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Method of Underground Wastewater Disposal into Deep Horizons

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***Abstract* - The method of underground wastewater disposal into deep horizonsis related to the mining engineering and can be used in the design, construction and operation of the liquid effluents deep storage (i.e. waste landfill).This method enables the most comprehensive use of underground space with reliable localization of industrial effluents within certain boundaries and within a givenperiod of time. Any risk of contamination of overlying aquifers containing water that is suitable for drinking and industrial water supply is prevented because areas of the underground environment are located at significant depths and safely isolated by thick aquitards.Injection of the industrial effluents into water-absorbing reservoir is carried out by means of disposal wells both in continuous mode and intermittently by controlling reservoir pressure at the level less than hydraulic fracturing pressure.**

Key words: **absorbing (disposal) well, industrial wastewater, injection, water absorbing reservoir.**

I. INTRODUCTION

There are several methods of underground disposal of industrial waste. The most common ones are wastewater injection into the deep aquifers; waste disposal in artificially created capacities in the low permeable clay and saline rocks using a mechanical rock excavation, hydraulic fracturing, underground explosion, salts dissolving and others; disposal into the loose rocks of the thick aeration zones by usingsorptive capacity of rocks; waste disposal in the dead pits; and the use of certain types of waste water in the oil reservoirs water flooding [1].

II. METHODOLOGY

The method of underground disposal of liquid wastes by injecting through disposal wells into reservoir beds is the most appropriate approach among the methods listed above[2], [3]. The main criteria for the area selection are: the presence of aquifer orreservoir bed with sufficiently high adsorbing capacity;the necessity of reservoir bed to be reliably isolated from overlying and underlying water-bearing strata by impermeable layers(e.g. clay, chalky clay, hydrous sulphate of lime, clay stone, salt etc.),herewith the impermeable layer must to be thick throughout; the reservoir bed must not crop out or have anany connection with day water in the immediate vicinity(i.e. within a radius of 20-30 km); the presence of buffer aquifer over the reservoir bed; Administratively, the area for disposal of produced water into Carbonate deposits is located in the Western Kazakhstan and refers to Atyrau-Aktobe region (Fig.1). The big enough threat to the natural environment in oil & gas industry here represented byimproper methods of industrial waste water discharge, which afterwards is able to filter and migrate, it penetrates deeply into the underground hydrosphere and spreads polluting substances over considerable distances into Carbonate reservoir near Ak to be city.

Fig.1. Republic of Kazakhstan

Treatment technology is not developed yet for severely toxic and difficult to decontaminate industrial waste water neither abroad and in our country, therefore increasingly should be disposedinto deep horizons as most safe method. The territory of pre-Caspian basin is conducive for searching for deep carbonate aquifers for the disposal of industrial waste water [4]. The most promising place for the disposal of industrial waste water is the water zone of the First Carbonate Column (Fig.2). Experimental works takes place at Hanaloc and Akilmel oil deposits, to disposeindustrial waste water into the water zone of the First the Carbonate Column. Industrial waste water is a technological solution, resulted after oil purification, consisting from hydrogen sulfide and ethyl-, and metil- mer captanes, on the crude oil demercaptanization facility [5]. The main physical-chemical features of industrial waste water are: pH value =12.3; the density of it- 10200mg/dm^3; total lack of dissolved carbon dioxide and oxygen;the concentration of hydrogen sulfide is 0.640 mg/dm^3;the amount of dissolved substances (solids, TDS) is 11022 mg/dm^3; the content of suspended solids (colloidal particles, TSS) is 106 mg/dm^3;the amount of calcium and magnesium are 40.0 and 24.0 mg/dm^3 accordingly;the content of chlorides is 266 mg/dm^3;the content of sulfates is 365 mg/dm^3, hydrocarbons - 366 mg/dm^3, carbonates is 9780 mg/dm^3, phenols is 0.0189 mg/dm^3, petroleum products is 34.8 mg/dm^3,common iron is 2.13 mg/dm^3. The contents of heavy metals (Cd, Pb, Cu, Zn) are 0.0052 mg/dm^3, 0.0482 mg/dm^3, 0.0188 mg/dm^3 and 0.0198 mg/dm^3 accordingly.

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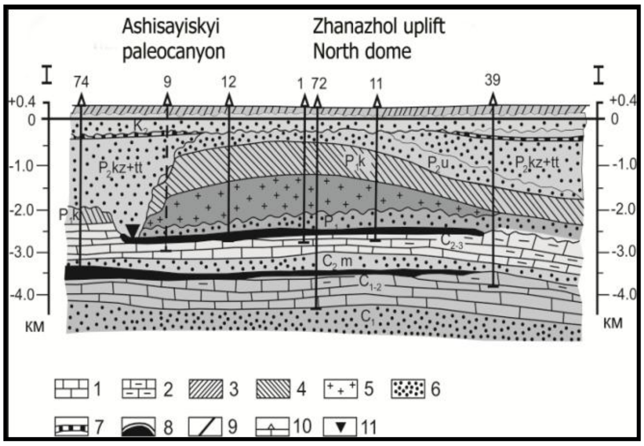
Fig.2. Regional geological profile section



1 – carbonate of Carbon System; 2 – dolomite of Carbon System; 3 – marls of Paleogene system and upper Cretaceous system; 4 – marls of Low Permian; 5 – salt of Low Permian; 6 – terrigenous deposits; 7 – coal; 8 – oil reservoirs; 9 – stratigraphic discontinuity; 10 – well; 11 – reservoir for injection(The First Carbonate Column).

The industrial waste water corresponds to the standards of governing document 39-01-041-81 "Methodology of predictive determining the quality standards of wastewater for water flooding of the new oil fields", where, in particular, the content of pumpable sludge solids up to 15-50 mg/dm3 and petroleum products up to 15-50 mg/dm3 [6]. According to the gathered experience, industrial waste water usually contains dissolved mineral salts, organic substances, particles and bacteria. Therefore, the chemical reactions occur while pumping the industrial waste water into the aquifer, which as a result cause sedimentation, release of heat and gas, etc. Together with the growth of the bacteria it can cause colmatage of porous absorbing part of the borehole hence lower the capacity. To prevent such occurrence, assessment of compatibility of industrial waste water from underground waters and aquifers, and special preparation of the industrial waste water for injection if necessary, is required. Assessment of the compatibility of the industrial waste water and the formation water complies with the industry standard 39-228-89 [7]. It compares the coefficient of permeability of rock samples measured before and after the interaction of injected water with reservoir water and rocks (considering also the process of precipitation of insoluble salts and sludge swelling clay particles). The experiments are carried out at the formation temperature and current pressure difference. The coefficient of permeability before and after the interaction of injected water with reservoir water and breed is defined by the Darcy equation (1):

$$Cperm = \frac{0.1Q\mu L}{tF\Delta P} \quad (1)$$

Where:

Q – Volume of water passed through the layer, cm^3;

t – Time of water filtration, s;

μ - Viscosity of water, mPa·s;

L – The length of the seam, cm;

F – the cross-sectional area of a reservoir, cm^2;

ΔP – the average pressure difference, MPa.

Set the increment coefficient of permeability (ΔCperm) models of rock formation element due to the interaction of the injected water with reservoir water and breed (2):

$$\Delta Cperm = Cperm - C'perm \quad (2)$$

where:

Cperm - the coefficient of permeability of the reservoir before the waters are interacted, mcm^2;

C'perm–is the coefficient of reservoir permeability after the interaction of formation and injected water, mcm^2.

Then calculate the absolute accuracy of determining permeability coefficient (ECperm). Injected water deemed compatible with reservoir water and strata if $\Delta Cperm \leq ECperm$ and, conversely, incompatible if $\Delta Cperm > ECperm$.

Examination of the compatibility of the water consists of the mixing the original types of waters in different ratios, storing them within a certain period of time and the weighting of the appeared sediment. To determine the compatibility, the filtered water was taken from the observation wells ##55, 132, 123, 405. Mixing was performed in volumetric ratio of 100: 0, 90: 10, 80: 20, 70: 30, 60: 40, 50: 50, 60: 40, 70: 30, 20: 80, 10: 90 and 0: 100 with filtered water from the line of pumping. Then samples were shaken during 4 hours, filtered through filter "Blue Ribbon" which was brought to constant weight, the sediment was dried at 110°C [8]. As a result of the above mentioned, due to chemical incompatibility of waters the sediment was formed. Below is presented chart as well as table showing result of chemical reaction products sedimentation (Fig.3 and Table 1).In order to obtain information about condition of groundwater, manufacturing monitoring is held through sampling of the observation wells and absorption wells. Sampling and analysis are carried out in accordance with the normative-methodical manuals applicable on the territory of the Republic of Kazakhstan [8], [9]. That provides maximum retention of salt and water gas composition. The volume of water required for the definition of substances, is selected depending on the method of analysis. The main disadvantages of mentioned method are related to inefficient use of underground space, caused mainly by excessively strict requirements for location of disposal sites. Solution of this problem is achieved by disposal of industrial effluents into water bearing strata. This approach involves selection of disposal area, construction of absorbing wells and injection of industrial effluents into water-containing areas of

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underground medium which are located at considerable depths. The necessary condition is a reliable isolation of the reservoir by thick confining layers (i.e. clay, chalky clay, hydrous sulphate of lime, clay stone, salt etc.).Industrial wastewater disposal into absorbing reservoir is carried out through adsorbing wells either in continuous mode or intermittently by controlling reservoir pressure at the level less than hydraulic fracturing pressure [10].

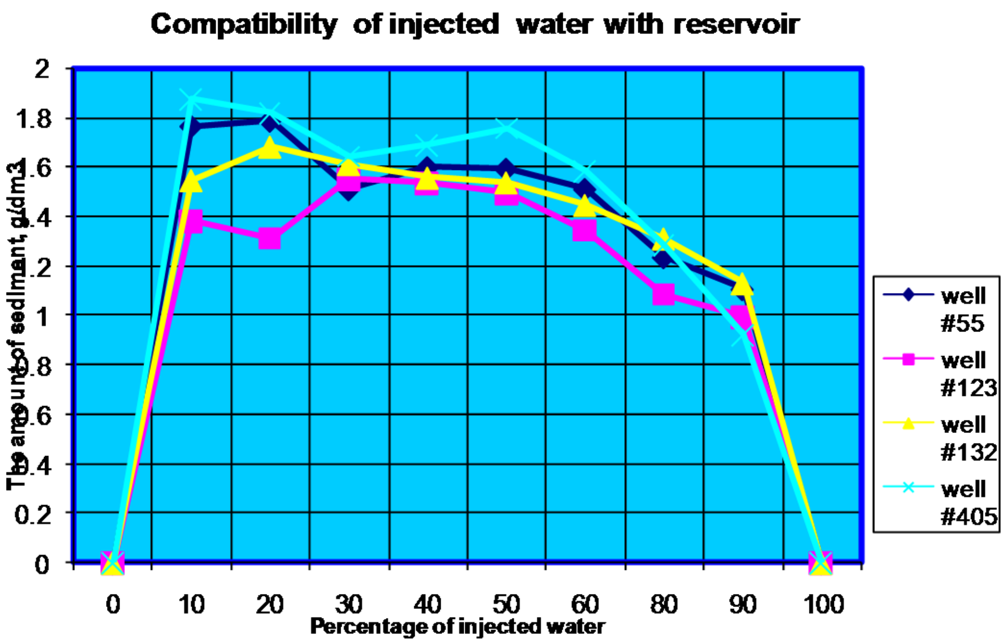

Fig.3. Research results

Table 1 - Compatibility of reservoir and injected water

Formation water	Injection water	Compatibilityofthewaters			
		Amount of sediment, g/dm^3			
		well#132	well #55	well #123	well #405
100	0	0	0	0	0
90	10	1.5479	1.7684	1.3889	1.8806
80	20	1.6835	1.7899	1.3165	1.8245
70	30	1.6129	1.5124	1.5583	1.6494
60	40	1.5581	1.6013	1.5397	1.6957
50	50	1.5389	1.5948	1.5012	1.7613
40	60	1.4476	1.5132	1.3499	1.5866
20	80	1,3122	1.2377	1.0912	1.2874
10	90	1.1310	1.1082	0.9984	0.9248
0	100	0	0	0	0
Maximumvalues		1.6835	1.7899	1.5583	1.8806

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This method has the following number of advantages and benefits (i.e. positive technical results) over existing methods of industrial wastewater disposal. The first advantage is location of wastewater disposal sites at considerable depth (up to 3000 m) and presence of the reliable insulating cover in the form of thick confining layer. In this case, compliance with the safe wastewater disposal requirements such as coverage of disposal area by weakly permeable strata and presence of a buffer horizon is not necessary because location of water-absorbing layers at significant depth is already the guarantee of safe disposal. The second advantage is carrying out wastewater disposal through working parts of absorption wells(e.g. filters, open hole or perforated intervals), which are located at significant depths within the reservoir rocks. Such a positioning of these working parts ensures the safety of disposal process during its realization and after its completion. After filling-in selected underground space with industrial effluents the recovering of natural sedimentation (i.e. water expelling conditions) occurs. In addition, the specified positioning of absorption wells' working parts allows using wells with different verticality deviation angles for the purpose of industrial wastewater disposal. This method of disposal is illustrated in the Fig.4. The well construction, facilities for the implementation of injection and elements of underground strata are presented in the Fig. 4 in the generilized form, where:

1 - Injection facilities, including pipes and pump;
2 - Injection station;
3 - ∅426 mm conductor casing;
4 - ∅324mm surface casing;
5 - ∅245 mm intermediate casing;
6 - ∅168mm production casing;
7 - Injection interval;
8 - Soft ground;
9 - Upper Cretaceous head water-bearing strata;
10 - Jurassic, Triassic and Upper Permian water-bearing strata;
11 - Upper regional confining bed;
12 - Main adsorbing horizon;
13 - Lower regional impermeable layer.

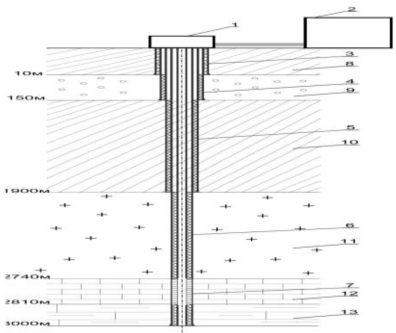

Fig.4.The scheme of wastewater disposal into deep horizons

As follows from Fig.4, the wastewater is preprocessed at the injection station 2. Then through the pipeline it is supplied by the pump 1 into the adsorbing well through the production casing 6, where the wastewater gets into the adsorbing horizon 12. The adsorbing horizon at the top and bottom is controlled by regional confining beds 11 and 13. For the purpose of reliability the well design provides for the following strings: the conductor pipe with a diameter of 426 mm which is lowered to a depth of 10 meters with the cementation up to wellhead in order to overlap recent unstable sediments and prevent a wellhead from dissolution by fluids 3; 324 mm diameter surface casing is lowered to a depth of 150 meter with installation of casing seat in the Upper Cretaceous deposits for reliable isolation of the water bearing strata, this casing 4 is cemented up to wellhead and equipped with blowout equipment; the intermediate casing string 5 with 245 mm diameter is lowered to a depth of 1900 m in order to overlap and isolate water-saturated beds and for installation of blowout equipment, it is cemented to the level of wellhead; the production casing 6 of 168 mm in diameter is lowered to 3000 meters designed depth and cemented to wellhead; injection intervals 7 are perforated within reservoir bed 12. The example of methodsproposed is given at the selected area of industrial wastewater disposal at the Hanaloc field in Aktobe region. The presence of regional aquifers there containing potable and industrial water, as well as abundance of tectonic disturbances, do not allow disposal of industrial wastewater in the shallow over saline sediments., but give great ability to dispose waste water subsalt strata. After completion actions in the well, the penetration degree is about 50%, i.e. $70m * 50\% = 35m$(Fig. 4). Likewise the rocks porosity of this area is 0.06, thus the volume of industrial wastewater that can be injected into this interval is $V = \pi * 0.06 * 1000^2 * 35m = 0.7 * 10^7 m^3$. The duration of continuous wastewater injection into this zone with flow rate of 1000m^3/day is 20 years.

III. CONCLUSION

In compliance with generally accepted technical rules of the industrial effluents disposal, in particular with such rules as high-quality construction of the adsorbing wells and injection of wastewater through them without formation hydraulic fracturing followed by vertical cracking, disposal at significant depths and others, the disposal into deep horizons proves to be reliable. In addition, reliability of this method is enhanced by the presence of natural regional confining beds.The proposed method can be used for the purposes of industrial wastewater injection into the deep depleted exploitation wells, namely into flooded zone of production reservoir bed.

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AUTHOR'S PROFILE

Lidiya Anichshenko was born in Russian Federation in 1955. Ms. Anichshenko graduated from Grozninskiy Oil Institute (Russia) in 1977 and earned Bachelor degree in mining engineering and hydrogeology there. In 2005 Lidiya completed post-graduate course at Institute of oil and gas (Atyrau, Kazakhstan). Afterwards in 2007 Lidiya obtained Master degree in oil & gas field, geology and reservoir engineering at Satpaev K.I. Kazakh-National Technical University (Almaty, Kazakhstan). At the present Ms. Anichshenko is working for degree of doctor at the same University.

Lidiya has 39 years of work experience in oil and gas sphere specifically in mine planning and design. She worked in private companies as well as in research institutes. Moreover Lidiya Anichshenko had foreign work experience of 3 years (Hague, Netherlands). At the present she works as Director in "Bolashak MunaiProject" Ltd (Almaty, Kazakhstan) engaged in mine planning and design. Since 2005 Ms. Anichshenko has worked on nearly 40 national and international projects regarding oil and gas reserves evaluation, calculation and supervision over industrial effluent pumping process etc. The most important projects concerns fields of TCO and Agip KCO in Kazakhstan.

From numerous publications of Lidiya Anichshenko the following important research papers may be distinguished: "Simulation of the produced Water Injection into Neocomian Deposits", "Underground disposal of manufacturing water as per the main effective method of industrial fluid waste recovery", and "Hydrogeology of Pricaspiy South-East". Lidiya owns two industrial patents for Method of industrial waste water injection into deep horizons - (21) 2013/1869.1 and Cleaning tool for exploitation and absorption hole filters (21) 2013/0090.1.

Andrey Anichshenko was born in Kazakhstan in 1991. In 2012 he earned Bachelor degree in petroleum engineering at Satpaev K.I. Kazakh-National Technical University (Almaty, Kazakhstan). At the present he holds Master degree in petroleum and gas engineering obtained in 2013 from University of Salford (Manchester, United Kingdom).

Andrey started his professional career in 2009 as wells operator in "ANACO" Ltd (Atyrau, Kazakhstan), then tried himself as driller assistant and handler of second category while having internships in oil and gas companies. For 3 years Mr. Anichshenko worked in "BolashakMunaiProject" Ltd as part-time petroleum reservoir engineer. Currently he is field support engineer in Nabors Drilling International Limited (Atyrau, Kazakhstan).

He has several course projects submitted in partial fulfillment of the requirements for the degree of Master of Science, namely "Produced water utilization into the deep horizons of Chimbulak field" (2013) and "The package of measures to increase efficiency of exploitation of Akshabulak reservoir" (2012). Andrey is co-inventor of industrial patent for Method of industrial waste water injection into deep horizons - (21) 2013/1869.1.

Mr. Anichshenko is member of International «Society of Petroleum Engineers» (SPE - 4113530) and «Institution of Gas Engineers and Managers» (IGEM).