas and on regionally imperative aquifers. The topsoil and subsoil, depending on their type, permeability and thickness, play a critical role in preventing chloride and sulphate groundwater contamination and mitigating the impact of many potential pollutants. They act as a protecting filtering layer over groundwater.

Numerous studies were undertaken in a study area to determine the effects of sewage-sludge disposal on the ground and surface water quality, to determine the fate of chloride and sulphate from sludge leachate. The result of investigations reveal that a large source of contamination exists in the soils of the study area owing to increased concentrations of chloride and sulphate because of sewage disposal (Tindall *et al.* 1994).

As a result of the investigation of the site, a potentially huge source of contamination remains in the soils in both buried and ploughed disposal areas due to increased concentrations of chloride and sulphate because of sewage sludge application. There is a need for continual monitoring of ground water to evaluate the long-term effects of waste disposal on water quality and to provide a background and database for ascertaining environmental impacts on surface and ground water quality of potential future sites from sewage sludge disposal (Tindall *et al.* 1994).

Guidance presented in these responses should be used to assist in the selection, design and management of landfill sites, and is based on the preventive principle. The concept of risk management should be used in the decision-making process for the selection of new landfill sites. In addition, the examined saline water intrusion is another source of sulphate and chloride contamination that occurs only in coastal areas (Panno *et al.* 2006). Influence of dyeing and bleaching industries increased the chloride level of ground water and made it not fit for irrigation purpose (Senthilnathan *et al.* 1999)

James A. Tindall *et al.* (1994) studied the effects of sewage-sludge disposal at the lowry sewage-sludge-disposal area Colorado, on the ground and surface water quality and to determine the fate of nitrate and chloride from sludge leachates. They also studied the potential for additional leaching from the disposal site area concentration of chloride and nitrate which were used as indicators to determine whether wells were affected by sewage-sludge leachate. These ions are very soluble, background concentrations are small, and they were present in large concentration in the applied sewage sludge. A relationship of concentrations of mean chloride to mean nitrate for all the wells in the land disposal of municipal sewage sludge was found. The result of investigations at these rival indications show that a potentially large source of contamination remains in the soils in both buried and ploughed disposal areas due to increased concentrations of nitrogen and major ions because of sewage sludge application. There will be a need for continual monitoring of ground water to evaluate the long-term effects of disposal on water quality and to provide a background and database for ascertaining environmental impacts on the surface and ground water quality.

Panno *et al.* (2006) have characterstics and studied the identified Na-Cl sources in ground water quantification of sulphate in water as a simple matter but, identifying the sources of sulphate can be problematic. To solve ground water and surface water contamination problems, it is first necessary to identify contamination sources. Numerous approaches have been used to identify some sources of sulphate in natural water. The purpose of this investigation was to characterize the natural background concentrations of sulphate-associated halides in meteoric and shallow ground water, the chemical composition of likely natural and anthropogenic sources of Na and Cl, to determine which geochemical and isotopic techniques would be the most effective for identifying the natural and anthropogenic sources of chloride and sulphate contamination in ground water and surface water.

Sulphate ions have been precipitated in hydrochloride medium with barium chloride to form barium sulphate crystals of a uniform size; light by the precipitate has been measured. The sulphate ion is one of the most important anions occurring in natural waters. It is of importance in public water supplies due to its cathartic effect upon humans when it is present in disproportionate amounts. For this reason the secondary standard for sulphate is 250 mg/L in waters intended for human consumption. Study on sulphate is important in both public and industrial water supplies because of the tendency of waters containing appreciable amounts to form hard scales in boilers and heat exchangers. Sulphate is of considerable concern because it is indirectly responsible for serious problems often associated with the handling and treatment of wastewaters. These are odor and sewer-corrosion problems resulting from the reduction of sulphate to hydrogen sulfide under anaerobic conditions.

The sulphate content of natural water is an important consideration in determining their suitability for public and industrial water supplies. The amount of sulphate in wastewater is a factor of concern in determining the magnitude of problems that can arise from reduction of sulphate to hydrogen sulfide. In anaerobic digestion of sludge and industrial wastes, sulphate is reduced to hydrogen sulfide, which is evolved with methane and carbon dioxide. If gas is to be used in gas engines, the hydrogen sulfide content should not exceed 750 ppm by volume. Knowledge of the sulphate content in the sludge or waste fed to digestion units provides a means of estimating the hydrogen sulfide content of the gas produced. From this information, the designing engineer can determine whether scrubbing facilities will be needed to remove hydrogen sulfide and what size of the units is required.

In the engineering and operation of treatment processes, especially anaerobic ones, knowledge of sulphate content can be of great importance. Sulphate-reducing bacteria generally compete out methanogens kinetically for organic carbon in anaerobic treatment of high-sulphate organic waste waters. Additionally, the sulfide produced can be toxic to methanogens. Thus, sulphate can have a highly adverse impact on mathanogenic process. In a similar manner, high sulphate concentrations in groundwater can hinder the natural anaerobic biodegradation of chlorinated solvents such as trichloroethylene and tetrachloroethene. Many organic compounds contain sulphur as sulphate, sulfonate, or sulfide. During anaerobic treatment of such wastes, complete utilization or dissimilation results in release of organically-bound sulphur as a sulphate ion, but under anaerobic treatment, sulphur is generally released as sulfide. The concentration of sources of chloride and sulphate in ground water are summarized in a table.

3. Collection of samples and procedures

Groundwater samples are collected quarterly in as month-long composites during single months in winter, spring, summer, and rainfall seasons. Groundwater samples were collected from confined sand and gravel aquifers. Water samples contaminated in the course of normal agricultural activities were collected from tile drains. Groundwater samples presumed to be contaminated with road salt were collected from shallow wells located within 10 to 20 m of salted roadways. Septic effluent samples were collected from the discharge points of private septic systems. Groundwater sampling was conducted from dry seasons, rainy seasons or monthly or fortnight bases.

The estimation of groundwater quality for individual aquifers uses self-potential logs for different aquifers in a major coastal sedimentary basin in south India. This involves establishing a relationship between resistivity of formation water and equivalent formation water resistivity for the system and then using analytical scatter diagrams between dissolved solids and various individual anions. (Gangudhara *et al.* 1990, U.S.P.A. 2000). The groundwater quality analysis using self-potential logs results obtained through these trend analyses and scatter plots for a multi-layered coastal system are compared with the chemical analyses of water samples and are found to be in close minimized uncertainties in the assessment of quality Gangudhara *et al.* 1990). Groundwater samples were collected from four wells at and near the Site (three monitoring wells and one residential well), to determine the concentrations of wastewater-affected "emerging contaminant" compounds (U.S.P.A. 2000).

The landfill operations ceased on landfill Superfund sites the carcinogen vinyl chloride monomer (VCM) has persisted in the site ground water at concentrations in places greater than 100 ppb. These values are significantly above both drinking water standards (>MCL of 2 ppb) and lifetime excess cancer risk from exposure since birth (>0.024 ppb). Sources for VCM are landfill wastes (PVC-sludge) and effluent from an on-site transfer station. Persistence of VCM concentrations is the result of leachate generation, mostly from multi-source wastes in the vadose zone, with subsequent infiltration into the regional aquifer.

Increases in VCM concentrations (new leachate generation) alternated with decrease in VCM concentrations (infiltration without leachate) in a cyclic fashion, during this 20-year period (Jacobs *et al.* 2006).

4. Environmental factors

4.1. Groundwater monitoring – suggested approach

Presented below is a summary of a suggested approach for establishing a groundwater monitoring program for landfills. (Fred Lee *et al.* 1991):

1. Conduct comprehensive, in-depth investigations of the geology and hydrogeology of the landfill area with particular reference to plausible transport of contaminants from the landfill to domestic or other water supply aquifers. It is essential that a good understanding of the flow paths and rates be developed before the groundwater-monitoring program is developed. The typical approach of arbitrarily placing one well up gradient and three wells down gradient of the landfill should not be allowed.
2. Define the monitoring objectives, i.e. 95% detection of incipient contamination of groundwater by leachate from any point of leakage in the landfill.
3. Groundwater contaminated by leachate at the objectives of the monitoring program considering both horizontal and vertical transport of leachate-contaminated groundwater.
4. Determine the frequency of sampling by assuming the time of traversing the zone of Capture of the monitoring wells based on groundwater velocities in the vicinity of the wells.
5. Collect and set aside funds from disposal fees that will be needed to operate and maintain (including well replacement) the groundwater monitoring system forever.
6. Utilize individuals who are highly knowledgeable in groundwater monitoring data review associated with the particular type of landfill being monitored, i.e. municipal solid-waste landfill, to review the groundwater quality data as it is collected.

Typical concentrations of sources of chloride and sulphate in groundwater

Sl. No	Occurrence	Reference	Typical maximum concentration in ppm	
			chloride	sulphate
1	Evaluation of hydrogeochemical parameters with Spontaneous potential logs	Radhakrishna T. Gangadhara rao, 1990	199-Lab test 323-Logs	50-Lab test 165-Logs
2	Municipal Solid-waste management: Long-term public health and environmental protection	G. Fred Lee *et al.* 1991	2000	1000
3	Human impact on regional groundwater composition through intervention in natural flow patterns and changes in land use	P.P. Sehot *et al.* 1992	290	349
4	Effects of land disposal of municipal sewage sludge on fate of nitrates in soil, streambed sediment, and water quality	James A. Tindall *et al.* 1994	300	*ND
5	Sugar-mill effluent at sonali, Mahastra, India	Pawar *et al.* 1998	352 .0	62.40
6	Dyeing and bleaching industries, Tirupur, India	Senthilnatan and Azeez 1999	3545	*ND
7	Amended record of decision Himco dump Elkhart, Indiana	U.S. Environmental Protection Agency,2002	Vinyl Chloride 0.7 J- 0.9 J μg/l	154,000 μg/l
8.	Agriculture and pesticides	Sharma *et al.* 2001	480	*ND
9	Groundwater quality characteristics near two waste sites in Ibadan and Logos, Nigeria	Ikem *et al.* 2002	300	40
10	Chloride ion in groundwater near disposal of solid wastes in landfills	Kazumasa Mizumura 2003	35 (River)	
11	Persistence of vinyl chloride in ground water at the wood lawn landfill superfund site, northeastern Maryland, USA, Environmental	Alan M. Jacobs *et al.* 2006.	250 ppb- VCM	*ND
12	precipitation, vadose zone water, uncontaminated and contaminated ground water, Midwestern United States (USA)	Panno *et al.* 2006 Precipitation septic effluent Animal waste Illions Landfill leachate Sea water	0.3 5620 1980 6170 18,800	*ND

*ND – not detected

4.2. Selected groundwater remedy and long-term monitoring – a case study on Himco Dump Site, USA (USPA 2000)

The aim of the work was design and complete groundwater investigation on Himco Dump Site (USA) to determine the contaminant concentration, rate and extent of all detected contaminants. The investigation will include the vertical characterization of the contaminants to optimize the placement of the additional long-term monitoring wells in the residential buffer zone area. One residential well to the east of the landfill noted 1, 2-dichloropropane contamination slightly above the standards. The Amendment calls for provision of a municipal water supply to the surrounding area. It is believed that the 1976 closure of the landfill, the 1992 landfill drum removal, and the 2004 enhancement of the existing landfill cover, coupled with the monitoring requirements stated Amendment are sufficient to address the contamination. Establish a long-term groundwater monitoring program to monitor the future groundwater conditions from all of the monitoring wells associated with the landfill including the newly-installed wells. The purpose is to determine if the groundwaters are not exceeded which would trigger the need for connection to the municipal water supply beyond the buffer zone.

If at any time the groundwater monitoring program indicates the possibility that contamination from the landfill is migrating beyond the presently known location, the potential need for additional alternative water supplies will be evaluated and an appropriate response action will be implemented.

Monitor all the groundwater-monitoring wells associated with Himco Dump for a minimum of 10 years; quarterly monitoring for the first two years. Samples are collected from all of the groundwater-monitoring wells. Water quality parameters (human effective compounds) have been analysed. Based on the results, groundwater-monitoring frequency may be decreased to semiannually for the next three years. The monitoring results will be evaluated to aid in predicting contaminant trends, and to evaluate seasonal effects. At the time of the five-year review (Superfund requirement for all the Sites where waste remains on-site), the groundwater long-term monitoring requirements will be reassessed to determine continued frequency and duration at that time. At each 5-year review, or earlier if necessary, EPA in consultation, will evaluate the following criteria to determine the need for more or less of remedial measures:

1. Groundwater results collected during the previous monitoring period to determine trends in contaminant concentrations, if any.
2. Effectiveness of the source control measures to prevent contaminant migration beyond the downgrading boundary.
3. Potential for contaminants in the groundwater to meet or exceed performance standard triggers level.

Additional measures may be necessary if an evaluation of the above criteria indicates that concentrations in the groundwater have not decreased; and source control measures do not meet the performance standards. Implement institutional controls with deed restrictions or utilize other institutional controls, which prohibit any future groundwater use, and prohibit the installation of any new private groundwater wells in the Site vicinity.

5. Remedial techniques

Depending upon the volume and characteristics of a contaminant, several techniques are available. The remedial techniques (Khan 2005) classified as follows:

1. Physical methods – excavation, soil washing, soil vapor extraction, etc.
2. Thermal methods – incineration, desorption, vitrification, etc.
3. Chemical treatment – chemical stabilization.
4. Bioremediation – in-situ biotreatment, ex-situ biotreratment, ex-situ slurry biodegradation, root zone treatment, etc.

5.1. Physical treatment

5.1.1. Excavation and removal:

This is a simple method suitable where volume of soil to be treated is small. The contaminated soil is excavated and disposed away from the site on a secured landfill. Important consideration in this method are the type of soil, type of contaminant and location of the area.

5.1.2. Soil washing

The soil may be washed in situ to remove a contaminant. A leaching agent may be added to water and a pressure gradient is maintained. Water for washing is allowed to enter the soil by constructing horizontal galleries or boreholes. The leachate is then intercepted or pumped out for treatment. This technique is good for nonhalogenated volatile organics with good soil permeability but is not suitable for clays. In the exsitu method, the excavated soil is removed and washed in a container. The water may enter from the top and collected at the bottom for its treatment before it is finally disposed off. The washed soil may then be replaced to its original position.

5.1.3. Soil vapor extraction

In this method air flow is generated through a well creating a pressure gradient. The air removes volatile components from the vadoze zone. This technique is especially good for halogenated, volatile and fuel hydrocarbons. The techniques are not suitable if air permeability is low or when carbon content is high or temperature is low.

5.3. Thermal treatment

5.3.1. Incineration

Thermal treatment is especially suitable for remediation of contaminants in the vadoze zone. The soil may be excavated and heated at a high temperature in the presence of oxygen, at about 1000–1500 °C. The organics are destroyed and the volatile fraction is removed. However,metals are not contaminants including fuel hydrocarbons. Clay or rock fraction should be removed from the soil before applying heat.

5.3.2. Thermal desorption

In these techniques, the excavated soil is subjected to a low temperature and the volatiles are collected for a separate treatment at high temperatures, halogenated volatiles and hydrocarbons are destroyed.

5.3.3. Vitrification

In this technique, heat is applied to the contaminated soil causing a melt which moves downward. It mobilizes the organics and destroys the volatiles. For in-situ vitrification, large graphite electrodes are inserted in the soil in a grid pattern (say 10 m × 10 m grid). A high electric current is applied resulting in the generation of heat which fuses the material. After the site/soil is cooled, the final material is inert. The technique is good for a long-term stability but consumes a large amount of energy.

5.4. Chemical treatment

Chemical treatment can also be carried out in situ or ex situ. These are essentially stabilization techniques which have been extensively developed. The contaminated soil is mixed with a binding material to reduce mobility of contaminants. Suitable binding materials include lime (for clays) cement (for sands) and thermoplastic binders. Thermoplastics binders are available in a variety of trade names. Protection may be required for soils with a high content of oil, grease or surfactants. Stabilization techniques are suitable for sludges or slurries contaminated with inorganics. These are not very effective for clays or for soils with a high organics, sulphate or chloride content.

6. Suggested remedies for solid-waste landfill site:

The following measures have been recommended for the protection of groundwater. Lining waste disposal and waterproofing the base of the lagoon (i.e. effluent storage ponds) and the streambed to prevent infiltration of the effluent. Treating the effluent to meet the standards established by local and international standards for releasing waste into the stream. First, if the regulatory agencies wish to persist with trying to keep solid wastes dry, then the landfill must be lined, capped, and maintained for as long as the wastes represent a potential for groundwater contamination in such a manner as to prevent such a contamination. It is expected that the duration of required landfill maintenance activities will be forever since municipal solid wastes contain a variety of highly toxic heavy metals, non-degradable organics and salts that will be available to be leached from the waste exposure to moisture.

7. Conclusion

On the basis of chloride and sulphate analysis of groundwater it is possible to establish that solid waste dumping site is a source of pollution of groundwater in the area. In most of countries groundwater is the major source of drinking-water supply. The efforts are focused on locating the groundwater reservoirs to satisfy drinking water needs and the quality aspect is often neglected. The solid waste-dumping site without environmental precautions may lead to serious health problems in the area. Many of these water-supply sources are unfit for human consumption. Water-quality management is an issue that must be given top priority. Well owners were educated on the implications of inadequate well protection from storm water/runoffs and sitting wells near waste sites or septic tanks. The measures are to be place to help curtail the disastrous effects of leachate migrations into groundwater include laws on discharge and disposal of wastes especially industrial wastes; new and better designed waste sites. The need for environmental education, adequate regulations and proper management of waste sites by the governmental agencies. Launching public-awareness programs and convincing the authorities to undertake groundwater protection measures.

Reference

Amended record of decision Himco dump Elkhart, Indiana. 2002. Report prepared by U.S. Environmental Protection Agency, Region 5, Chicago, Illinois.

Fred Lee, G.; Anne Jones, R. 1991. Municipal solid waste management: long-term public health and environmental protection, in *Workshop on landfills and groundwater quality NWWA National Outdoor Action Conference*, Las Vegas, Nevada, 5–40.

Friedman, G. M.; Mukhopadhyay, P. K.; Moch, A.; Ahmed, M. 2000. Waters and organic-rich waste near dumping grounds in the New York Bight, *International Journal of Coal Geology*, 325–355.

Gangadhara, R. T. 1990. Evaluation of hydrogeochemical parameters with Spontaneous potential logs, *Journal of Hydrology*, 245–257.

Ikem, A.; Osibanjo, O.; Sridhar, M.K.C.; Sobande, A. 2002. Evaluation of Groundwater quality characteristics near two waste sites in Ibadan and Logos, Nigeria, *Water, Air and Soil Pollution* 140: 307–333.

Khan, I. H. 2005. *Textbook of Geotechnical Engineering*. Prentice-Hall of India limited. New Delhi. 411 p.

Jacobs, A. M.; Amin, I. E.; Fisher, O. N. 2006. Persistence of vinyl chloride in ground water at the wood lawn landfill superfund site, northeastern Maryland, USA, *Environmental Geology*, 254–262.

Marini, L.; Canepa, M.; Cipolli, F.; Ottonello, G.; Zuccolini, M. V. 2001. Use of stream sediment chemistry to predict trace element chemistry of groundwater. A case study from the Bisagno valley (Genoa, Italy), *Journal of Hydrology*, 194–220.

Mizumura, K. 2003. Chloride Ion in Groundwater near Disposal of Solid Wastes in Landfills, *Journal of Hydrologic Engineering* 8(4): 204–213.

Njitchoua, R.; Dever, L.; Fontes, J. Ch.; Naah, E. 1997. Geochemistry, origin and recharge mechanisms of ground waters from the Garoua Sandstone aquifer, northern Cameroon, *Journal of Hydrology* 190: 123–140.

Panno, S. V.; Hackley, K. C.; Hwang, H. H.; Greenberg, S. E.; Krapac, I. G.; Landsberger, S.; O'Kelly, D. J. 2006. Characterization of Na-Cl sources in ground water, *Ground Water* 44(2): 176–187.

Pawar, N. J.; Pondhe, G. M.; Patil, S. F. 1998. Groundwater pollution due to sugar-mill effluent, at Sonai, Maharashtra, India, *Environmental Geology* 34: 151–158.

Pujari, P. R.; Deshpande, V. 2005. Source apportionment of groundwater pollution around landfill site in Nagpur, India, *Environmental Monitoring and Assessment* 111: 43–54.

Ritter, W. F.; Chirnside, A. E. M. 1995. Impact of dead-bird disposal pits on groundwater quality on the Delmarva Peninsula, *Bioresearch Technology*, 105–111.

Sabanayagam, R.; Selvakumar, M. 2000. Hydrogeochemical investigation of ground water around Korattur-Ambattur area, in *Tiruvallur District, Tamil Nadu, UGC state conference on Ground Water Exploration Techniques*, 182–187.

Sehot, P. P.; J. van der Wal. 1992. Human impact on regional groundwater composition through intervention in natural flow patterns and changes in land use, *Journal of Hydrology* 134: 297–313.

Senthilnathan, S.; Azeez, P. A. 1999. Influence of dyeing and bleaching industries on ground water of Tirupur, Tamilnadu, India, Bulletin of Environmental Contamination, *Toxicology* 62: 330–335.

Sharma, H. C.; Kumar, Sh.; Kumar, A.; Sharama, N. 2001. Ground water quality of phreatic aquifer in Tari belt of Udham Sing Nagar Distr*ict, Journal of Applied Hydrology* 14(4): 10–15.

Sing, O.; Rai, S. P.; Kumar, V. 2002. Ground water quality assessment for irrigation in Jammu and Kathua Districts, XV: 9–19.

Tindall, J. A.; Lull, K. J.; Gaggiani, N. G. 1994. Effects of land disposal of municipal sewage sludge on fate of nitrates in soil, streambed sediment, and water quality, *Journal of Hydrology* 163: 147–185.

Venkateswara, R. N.; Malaini, B. H.; Nageswara Rao, K. 2003. Ground water quality in the changing urban and industrial environment of Visakhapatnam city, *Journal of Applied Hydrology* 16(3): 46–51.

CHLORIDŲ IR SULFATŲ MAŽINIMO POŽEMINIAME VANDENYJE ŠALIA SĄVARTYNŲ PROBLEMOS

G. Venkatesan, G. Swaminathan

Santrauka

Rajonuose, kur paviršinio vandens dėl kritulių nepastovumo ir klimatinių sąlygų nepakanka, yra pakilęs požeminio vandens, naudojamo drėkinimui, gėrimui, pramonėje, lygis. Dėl komunalinių ir pramoninių atliekų sąvartynų požeminiame vandenyje padaugėja chloridų (Cl^-) ir sulfatų (SO_4^-). Jų koncentracijų padidėjimas paviršiniame ir požeminiame vandenyje dažnas visose šalyse, tuo galima remtis kaip požeminio vandens taršos indikatoriumi. Turime apibūdinti labiausiai paplitusius natūralius ir antropogeninius chloridų ir sulfatų šaltinius, teršiančius požeminį vandenį, ir ištirti metodus, kuriuos galima būtų taikyti šaltiniams nustatyti. Daugelyje besivystančių šalių būtinos papildomos atliekų tvarkymo vietos. Dabartinis komunalinių atliekų sąvartynų projektavimas, eksploatavimas, uždarymas ir atkūrimas negarantuoja pakankamos požeminio vandens išteklių apsaugos sąvartynų įtakos zonoje gyvenančių žmonių sveikatos ir aplinkos atžvilgiais. Praeityje komunalinių atliekų sąvartynai, beveik visi be išimties, teršė požeminį vandenį toje teritorijoje. Dėl patirties stokos daugelyje urbanizuotų teritorijų nekreipta dėmesio į gyvenančius netoliese. Reikšmingi pokyčiai turi būti padaryti dėl sąvartynų, kuriuose šalinamos didmiesčių atliekos, tvarkymo. Chloridų ir sulfatų kiekiai gali būti laikomi kritiniais parametrais požeminio vandens kokybei vertinti.

Reikšminiai žodžiai: požeminis vanduo, chloridai, užkastos atliekos, sulfatai, atliekos.

УМЕНЬШЕНИЕ ХЛОРИДОВ И СУЛЬФАТОВ В ПОДЗЕМНЫХ ВОДАХ ВБЛИЗИ СВАЛОК

Г. Венкатесан, Г. Сваминатган

Резюме

Потребляемость подземной воды для полива, питья, промышленных нужд увеличена в тех районах, в которых поверхностной воды недостаточно из-за непериодических осадков и климатических условий. В таких водах количество хлоридов и сульфатов оказывается увеличенным из-за коммунальных и промышленных отходов на свалках. Увеличение концентраций хлоридов (Cl^-) и сульфатов (SO_4^-) в поверхностных и подземных водах – явление, часто наблюдаемое во всех странах. Этот фактор может рассматриваться как индикатор загрязненности подземной воды. Авторы статьи ставили целью охарактеризовать наиболее распространенные естественные и антропогенные источники хлоридов и сульфатов, загрязняющих подземные воды, и исследовать методы, которые могут применяться для очищения таких источников. Во многих развивающихся странах необходимо оборудование дополнительных мест для отходов. Современные способы проектирования, эксплуатации, закрытия и открытия новых мест свалок не гарантируют достаточную защиту источников подземных вод в зоне свалок относительно здоровья людей и охраны окружающей среды. Особое внимание должно уделяться свалкам, на которые вывозятся отходы из больших городов. Хлориды и сульфаты могут использоваться в качестве критических параметров для оценки качества подземных вод.

Ключевые слова: подземные воды, хлориды, свалки, сульфаты, отходы.

G. VENKATESAN is a lecturer in the School of Civil Engineering at SASTRA University, India and research scholar at department of Civil Engineering at National Institute of Technology, Tiruchirappalli, India. He has been involved in teaching, research and industrial experience for the past 11 years. His research includes environmental geotechnology, solid waste management, landfill design and irrigation water management techniques.

Dr. G. SWAMINATHAN is a Professor in the Department of Civil Engineering at National Institute of Technology, Tiruchirappalli. He is a life member of IEI and ISTE. He has been involved in teaching, research and consultancy activities for the past 30 years. His research includes water quality modeling, waster water treatment methods, EIA and biological process of waste water.