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TO THE ISSUE OF IMPROVING QUALITY OF INTEGRATED ASSESSMENT OF IMPACT OF OIL AND GAS TECHNOGENESIS ON HYDROGEOSPHERE OF OIL FIELDS IN WESTERN SIBERIA

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A B S T R A C T

The study aimed to substantiate a new approach to improving the quality of integrated assessment of the impact of oil and gas technogenesis on the hydrogeosphere of oilfields in Western Siberia. The object of the study is the Apt-Alb-Cenomanian reservoir complex of some oilfields in Western Siberia. The main method is the matrix method of pairwise comparisons (the method of hierarchy analysis), which allows to establish a rating system for the analyzed objects. In this case, it allowed a comparative assessment of the degree of influence of oil and gas technogenesis on the state of the geological environment of the investigated water-bearing complex. Results obtained: comparative assessment of the degree of negative impact of oil and gas technogenesis on the underground hydrosphere of Krasnoleninskoye, Zapadno-Ust-Balykskoye, Megionskoye, Tevlinsko-Russkinskoye, Aganskoye and Kogalymskoye oil fields.

1. INTRODUCTION

Analysis and control of indicators of the condition of aquifer complexes during the development and operation of hydrocarbon fields is an integral part of subsoil use in all oil and gas producing regions of the world. Due to the increasing scale and diversity of anthropogenic impact on the natural environment, there are significant changes in the quality of groundwater horizons located both near the earth's surface and deep-seated oil and gas-bearing horizons, the consequence of which is the development of chain reactions and relatively irreversible changes in natural systems (Kholmirzaev & Akhmedov, 2020).

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At the same time, oil and gas producers face a number of problems concerning the need to safely dispose of the growing volumes of associated water produced at oil fields (Azizov et al., 2021; Kazanenkov et al., 2019; Filimonova et al., 2019; Fakhru'l-Razi et al., 2009). Assosiated waters are traditionally considered a waste product. After the associated water quality indicators are brought to the levels required by the legislation of the oil-producing country, their discharge into surface sources is potentially possible, but due to the significant volumes of associated water, as well as high amplitudes of fluctuations in the content of certain pollutants in different periods of field operation, it is often not economically feasible to carry out water treatment measures (Jakubowicz et al., 2022).

As part of managing recycled water volumes, researchers, environmental and expert government agencies have the following goals:

- reducing environmental risks to all components of the geologic environment (Wu & Tang, 2022; Clark & Berryman, 2017);
- increasing the efficiency of associated and waste water management while maintaining the trends of rational use of minerals (Filimonova et al., 2019; Azizov et al., 2021; Ferreira et al., 2015);
- development of high-tech service and engineering services for water resources management and reduction of unnecessary capital and operating costs (Kazanenkov et al., 2019, Aristov & Hoek, 2015);
- effective use of scientific developments in the documentation regulating water utilization (Ferreira et al., 2015; Li et al., 2021), but while maintaining a balance between increasing the informativeness of monitoring and the technological burden on the subsoil user associated with obtaining reliable information;
- improving the quality of quantitative assessment of the research object based on the use of methods of cumulative action of technogenesis factors (He et al., 2023).

The main tools for achieving the above objectives are:

- interdisciplinary approach in justifying solutions for wastewater utilization (Aristov & Hoek, 2015);
- creation of an effective system of criteria for eco-geological environmental safety during hydrocarbon production, including the management of utilized fluids (Gurioli et al., 2010; Shao et al., 2016), taking into account regional natural geological conditions, their heterogeneity and discreteness (Hooper et al., 2017; Zvonarev et al., 2019), as well as the resulting mutual influence of natural and anthropogenic factors in time (Sun et al., 2020; Jin et al., 2021; Clark & Berryman, 2017);
- the relative standardization of the process of assessing criteria, the transparency of the evidence for these assessments, and the control of the validity of the evidence used (Dai et al., 2021).

Researchers have comprehensively characterized the mechanisms and models of the response of the natural environment of hydrocarbon deposits to anthropogenic impact, which should be based on the development of approaches to the integrated assessment of the state of the object of study (horizon, complex). In general, the models represent a pressure-state-response logic bundle (Li et al., 2021) with a number of case-selected evaluation criteria (indicators) (Berger, 1997; Sun et al., 2020). Despite the fact that some progress has been made in studying the response of the natural environment to anthropogenic impacts, there are few studies devoted to assessing the quality of accuracy of the criteria responsible for recording the dynamics of the processes under study (He et al., 2023). Sun et al. (2020) note that the choice of assessment criteria should reflect the ecological state of the geologic environment both statically and dynamically. The selected indicators should have practical significance in the long term, as well as reliability, accessibility: directly or indirectly through calculation to ensure the index performance. In the system of assessment indices closely related criteria should be grouped to form different assessment levels that can fully reflect the processes of oil and gas technogenesis impact on the natural environment. Of course, the complexity of the described approaches is undeniable, as one must strive to handle and analyze the non-linear relationships between different impact factors while maintaining the integrity and hierarchy of the evaluation system (Chen et al., 2011). As noted by Jakubowicz et al. (2022) the system "injected water – formation water – reservoir rock" is characterized by a high degree of complexity, its modeling must consider all factors affecting the change in the physical and chemical properties of fluids, as well as a wide range of interactions between the individual components. In the presence of complex, long-term natural-technogenic systems, the interactions between factors may well be fuzzy and stochastic, making it difficult to accurately and quantitatively describe the assessment results (Zhang et al., 2021). To solve this problem, it is necessary to develop a suitable nonlinear multivariate data processing system and a "smooth" regional methodology for assessing the complex state of a natural site, which can solve the problem of uncertainty in the relationships between mutually influencing natural and man-made factors (Chen et al., 2011).

The current situation with surplus produced water in the Khanty-Mansiysk District of the Russian Federation is characterized by a constant increase in the volume of water to be disposed of. Over a period of about 10 years (until 2021), the total volume of utilized produced water at 16 injection sites was 196.2 million m^3 (Salnikova, 2021). Associated water is also used to maintain reservoir pressure in productive horizons, but the surplus produced is many times greater than the need to provide the reservoir pressure maintenance system.

The condition of the Apt-Alb-Cenomanian aquifer complex (AAC AC) according to the current regulatory documents is assessed only by a small number of indicators, including 6-component analysis (as a rule, once every six months) and detailed chemical analysis (once a year), hydrodynamic studies in water intake wells, assessment of the volume of produced water, measurement of formation water levels and pressures in the intertubular space of wells, as well as monitoring of the technical condition of wells.

Comprehensive assessment of the real state of the complex, the level of mutual influence of factors taking into account specific geological and hydrogeological conditions is a complex, multilevel study, requiring the work of scientists of different directions.

The purpose of the study was to provide an integrated quantitative assessment of the degree of impact of oil and gas technogenesis on AAC AC at a number of operating oil and gas fields using the method of hierarchy analysis (matrix method of pairwise relations). The factors selected based on the experts' opinion as the most informative criteria characterizing technogenic impact on AAC AC and having quantitative value were used as input data.

2. MATERIALS

2.1 General information on geological and hydrogeological conditions

In the course of the study the materials obtained during the assessment of groundwater reserves of AAC AC were analyzed for the purpose of their use in the systems of reservoir pressure maintenance of oil deposits, as well as within the framework of hydrogeological justification for the placement of excess associated waters. Six oil fields located in different parts of the Khanty-Mansiysk Autonomous Okrug (KhMAO) of the Tyumen Region of the Russian Federation were selected for analysis: Krasnoleninskoye (1), Zapadno-Ust-Balykskoye (2), Megionskoye (3), Tevlinsko-Russkinskoye (4), Aganskoye (5) and Kogalymskoye (6). Hydrogeological conditions of the deposits under consideration are determined by their belonging to the western, central and eastern parts of the West Siberian megabasin (Matusevich & Kovyatkina, 2010). AAC AC belongs to the upper part of the Mesozoic hydrogeologic basin (Figure 1).

Across the studied field areas, the average total AAC AC thickness varies from 721 to 831 m. The complex is composed of sandy-silty-clayey sediments of marine, coastal-marine and continental genesis. In the western part, the hydrocarbonate sodium type of waters prevails with a mineralization of up to 10 g/dm^3. In the central areas of the basin, the type of AAC AC waters changes to sodium chloride, and mineralization increases to 20-30 g/dm^3.

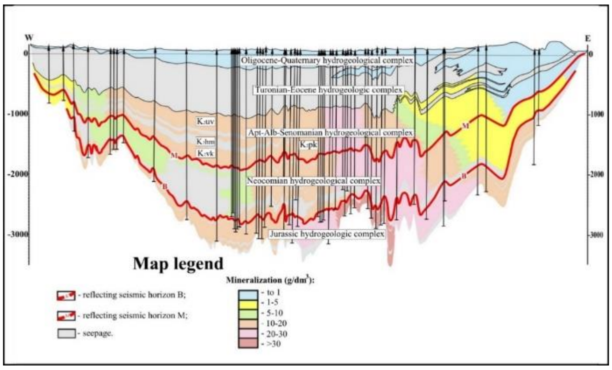

Figure 1. Schematic regional hydrogeological section of the territory of the Khanty-Mansiysk Autonomous Okrug

According to the oil and geological zoning, the fields under consideration are located in the Sredneobskaya oil and gas region, except for the Krasnoleninskoye field area, which belongs to the Krasnoleninsk region (Figure 2). Developed intervals of the field section of Surgutsk (Zapadno-Ust-Balykskoye, Tevlinsko-Ruskinskoe and Aganskoye fields) and Vartovskoye (Megionskoye and Kogalymskoye fields) oil and gas bearing districts are BV1, BV8 and BS10 formations of the Neocomian complex. In the area of the Krasnoleninskoye field (Figure 1) and productive are formations AC 1-3 of the Aptian and Yu 0-9 of the Lower and Middle Jurassic oil-and-gas bearing complexes.

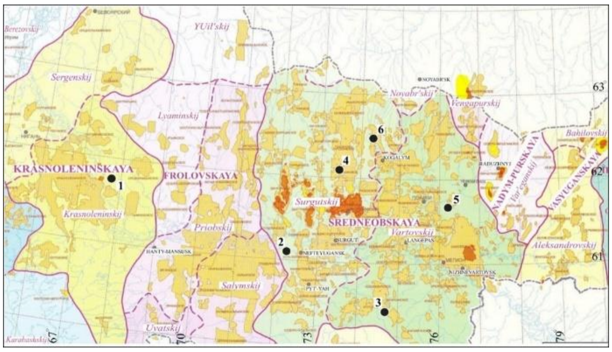

Figure 2. Map of petroleum geological zoning of the Khanty-Mansiysk Autonomous Okrug (Atlas "Geology and oil and gas potential…", 2004). Map legend: – oil and gas region boundaries; FROLOVSKAYA – name of the oil and gas region; – petroleum province boundaries; *Priobskij* – petroleum province name; – oil fields; – gas condensate deposits; – gas deposits; – border of Khanty-Mansiysk Autonomous Okrug; – inhabited locality; 1 – explored deposit

2.2 Input data and their justification for hierarchy analysis (matrix method of pairwise correlations)

The choice of deposits is conditioned by their significance as objects with high and long-term technogenic load on the underground hydrosphere. The western part of the Krasnoleninskoye field (1) has been developed since 1992, the eastern part since 1994; the Zapadno-Ust-Balykskoye field (2) was brought into commercial development in 2005; the Megionskoye field (3) in 1964; the Tevlinsko-Russkinskoye field (4) in 1986; the Aganskoye field (5) in 1973; and the Kogalymskoye field (6) in 1985.

The data selected from the list of quantitative indicators of technogenic impact on AAC AC controlled by subsoil users by the expert community of specialists are systematized for the specified fields. The community included experts in the field of environmental risks in hydrocarbon development, hydrogeology and field development. As the most stable and informative criteria of oil and gas technogenesis the following were chosen: accumulated volumes of associated water disposal into reservoir beds of AAC AC (from the beginning of utilization of excess associated water in AAC AC until the end of 2023), accumulated volumes of groundwater extraction from AAC AC (from the beginning of the reservoir pressure maintenance system at the field until the end of 2023), average values for 2023 of such parameters of associated water injected into AAC AC as: the amount of mechanical impurities, oil products, sludge from mixing of AAC AC formation water and injected associated water. The values of the above parameters, as well as some general characteristics of AAC AC are given in Table 1.

The choice of these parameters by the expert community is in line with the general tendencies of indicating their importance and sustainability in scientific publications on associated water utilization and oil flooding.

Table 1. General characteristics and input data for hierarchy analysis AAC AC technogenesis factors.

	Field					
Parameters	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
General information about AAC AC						
Bedding interval, m	990-1715	1033-1786	963-1658	1020-1851	997-1718	1018-1778
Average temperature, ^{0}C	52	43.25	50.9	43.65	42.95	41.6
Year of associated waters utilization start into the complex	2004	2005	2015	2023	2015	2017
Year of water extraction start from the complex for reservoir pressure maintenance	2003	2011	1967	1987	1974	1986
Selected parameters of oil and gas technogenesis affecting AAC AC						
Volume of produced water disposed in the complex, thousand m^3	15165.4	10715.1	16152	571.818	45920.8	75429.03
Volume of water extracted from the complex, thousand m^3	196.3	14709	33019	299272.6	65377.5	637.5
Mechanical impurities, mg/dm^3	168	67.4	27.7	7.5	54.5	11.5
Petroleum products, mg/dm^3	0.11	22.8	21.7	2.3	24.9	0.01
Precipitation during mixing of waters, g/dm^3	0.389	0.255	0.064	0.033	0.125	0.07

In the “injected water/formation water/reservoir rock” system the volumes of injected water undoubtedly play an important role, determining the scale of processes inside the absorbing horizon. In this regard, the choice of this parameter by experts as a significant one is quite justified. Also, formation water has been extracted from AAC AC for decades to maintain formation pressure in productive horizons, which further shifts the equilibrium in the water-rock system. Both described processes over time began to overlap with each other at all the considered fields (Table 1), forming a complex hydrogeological natural-technogenic system. The main features and characteristics of such systems of oil and gas bearing basins of Russia with technogenically altered hydrogeochemical, hydrogeodynamic and geotemperature regimes are described in the works of Kartsev & Nikanorov (1983), Matusevich & Kovyatkina (2010).

Control of values of such parameters as average content of mechanical impurities, oil products, sediment at mixing of AAC AC formation water and injected associated water are not less significant for maintaining injectivity, structural strength of rocks and AAC AC condition in general.

2.3 Mechanical impurities

The main means to improve the quality of produced water injected into AAC AC in terms of “mechanical impurities” is filtration before utilization. However, in many cases it is not enough, as in many oil fields, due to the presence of fine particles, suspended solids not captured by filters, as well as iron oxide deposits formed by contact with air (Jakubowicz et al., 2022). It is noted that while in high-permeability formations these impurities penetrate relatively freely into the formation, in low-permeability reservoirs there is an intensive contamination of the bottomhole zone with a significant reduction in its permeability. Maintaining injection rates leads to increased bottomhole pressures and formation of autohydraulic fractures (Fedorov et al., 2024). These processes occur due to the retention of mechanical impurities by the rock matrix due to multiple physical mechanisms: attachment by electrical forces, deformation of rocks at high injection pressures, formation of "bridges" by particles, diffusion processes, etc. (Vaz et al., 2017). In the problem of controlling the parameter "mechanical impurities" the importance of injection rate and injection pressures, and more precisely their changes are also pointed out by other authors (Ochi & Vernoux, 1998, Turbakov et al., 2022, Azizov et al., 2021). As noted by Turbakov et al. (2022), changes in pumping rate result in the release of colloids that may be located on pore walls, in pore channels, plugging interstices and in stagnant zones.

The presence of clay particles both in the injected water and in the composition of AAC AC rocks also plays an important role. The mineralogical composition of AAC AC rocks of the study area is characterized by an average content of clay minerals 17-20 %, with the share of kaolinite group minerals averaging 44 %. The negative influence of the presence of clay particles with unbalanced surface charge density and rather large specific surface area in the injected water on the pore space of the absorbing horizon is indicated in the work of Rosenbrand et al. (2014). He notes that these particles can form "bulky clusters" capable of clogging pore channels, unlike bulkier particles such as silica which generally have a weaker and more homogeneous (negative) surface charge distribution than lamellar clay particles. The accumulation of clay particles can subsequently lead to a continuous pressure increase in the injection well for a short period, a significant reduction in fluid flow channels, pore plugging, primarily in the near-wellbore space (Ochi & Vernoux, 1998; Valdes & Santamarina, 2007), in which the injection well cannot continue pumping (Rosenbrand et al., 2014).

2.4 Petroleum products

The content of petroleum products in AAC AC injected into the AAC AC is subject to control for various reasons. The first of which is the potential for contamination of fresh groundwater horizons, which are the target objects for domestic drinking water supply. This is possible not only in case of spills of oil-contaminated water on the surface, but also in case of breach of integrity of the annular space and probable vertical water flows from the absorbing horizon. The described situation is complicated by the state of the well stock in Western Siberia (Filimonova et al., 2020, Chertenkov et al., 2015). According to normative documents regulating associated water utilization in the Russian Federation, the maximum permissible content of oil products is 50 mg/dm^3. Subsoil users are obliged to comply with this agreement, but experts agree that current technologies for treating water for disposal cannot remove fine suspended oil particles and dissolved elements (Fakhru'l-Razi et al., 2009).

The second equally serious reason for the need to control the presence of petroleum products in injected water is their ability to acidify the formation as a result of microbial activity, formation of technogenic deposits and corrosion (Zuluaga et al., 2011).

And of course, the fact of influence of oil products content in injected water on filtration-capacitance properties of the reservoir remains important. According to experimental studies, even the smallest oil droplets can form an internal crust at a low rate of penetration into the pore space (Bennion et al., 2001). Also of interest are studies aimed at elucidating the nature of the effect on reservoir permeability of fluid input containing both mechanical impurities and petroleum products (Ochi & Oughanem, 2018): permeability reduction caused by oil droplets and solids together is more severe than each component separately. This is due to the fact that oil droplets are stabilized by rock particles, which contribute to the colmatation of pore channels (Azizov et al., 2021). This mechanism is also described in the study of : coating solids with resins and asphaltenes affects their attachment to the pore walls or promotes adhesion to each other, creating a "schmoo"-like substance that ultimately degrades the filtration-capacitance properties of the formation.

2.5 Sediment at mixing of formation and injected water

The mixing of different solutions, which are initially produced water and injected produced water that differ in dissolved electrolyte content, can cause either precipitation or dissolution of rock-forming minerals. The reactions between the rock and the injected water can be referred to as multicomponent ion exchange (Lager et al., 2008; Sorbie & Collins, 2010). A wide range of possible interactions in the system "injected water/natural water/field rock" does not always allow to correctly interpret the processes and their influence on the permeability of the downhole zone (Jakubowicz et al., 2022).

Sludge formation can be caused by changes in physical and chemical properties when mixing produced and injected water (e.g., changes in pH, redox potential, temperature, etc.) (Abbasi et al., 2020; Jakubowicz et al., 2022; Abukova et al., 2013). One of the factors having a decisive influence on dissolution/precipitation is temperature change (Jakubowicz et al., 2022; Salnikova, 2021; Mulyak et al., 2007), which is unavoidable, since separation of oil from produced water requires lifting to the earth's surface both in Western Siberia and in other regions, the temperature of injected water turns out to be much lower than formation water, even in the presence of special heating facilities. In case of mixing of AAC AC waters and formation waters of underlying productive sediments, despite their genetic similarity, we deal to a greater extent with sediment formation and, therefore, with possible development of pore space colmatation areas.

The difficulty of using the results of predicting the amount of sediment at mixing of formation and injected water is that mixing of water is usually reproduced (experimentally or mathematically) in given volume ratios without taking into account the real rates of advancement of injected produced water, lithological composition of rocks and their initial capacitive-filtration properties.

The choice of the group of the above-mentioned controlled parameters as the most stable factors of oil and gas technogenesis in our opinion is reasonable and suitable for realization of the method of hierarchy analysis (matrix method of pairwise relations) for the studied fields.

3. METHODOLOGY

The chosen method of hierarchy analysis (matrix method of pairwise relations), developed by the outstanding mathematician and business analyst T. Saaty (2008) is applicable to the analysis of the most diverse natural, technical and social systems. There has also been a sharp increase in the volume of review publications on the methodology under discussion in the last decade.

There are publications devoted to the use of the method directly to solve classification problems in the field of geology, mining and oilfield engineering (Adiat et al., 2012; Feizi et al., 2017; Kumar et al., 2014). Thus, the issues of predicting the most promising areas of search for fresh groundwater are solved, taking into account the difference in the spatial manifestation of the leading factors of their localization of freshwater in the subsurface of Malaysia (Adiat et al., 2012). A similar problem based on matrix pairwise matrix relation method has been solved for Durg district in Chhattisgarh state of India (Feizi et al., 2017). No less interesting is the example of using MPMR to search for calcic iron skarn deposits in central Iran. The use of geochemical geophysical, geographic data in one system allowed the most significant areas to be identified for prospecting, which was satisfactorily confirmed by prospecting work in three target areas (Feizi et al., 2017).

The method has gained popularity due to the following principal advantages: (1) taking into account the opinion of the expert community on the informativeness of the criteria used to describe the object, process or phenomenon under study; (2) matrix representation of pairwise comparison of the significance of criteria, which greatly facilitates the work of experts; (3) the possibility of operating only those criteria that have a stable response to the processes under study; (4) joint use of quantitative and qualitative criteria in the feature space (Vaidya & Kumar, 2006); (5) normalization of each parameter, which excludes the influence of the range of numerical values or gradations of manifestation of qualitative characteristics (Saaty, 2008); (6) the method is applicable to objects of any complexity and any level of study (Mogaji et al., 2015; Vaidya & Kumar, 2006).

The role of the expert community in determining the factor weights is based on the scale of relative closeness/dissimilarity of criteria: 1 – equal value (equal importance) of the factor; differences: 3 – moderate, 5 – significant, 7 – significant; 9 – complete; intermediate states between them are defined by corresponding even indices (Saaty, 2008). The requirements in the feature space are taken into account in terms of sufficiency, redundancy and consistency (Saaty, 2008).

The mathematical apparatus of the method is detailed in numerous literature, so it is not discussed here.

For each matrix of pairwise comparisons, the expert community was evaluated. In our case, it is represented by the opinion of 23 experienced specialists who expressed their opinion about informative possibilities of the selected factors for characterizing the impact of oil and gas technogenesis on the geoecology of the objects of study through a ballot assessment. The median expert judgment values were chosen to make inverse pairwise matrices.

The sequence and results of the method are partially reflected in Table 2.

4. RESULTS AND DISCUSSION

In accordance with the above results, the matrices of pairwise comparisons of factors of AAC AC environmental condition assessment for the specified fields of KhMAO were compiled. The matrix of pairwise comparisons of the selected factors based on the results of the collective expert survey is presented in Table 3.

In the course of the study we calculated the values of the local priority vector for the 5 most sustainable factors of oil and gas technogenesis mentioned above. For example, the matrix of calculation of the local priority vector of the factor “Volume of produced water disposed in the complex” is given (Table 4).

Table 5 presents the results of determining the global priority as a quantitative measure of the degree of oil and gas technogenesis development in the studied set of oilfield objects. For the studied objects it is maximum for the Kogalymskoye field (0.286), and further decreases in the following sequence: Aganskoye (0.245), Tevlinsko-Russkinskoye (0.138), Kamennoye (0.118), Zapadno-Ust-Balykskoye (0.113), Megionskoye (0.1).

Table 2. Operational sequence of implementation of the method of pairwise matrix hierarchy.

Sequence of method application.
1. Selection of the most stable factors of oil and gas technogenesis (described in the Materials section).
2. Compilation of matrices of pairwise comparison of the importance of the selected factors, determination of local vectors in accordance with the scale of relative importance justified by the author of the method (Saaty, 2008)
Based on expert assessments, matrices of pairwise significance of the selected factors were drawn up. By dividing the geometric mean for each row of the matrix by the sum of all geometric averages, the relative weight of each criterion in their weighted aggregate is found; in the aggregate, the normalized weight of the entire aggregate should equal 1.00 (Tables 3-5).
3. Evaluation of the consistency index (CI) for each matrix
Evaluation of the consistency index (CI) for each matrix through the values of its dimensionality (n) and the value λ_{max}, calculated by three mathematical operations: (1) finding the sum of each column of the matrix of pairwise comparisons, (2) multiplying the sum of the first column by the first component of the local vector, respectively, the sum of the second and subsequent columns of the matrix by the corresponding components of the local vector, (3) adding the obtained products For the matrix in question, n=5. IC=(λ_{max}-n)/(n-1) is calculated for all paired matrices. By the following procedure, they were correlated with the tabulated values of random consistency (RC) given in many reference books and publications on T. Saaty's method [6]. The partial of dividing IC and RC represents the sought-after consistency ratio (IC=IC/CC) and for a consistent set of expert opinions, the CR should be less than 0.1.
4. Determination of global priority as a quantitative measure of the degree of development of oil and gas technogenesis in the studied set of oilfield objects
Global priorities, calculated by multiplying local priorities by objects by those by factors, constitute the final quantitative assessment of the degree of oil and gas technogenesis development.

Table 3. Matrix of pairwise comparisons of selected factors for assessing the impact of oil and gas technogenesis on the geo-ecological state of the subsoil (based on the results of expert assessments).

Factors	**Volume of produced water disposed in the complex, thousand m^3**	**Volume of water extracted from the complex, thousand m^3**	**Mechanical impurities, mg/dm^3**	**Oil products, mg/dm^3**	**Sediment at water mixing, g/dm^3**	**Local priority vector**
Volume of produced water disposed in the complex, thousand m^3	1.00	3.00	5.00	5.00	9.00	**0.51**
Volume of water extracted from the complex, thousand m^3	0.33	1.00	3.00	3.00	5.00	0.22
Mechanical impurities, mg/dm^3	0.20	0.33	1.00	2.00	3.00	0.12
Petroleum products, mg/dm^3	0.20	0.33	0.50	1.00	3.00	0.10
Precipitation during mixing of waters, g/dm^3	0.11	0.20	0.33	0.33	1.00	0.05
TOTAL	1.84	4.87	9.83	11.33	21.00	1.00

Notes: matrix dimension – 5, random consistency – 1.12, λmax – 5.35, CI – 0.09, CR – 0.08

Table 4. Local factor priority vector "Volume of produced water disposed in the complex".

Field	**Krasnoleninskoe**	**Zapadno-Ust-Balykskoye**	**Megionskoe**	**Tevlinsko-Ruskinskoe**	**Aganskoe**	**Kogalymskoe**	**Local priority vector**
Krasnoleninskoe	1.00	2.00	0.50	3.00	0.20	0.14	0.07
Zapadno-Ust-Balykskoye	0.50	1.00	0.33	3.00	0.20	0.14	0.05
Megionskoe	2.00	3.00	1.00	0.33	0.20	0.14	0.07
Tevlinsko-Ruskinskoe	0.33	0.33	3.00	1.00	0.20	0.11	0.05
Aganskoe	5.00	5.00	5.00	5.00	1.00	0.33	0.26
Kogalymskoe	7.00	7.00	7.00	9.00	3.00	1.00	0.50
TOTAL	15.83	18.33	16.83	21.33	4.80	1.87	1.00

Notes: λmax – 6.46, CI – 0.09, CR – 0.07

Table 5. Calculation of global priority (as a measure of the impact of oil and gas technogenesis on the geo-ecological state of AAC AC).

Criteria	Volume of produced water disposed in the complex, thousand m^3	Volume of waters extracted from the complex, thousand m^3	Mechanical impurities, mg/dm^3	Petroleum products, mg/dm^3	Precipitation during mixing of waters, g/dm^3	Global priority as a measure of technogenic impact
	Local priority vectors					
Facilities	0.514	0.219	0.120	0.095	0.051	
Krasnoleninskoe	0.07	0.05	0.39	0.08	0.31	0.118
Zapadno-Ust-Balykskoye	0.05	0.10	0.23	0.24	0.25	0.113
Megionskoe	0.07	0.14	0.10	0.19	0.09	0.100
Tevlinsko-Ruskinskoe	0.05	0.43	0.05	0.11	0.06	0.138
Aganskoe	0.26	0.23	0.17	0.31	0.18	0.245
Kogalymskoe	0.50	0.05	0.07	0.06	0.11	**0.286**
TOTAL						1.0

5. CONCLUSION

The obtained definitions of global priority and local priorities show the degree of heterogeneity of the impact of oil and gas technogenesis on the state of AAC AC, and the need to continue studies of the regional natural-technogenic system within the Khanty-Mansi Autonomous Okrug of Western Siberia.

The factor “Volume of produced water disposed in the complex” is characterized by the maximum value of the local priority vector (0.51), which is probably due to the fact that disposal volumes determine the overall scale of technogenic changes within AAC AC. For Kogalymskoye and Aganskoye fields the maximum values of global priority were obtained, 0.286 and 0.245 respectively, which corresponds to the overall level of anthropogenic load, the total level of which before these results were obtained could be judged only at the qualitative level. Expansion of initial assessment factors, as well as approbation at other oilfield facilities of Western Siberia in the direction of AAC AC state assessment using the method of hierarchy analysis (matrix method of paired ratios) will contribute to improving the quality of informativeness of indicators of the complex state of natural objects under the influence of oil and gas technogenesis.

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