GEOLOGO-GEOCHEMICAL MONITORING OF INFRASTRUCTURE 
AND CONSTRUCTIONS PLACED AT THE AREAS OF 
UNDERGROUND GAS STORAGES

A. P. Zubarev

Russia
ABSTRACT

Geologo-geochemical monitoring of underground gas storage (UGS) areas is a system of both regular observation for estimation of environmental conditions and geotectonic, and analysis of nature processes which occur in the UGS areas. The purpose of monitoring is a timely revealing and control of these processes for securing the non-breakdown UGS exploitation. In Russia there is a modern up-to-date system of UGS, containing more than 30% of natural gas consumption. The average daily production of Russian UGS amounts to 450-470x10^6 m^3, and at a pick production amounts up to 580 x10^6 m^3 per day. The gas storage system includes 24 UGS evenly placed around Russia. The works of gas volume audit, securing of hermetic conditions, geoecological monitoring are performed being based at results of regular geophysical well and surface investigations. This created system of regular observation by geological, geophysical monitoring pursues the following:

- Estimation and prognosis of ecological situation of UGS area
- Control of the contaminant utilization
- Data acquisition of current conditions of environment elements and neotectonic processes, revealing of active geodynamic zones and zones of disintegrated rocks.
- Definition and scale estimation of interconnected influence in environment-UGS system.
- Creating of corporative base of geoinformation system (GIS) at a united methodological and spatial basis.

Methodology of geologo-geophysical monitoring conducting, based on consistent performing of geological, geophysical and geochemical works, such as seismic, electric (near-zone electric field establishment) radon-toron, underground soil hydrocarbon survey, gravimetry, well seismic tomography, well investigation by gamma-ray, acoustic, impulse neutron, gas-dynamic, magnetic-impulse logging. Also hydrogeochemical works conducted in a frame of system work of reservoir fluid investigation aimed to control of hermetic conditions of reservoirs and wells (cementing, clutches, casing, tubing, packer etc.).

So, the up-to-date geochemical and geophysical methods allows securing the reliability and safety of UGS exploitation. Geological and technological models, created by geophysical and production data are the effective tools for optimization the well and UGS on the whole exploitation, allowing also preventing accidents, or taking timely measurement to localize and eliminate the possible accident.
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Geologo-geochemical monitoring of underground gas storage (UGS) areas is a system of both regular observation for estimation of environmental conditions and geotectonic, and analysis of nature processes which occur in the UGS areas. The purpose of monitoring is a timely revealing and control of these processes for securing the non-breakdown UGS exploitation. In Russia there is a modern up-to-date system of UGS, containing more than 30% of natural gas consumption. The average daily production of Russian UGS amounts to 450-470 \times 10^6 \text{m}^3, and at a pick production amounts up to 580 \times 10^6 \text{m}^3 per day. The gas storage system includes 24 UGS evenly placed around Russia. The works of gas volume audit, securing of hermetic conditions, geoeological monitoring are performed being based at results of regular geophysical well and surface investigations. This created system of regular observation by geological, geophysical monitoring pursues the following:

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Methodology of geologo-geophysical monitoring conducting (Fig. 1), based on consistent performing of geological, geophysical and geochemical works, such as seismic, electric (near-zone electric field establishment) radon-toron, underground soil hydrocarbon survey, gravimetry, well seismic tomography, well investigation by gamma-ray, acoustic, impulse neutron, gas-dynamic, magnetic-impulse logging. Also hydrogeochemical works conducted in a frame of system work of reservoir fluid investigation aimed to control of hermetic conditions of reservoirs and wells (cementing, clutches, casing, tubing, packer etc.).

Integrated interpretation of high sensitive geophysical investigations (such as 2-sound impulse neutron gamma method, high sensitive thermometry, barometry, noise-level measurement), conducted in wells of different types (production, observing, piesometric, devouring) allows obtaining the trustworthy and detailed geotechnological information along and between the wells. Further it opens the prospect of reliability of effective UGS exploitation as a united system, being exploited under alternative pressure gradient while injection-production cycles. An example of effective thickness and gas-water contact definition by the well logging results is shown at Fig. 2.

Statistic processing and spatial correlation analysis of GIS data around 22 UGS showed, that the main source of geochemical influence at a natural water is the wells of prospecting and production types at all stages of their lives (drilling, workover, production/injection), the plants of gas preparation and production sewage stock areas. Such parameters as gas-saturated thickness, gas volume, prognoses of optimal injection/production regime, diagnose of well technical conditions (elements of constructions, annular space, out-of casing fluid migration and accumulations) are revealed by geophysical works, conducted in a frame of system works at all UGS of JSC “Gazprom”.

Projecting of optimal system for UGS creation and exploitation as well as inculcation of effective measurements and technologies stays in straight dependence of degree of UGS gasdynamic system study. The main informational source of reservoir filtration capacities is gas-dynamic well investigations. They are widely used in production practice, being the base direct methods which give knowledge of the processes taking place in reservoir while injection/production.
The trustworthiness and representation of obtained geologo-geophysical information are stipulated by reliable methodology and interpretation. Methodology of gas-dynamic investigation of UGS wells is analogous on the whole to the gas-dynamic investigation of gas-field wells (variants of stable and unstable production).

The gas-dynamic investigation result of unstable well production, the gas, or water debit (injective capacity) -pressure interrelation is defined, as well as geothermal characteristics of filtration resistance, the pressure losses in tubing, the well potential debit. As a result, the permeability of near-face zone of reservoir is defined, skin-factor of the well and a perfection of reservoir opening in the well.
Fig. 1. Methodology of geologo-geophysical monitoring
<table>
<thead>
<tr>
<th>SP, GR, SGR</th>
<th>Component model</th>
<th>Well diameter, mm</th>
<th>INGR, score rate</th>
<th>C/O logging</th>
<th>Fluidic component model</th>
</tr>
</thead>
<tbody>
<tr>
<td>APS</td>
<td>Kp ws-SER</td>
<td>150</td>
<td>21000</td>
<td>C/O</td>
<td>Kp total %</td>
</tr>
<tr>
<td>GR 1, mcrh</td>
<td>Kp og-SER</td>
<td>300</td>
<td>1200</td>
<td>Ca/Sl</td>
<td>Kp og-SER %</td>
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<tr>
<td>GR 2, mcrh</td>
<td>Sand</td>
<td></td>
<td></td>
<td></td>
<td>Kp og-current %</td>
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<tr>
<td></td>
<td>Silt</td>
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<td></td>
<td>Limestone</td>
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**Fig. 2.** Gas-saturated reservoir definition by geophysical well investigation

**Fig. 3.** Injection interval definition by fibro-optical sensors
Geothermal methods of well investigations allow solving the wide spectrum of geological-technical tasks at UGS. They are the definition of phone level of exploiting reservoir, control of cyclic exploitation, the well technical control etc. These tasks are solved in complex of thermometrical methods and high-sensitive fibro-optical technology (FOT). Experience of FOT applying for control of the gas spreading direction while injection shows the effectiveness of this method. It allows simple (non-ambiguous) differential definition of gas saturated reservoirs, working thickness, non-hermetic intervals of casing or cover. The FOT diagram obtained while injection process is shown at Fig. 4, the temperature lowering opposite the layers points out to gas spreading directions.

Permanently improving geochemical methods of control play the important part in optimization of observation system. Geochemical methods allows to trace the dynamic of physical processes in a reservoir and adjusting water saturated area, interconnection of natural and injected hydrocarbons. They give the possibility to define if the gas belongs to accumulation of technical genesis or to natural pool, timely reveal the degree of near-face zone contamination, etc. Isotopic methods are important in deciphering many natural or technical processes. Mass-spectrometry methods of stable hydrogen/oxygen isotopes allows to define most precisely the genetic belonging of reservoir fluid.

Gas-geochemical investigation and undersoil geochemical survey are widely used at UGS. Their results (express-analysis of free or dissolved gas content, chromatographic gas analysis) reveal the sources of ecological contamination to take timely measurement to avoid the accidents.

The helium and radon-toron survey plays the important role in further improvement of geochemical methods. The helium and radon, having an unique permeability, allows revealing disintegrated zones, conducting the gas along with. These zones can be as of a new-tectonic character, as well shafts. In a first case the zones have a linear character and placed at the non-drilled territories. In the second case they have the isometric form and are necessarily placed near the wells or boreholes. The control of helium behavior allows at the earliest stages defining, for instance, reviving the some fracture, or arising some disintegrated zone after gas injection and pressure increasing, finding non-hermetic wells. Still more important is defining the radon/helium distribution at a UGS projecting stage: anomalies points to possibilities of gas leakages. This information helps to decide the question of an expedience of UGS creation at this area. The future is for these investigations.

Natural gases are interconnected with an underground hydrosphere, which contents the most full genetic information of the gas. Because of that hydrogeological investigations are the undividable part of technological processes of UGS creation and exploitation.

The high requirement is raised to quality of water bearing horizons separating. Geophysical estimation of cementing quality is divided into three categories: rigid, partial and absent cohesion with casing. The rigid category implies the presence of cementing absent intervals at a length less than the sound length. Intervals of bad contact with gap less than 35 mm are regarded belonging to the partial category.

So, the up-to-date geochemical and geophysical methods allows securing the reliability and safety of UGS exploitation. Geological and technological models, created by geophysical and production data are the effective tools for optimization the well and UGS on the whole exploitation, allowing also preventing accidents, or taking timely measurement to localize and eliminate the possible accident.
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