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Environmental hazard accompanying the liquid waste storage in the mass

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Environmentálne riziko pri ukladaní kvapalných odpadov do horninotvorného masívu

Although the liquid waste storage is environmentally safe, the injection process can be potentially accompanied by failures, resulting in some negative environmental impacts.

This paper discusses the problem of environmental hazards related with failures of the injection installment on the surface and underground. The surface failures are most frequently related with sewage and waste pits, injection pumps, systems for physical and chemical processing of waste before injection, pumping pipelines, and wellhead in the injection well. The most common failures of the underground parts are: failures of pumping columns, sealing packer, casing and the cement layer in the angular space.

Key words: *liquid waste, njection process*

Introduction

Injection of sewage and liquid waste, produced during the completion and exploitation of hydrocarbon deposits, into depleted oil and natural gas strata and hydrogeological structures is the most efficient ways of their utilization. Although this method is considered to be environmentally safe, failure may occur during injection. This may have a negative impact on some elements of the environment [6]. Complications and failures may occur both at the surface and in the underground part of the injection installment.

The surface breakdowns are most frequently related with the failure of liquid waste pits, pumps, systems for physical and chemical treatment of liquid waste, pumping pipelines and wellhead in the injection well. Underground breakdowns are most frequently related with the failure of pumping columns, sealing packer, casing and cement layer in the annular space.

The deposition of waste in the rock mass may also result in the contamination of the water and ground environment, being a consequence of migration of the injected waste beyond the storage structure. The migration of waste may take place through fractures and discontinuities in the form of, e.g. faults, tectonic windows in the onlying strata, etc. The intensity of flow of waste beyond the structure may be assessed on the basis of manifestations observed in observation wells as well as with the use of simulators of the contamination migration.

A quick advancement of science and technology enables to limit the risk of occurrence of these failures and their consequences. However, the applied technical and technological solutions are not fully reliable and cannot guarantee that no such event takes place at all. Therefore, it is necessary to monitor the environment in the direct vicinity of the place where liquid waste is injected to the rock mass.

Soil, ground, surface- and groundwaters – potential hazards

During the regular exploitation of a liquid waste injection equipment, the ground, soil as well as surface and groundwater may get contaminated as a result of leaking the injection gas pipeline, wellhead or the storage pits. These hazards also appear during the maintenance, fixing operations and the closing of the installment. The risk can be minimized if works are carried out in line with the technological schedules.

The failure risk can be minimized by:

- Proper technology of performance, the use of materials which do not chemically interact with the ground,
- Constant control of the pressure drop in pumping pipelines,
- Periodic geochemical monitoring of soil over the pipeline,
- Periodic tightness tests of the pipeline.

An actual environmental hazard of soil may only appear during construction earthworks and the maintenance of the pipeline. However, owing to the characteristic of this transformation, i.e. the

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short time of realization and the easiness of the remediation, they may be treated as marginal and environmentally safe.

In the case of leaking storing or technological pits, contaminations may only appear within embankments. All liquid waste storing pits should be disposed in earth embankments, the geometric parameters should ensure that all the volume of gathered waste has been admitted. The area of the embankment, should be lined with a geomembrane from inside as it protects the liquid waste penetration to ground and groundwaters.

A significant hazard for groundwaters appears when the injection equipment is leaking. The injected waste may penetrate to the onlying useful groundwater horizons and mineral deposits. Leaking the well may be caused by a mechanical or a corrosion damage to the casing and cement plug, sealing the annular space between the casing and the well wall. This risk can be eliminated by the monitoring of technological, reservoir and physicochemical parameters of the injected waste (Fig. 1). The waste injection process should be completed before reaching the original pressure in the depleted deposit, and in the case of injection to aquifers, before reaching the maximal injection pressure calculated from a mathematical injection model.

The physicochemical character of waste which is planned to be injected, should be controlled on the basis of laboratory analyses [3]. The following data should be registered and listed during the liquid waste injection:

- Quantity of liquid waste injected to the rock mass,
- Type of liquid waste and source of its origin,
- Time of injection (date, process duration),
- Parameters of injected liquids.

With such data it will be possible to evaluate the degree to which the free space has been filled with the waste and to make a detailed plan of further injection.

Hazard to the atmospheric air

Owing to the fact that the injection itself is performed in a closed system, the liquid waste injection to the rock mass is not accompanied by emissions to the atmosphere. One of sources of the emission of the surface equipment are liquid waste pits. This is the case when highly compressible vapours with, e.g. a hydrocarbon admixture, are store there. Two types of emission from storage pits can be considered:

- „little breath" – the emission from valves of degassing storage pits as a result of daily oscillations of external temperatures,
- „big breath" – the emission accompanying the filling of the pits, when the hydrocarbon vapours accumulating over the liquid phase are expelled through the degassing valve.

The magnitude of emission of storage pits will depend on:

- quantity of utilized waste,
- frequency of filling the pits,
- volume of the storage pits,
- type of stored waste.

The composition of vapours in the storage pits will mainly depend on the chemical composition of liquid waste admitted for the utilization.

To limit the emission of waste, novel technical solutions should be employed for providing a full hermetization of waste in the storage and re-pumping equipment.

The waste emission to the atmosphere may potentially take place during tests and measurements conducted in the injection wells, during the replacement or the maintenance of specific elements of the installment or technical utility.

Acoustic emission

According to the authors' papers about the noise emission [3, 4, 5, 6], the noise emitted by the liquid waste injection installment shall not exceed admissible standards for housing areas during the day and night. The only noise may periodically appear from pumps, driving engines and the means of the transport delivering the waste. It can be reduced by using a “silent” equipment. In the case of noise hazard, the operating equipment should be cased or screened.

Environmental hazard in failure situations

The most frequent causes of failure are:

- wrong localization of the injection installment in respect to the housing and industrial objects, other technical infrastructure and the natural objects,
- uncontrollable forces of nature.
- Incorrect activity of man during the exploitation and in the post-production situations,
- Physicochemical properties of injected substances,
- Incorrect technological operations in the well and absorptive strata.

The ground and water environment is most hazarded in a failure situation. During a breakdown, the liquid waste will not migrate at distances thanks to double-coated pits, the collective anti-spill tray with a sealed bottom and escarps with a geomembrane and automatic system of monitoring of the injection process.

Tightness check up of injection wells

The tightness of a well with the injected liquid waste is mainly influenced by the technical equipment of specific casing columns and the cementation method. A good design should account for geological drilling conditions and a designation of the well. It should create favourable conditions for drilling to a required depth.

For determining optimal technical drilling conditions, it is recommended that the following elements were accounted for in the process of designing the casing and drilling string:

- Stability of rocks assessed from the view of rock slide and goafs formation, and caverning of the walls;
- Temperature in the well;
- Permeability of rocks;
- Formation fluid pressure;
- Presence of places and zones of lost circulations, where drilling complications may occur;
- Presence of water-bearing, brines, oil and natural gas layers formation parameters reservoir rock typical for a given structure, type and frequency of interbeddings in soft rocks, and the angle of inclination of a layer.

Casing should provide a suitable diameter of the well, isolation sealing of drilled rocks to the disable penetration of liquid waste from one layer to another. The strength of specific casing columns makes it possible to dispose of installments and utilities which will protect the environment against leakages.

Monitoring of tightness of absorptive layers

In the course of injection of liquid waste to the rock, a mass migration beyond the planned injection zone (geological structure) is possible. The housing space for the liquid waste can be monitored by checking out the water level in the observation wells as well as by the reconnaissance and the detailed surface analyses of gas content in the soil air, which are injected to the rock mass or accompany the injected waste. Monitoring of the water level in the observation wells is very important as the waste migrating in absorptive horizons change the hydrogeological parameters of the surrounding rock mass [8].

The observation wells, drilled at various depths, are recommended in the area where the liquid waste is injected, Fig. 1. The following measurements can be made:

- Pressure and changes of water level,
- Gas monitoring,
- Geophysical measurements in wells to check out a gas saturation level and the chemical composition of rear waters.

More detailed measurements can be made:

- Neutron logging for detecting a gas beyond the casing,
- Temperature logging.

The observation of pressure in the observation wells drilled to the first water-bearing horizon, closest to the absorptive strata, is very important. Initially, the migration of gas or liquid waste from absorptive layers manifests in a higher water level in the observation wells; after passing through the observed water-bearing layer, the wellhead pressure increases.

Monitoring of absorptive layers tightness on the basis of geochemical analyses

Apart from technical problems related with the construction and the exploitation of open waste storages in the rock mass, it is crucial to safeguard a safe and reliable exploitation of the storage. The biggest hazard for the environment and human health is related with the operation of landfills of waste in depleted hydrocarbon deposits or water-bearing structures. This is mainly connected with a potential migration of gases or liquid waste to the surrounding elements of the environment as a result of leakages from the geological structure.

In the case of migration of waste with volatile hydrocarbons, an explosive mixture may be formed. Explosions may result in the destruction of buildings, technical infrastructure and the fires. The presence of high concentrations of volatile hydrocarbons in the soil air may have a negative influence on the process of vegetation. Besides, methane emissions to the air contribute to the global warming effect [11].

The main objective of the geochemical monitoring is finding uncontrolled gas migrations as well as the identification of sources and pathways along which the deposited gases migrate. Then, the results of monitoring enable undertaking efficient measures of eliminating hazards and so the failure situations.

Monitoring of water-bearing horizons in the area of an underground waste storage

The local monitoring of water around underground waste storages lies in recognizing and inspecting (on a regular basis) its influence on the ground and water environment. A correct monitoring should encompass measurements and samplings in a set observation network, as well as laboratory analyses made in congruence with methodics recommended by the Polish Environmental Inspection and possibly the guidelines of the EU Council project establishing a water policy for EC countries (Directive no. 85/337/ECC; Directive no. 96/62/EC; Directive no. 97/11/EC).

Monitoring of groundwaters should enable to obtain data, on the basis of which it will be possible to:

- Determine the state and trends of changes of groundwater quality in the surrounding of the underground waste storages,
- Predict hydrochemical effects caused by the underground waste storage,
- Modify the scope of analyses and tests,
- Formulate conclusions enabling making decisions on closing or limiting the negative environmental impact of underground waste storages on the water environment.

A properly designed and implemented local monitoring of waters should be based on a thorough knowledge of local geological and hydrogeological conditions. Accounting for the liability of the monitored water-bearing layer to contaminations is vital [1, 2]. These conditions also decide about the depth at which filters are applied to the observation wells, the density of measurement stations and the frequency of logs.

Having disposed the filters correctly, it is possible to collect representative water samples for determining representative physicochemical indices of stored substances. The recognition of the range of contamination will significantly depend on a proper distribution of the observation wells, as well as on accounting for the direction of water flow and their hydraulic gradient [9]. Assessing the extent of contamination in detail can be done only on the basis of hydrochemical background of groundwaters. The results of groundwater sampling are also sensitive to the quality of the observation wells.

Observation wells

The basic task of observation wells is detecting possible leakages of stored substances to absorptive horizons. The possible “escapes” of substances stored in the rock mass can be caused by technical breakdowns of equipment, expected during the years of injection.

The planned design of observation wells and their localization should enable systematic observations and measurements in water-bearing strata, within the rock mass overlying the absorptive layers. Observations in wells should be made quarterly [10]:

- measurement of water table in the well,
- sampling of filtered water sample for the physicochemical analysis and checking out the changes of chemistry,
- owing to the high salinity and frequently non-mixing character of waters in the well, the water samples should be collected at a specific depth with a specialist probe [7, 10, 11]. Chemical analyses should be made by one laboratory, following the same methodics.

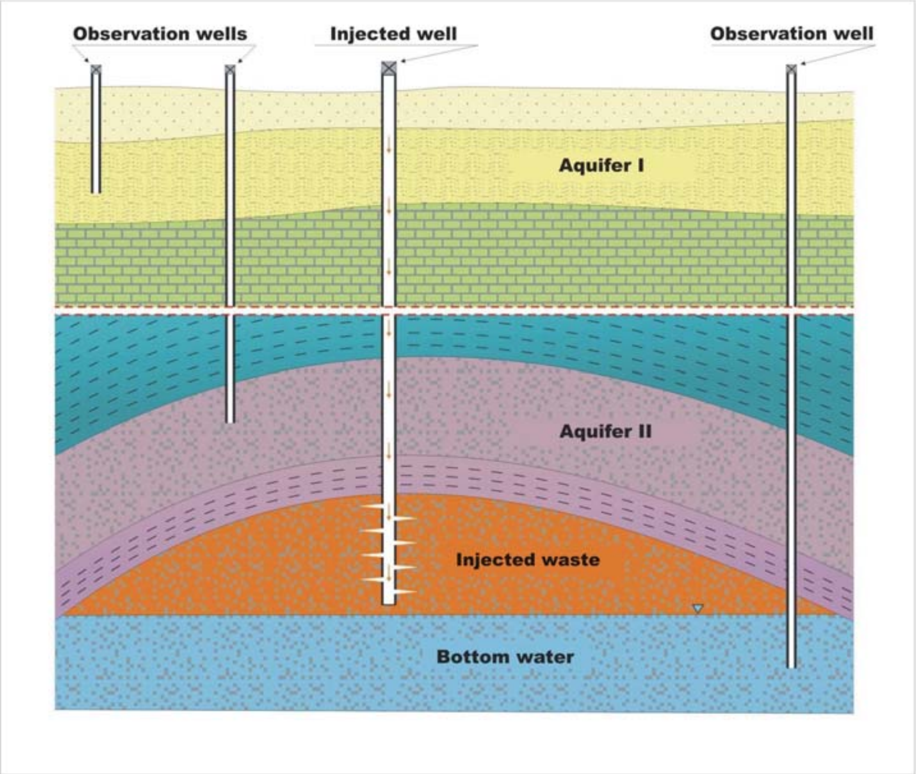

Fig. 1. System of observation wells with an injected well.

Conclusions

1. For protecting the ground-water environment against a toxic contamination by substances in a liquid waste, all surface installments should be localized on the area sealed with geoembranes, and the pits should be disposed in special embankments.
2. For eliminating the negative environmental impact of underground liquid waste storage, all technological, reservoir and physicochemical parameters of the injected waste should be monitored on a regular and constant basis.
3. For limiting emissions to the atmosphere from surface installments, new technological solutions should be applied as they make hermetization of waste circulation possible in the storage and re-pumping systems.
4. For limiting the noise emission, a low acoustic power equipment should be used.
5. For controlling the tightness of underground liquid waste storage, a periodic geochemical and hydrochemical monitoring is recommended.

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References

[1] Bourdet, D., Gringarten, A., C.: Determination of Fissured Volume and Block Size in Fractured Reservoirs by Type Curve Analysis. *SPE Paper 9283, 1980.*

[2] Britt, L., K., Jones, J., R., Pardini, R., E., Plum, G., L.: Reservoir description by interference testing of the Clayton Field. *JPT, May 1991, p. 524-577.*

[3] Macuda, J.: Badanie zmian chemizmu wód podziemnych w rejonie składowiska odpadów przemysłowych. *AGH Uczelniane Wydawnictwa Naukowo-Dydaktyczne. Wiertnictwo, Nafta Gaz, 2005 R. 22/1.*

[4] Macuda, J., Zawisza, L.: Monitoring środowiska gruntowo-wodnego w rejonie likwidowanych kopalń. *Materiały Szkoły Eksploatacji Podziemnej 2006 : Szczyrk, 20–24 luty 2006.*

[5] Macuda, J., Zawisza, L.: Techniczne uwarunkowania składowania odpadów płynnych w górotworze metodą otworową. *AGH Uczelniane Wydawnictwa Naukowo-Dydaktyczne, Wiertnictwo, Nafta, Gaz, 2006 R. 23/1.*

[6] Macuda, J., Nagy, S., Zawisza, L.: Ecological Aspects of Underground Gas Storag (UGS) Development and Eksploitation. *5th International Symposium on the reclamation, Treatment and Utilization of Coal Mining Wastes & 3rd Conference on Environmental and Mineral Processing. Part II. 10 - 13 September 1996, Ostrava - Poruba Czech Republic.*

[7] Rogowska, Kwas, R., Macuda J.: Estimation of impact of industrial landfills on groundwater. *Sankt-Peterburgskij Gosudarstvennyj Gornyj Institut (Tehniceskij Universitet).Zapiski Gornogo Instituta, t. 167, nr 2, 2006.*

[8] Siemek, J., Zawisza, L., Macuda, J.: Cel i metody pomiarów tła geochemicznego węglowodorów na obszarem koncesyjnym i w jego otoczeniu. W Ocena i możliwości wykorzystania wyrobisk górniczych likwidowanych kopalń węgla kamiennego na podziemne magazyny gazu i paliw. *Praca niepublikowana, GIG Katowice, 2003.*

[9] Theis, C., V.: The relationship between the lowering of piezometric surface and rate and duration of discharge using groundwater storage. *Trans. AGU (1935), p.519.*

[10] Zawisza, L., Macuda, J.: Modelowanie zmian jakościowych wód podziemnych w zlikwidowanej kopalni węgla kamiennego „Grodziec”. *IV międzynarodowa konferencja Techniki Urabiania 2005, Kraków–Krynica.*

[11] Zawisza, L., Macuda, J., Nagy, S. i in.: Klasyfikacja wgłębnych struktur geologicznych pod kątem możliwości składowania odpadów w górotworze metodą otworową. *Praca niepublikowana, PG Kraków, 2005.*