STATE-OF-THE-ART, PROBLEMS AND PROSPECTS OF ENVIRONMENTAL RESTORATION IN OIL AND GAS INDUSTRY OF RUSSIA

Yu.S. Koryakovskiy[1], A.F. Nechaev[1], V.I. Tsvetkov[1], V.P. Saveliev[2].

[1]St.Petersburg State Institute of Technology; Moskovsky Prospect, 26; St.Petersburg, 198013 Russia
Phone/Fax: +7(812)315-1036, e-mail: anechaev@tu.spb.ru

[2]"LenTransGas"Ltd.; Varshavskaya str., 3; St.Petersburg, 196128 Russia
Phone: +7(812)324-4262, Fax: +7(812)389-2280, e-mail: vsaveliev@ltd.ru

Abstract
This study is analytical review of the legal, administrative and technological issues related to the problem of naturally occurring radioactive materials (**NORM**) management in Oil and Gas Industry (**OGI**) in Russia. In the recent years noticeable progress was achieved in the development of legal and regulatory framework aiming at providing reliable basis for classification of waste; safety, radiological and environmental objectives; quality assurance; planning; technologies and techniques for NORM treatment, storage, disposal, as well as for environmental restoration of contaminated industrial sites. In a series of urgent tasks it would be reasonably to emphasize the lack of commercially available technologies and equipment; deficiency of waste storage/disposal capacities; uncertainties of licensing procedures and responsibilities of regulatory bodies; lack of clearly defined mechanisms for funding of waste management and environmental restoration activities in **OGI**. So, understanding "what must be done" it is necessary to devote serious energies to define "how it can be done". This study was performed in the framework of the International Atomic Energy Agency Co-ordinated Research Project T2.40.06.

1. Prehistory

Fuel and Power Complex (**FPC**) of Russia is the largest, and one of the most prospective sector of the national economy. FPC activities involves exploration, extraction, transportation and utilization of fossil fuel for energy production. More than 2700 enterprises of FPC are distributed all over the country.

It well known that naturally occurring radioactive materials (NORM) are present in oil, gas, carbon and thermal water operations and can deposit in elevated concentrations in well tubulars, surface piping, vessels, pumps and other producing and processing equipment and sites.

Potentially this may cause radiation exposure of employees, population and environment. Total volume of NORM contaminated sludges is assessed in the range from **50 to 200 mln. tons** (1).

Selective radiological investigation of oil extraction enterprises, carried out in Orenburg, Perm, Samara, Saratov, Stavropol, Vuctyl, Tatarstan, Astrakhan regions, have shown that the maximum values of the dose rate can exceed the "normal" radiation background at least by factor 10, and in a number of enterprises it exceeds the dose rate limit, established by the National Radiation Safety Standard (2).

Consequences of "peaceful" nuclear explosions, carried out for intensification of oil extraction and creation of large underground reservoirs for gas-condensate storage, are additional reason for thorough analysis of radioecological situation in OGI. In Astrakhan region, for example, in 1980–1984, 15 underground reservoirs have been created by nuclear explosions, and today specific activity of ^{137}Cs in soil of adjoining areas reached 250000 Bq/kg and the maximum dose rate come to 50 mSv/h (3). At present, in 50-70 localities – adjoining zones of the past nuclear explosions, – extraction of natural resources, storage of hydrocarbon raw materials and disposal of hazardous industrial wastes are realized (3).

The key aspect of the problem of radioecological safety in FPC of Russia was the absence of methodic-organizational and managerial unity both in the assessment of the real risk and realization of the measures required to minimize radiation impact of NORM and man-made radionuclides.

The Parliament Hearings of 1997 on "Ensuring of Radioecological Safety in Fuel & Power Complex of Russia" and on "Ecological Consequences of Underground Nuclear Explosions" could be considered as a starting point for co-ordinated activity in this area with involvement of all the parties concerned. To co-ordinate and manage these activities Center of Radiation Safety of Ministry of Fuel and Power (**MFP**) has been organized in September 1997. As the urgent measures, Center worked out the program of pressing and long-term actions including the structure of Radiation Safety Service for FPS enterprises.

2. Legislative, normative and administrative regulation

Over the last five years noticeable progress has been achieved in regulatory and organizational areas. At present regulation of radioecological safety in OGI is represented by the three-level scheme.

The highest level of legislative regulation includes two Federal Laws: "On Radiation Safety of the Population" (№3-FZ of 09.11.1996) and "On Sanitary-Epidemiological Prosperity of the Population" (№52-FZ of 30.03.1999).

The next Federal level of regulation is represented by a number of Normative Acts (Safety Standards) of overall purpose (2,4,5), and one standard specially addressed the radiation safety issues in OGI: "Radiation Safety Ensuring During Management of Industrial Waste with Enhanced Concentrations of Natural Radionuclides at the Objects of Oil and Gas Industry of the Russian Federation" (SP 2.6.6.1169-02) registered by the Ministry of Justice on 29.11.2002. This recent document clearly defines: **"the administrations of the organizations, enterprises, establishments and other independent juridical persons, which extract, process, store, use, transport organic fuel (i.e. oil and gas); and also construct the enterprises, oil- and gas pipe-lines, *are obliged* to ensure radiation safety of the personnel and population at all the stages of the life cycle of enterprise."**

According to SP 2.6.6.1169-02, industrial wastes with enhanced concentration of natural radionuclides in OGI are categorized in accordance with the dose rates of gamma-radiation and effective specific activities ($\mathbf{A_{eff}}$):

Category of Waste	Effective specific activity of natural radionuclides $\mathbf{A_{eff}}$, kBq/kg	Dose rate of gamma-radiation of radionuclides in waste products – **H**, μGy/h
I category	$A_{eff} < 1.5$	$H < 0.7$
II category	$1.5 < A_{eff} < 10.0$	$0.7 < H < 4.4$
III category	$A_{eff} > 10.0$	$H > 4.4$

The document also includes clear and strict requirements on how to manage each category of NORM-contaminated waste in OGI.

The third level of regulation is represented by the set of sectoral documents included (in hierarchical sequence) Standard Regulations, Rules, Instructions, and Recommendations. These documents have been developed by MFP RF, they cover such important topics as structure, rights and duties of Radiation Protection Service (**RPS**), sampling and radiation control; protection of personnel and environment, decontamination and waste management (both for NORM and man-made radionuclides).

To meet regulatory requirements and to ensure practical measures of radiation protection in OGI companies, administrative structure of supervision has been developed (Fig.1), and Radiation Protection and Radiation Control Services (**RCS**) have been organized in a number of companies: "PermOil", "RosOil-StavropolOilGas", "SamaraOilGas", "AstrakhanGasprom", "OrenburgOil", "SaratovOilGas", "TatOil", "BashOil", etc.

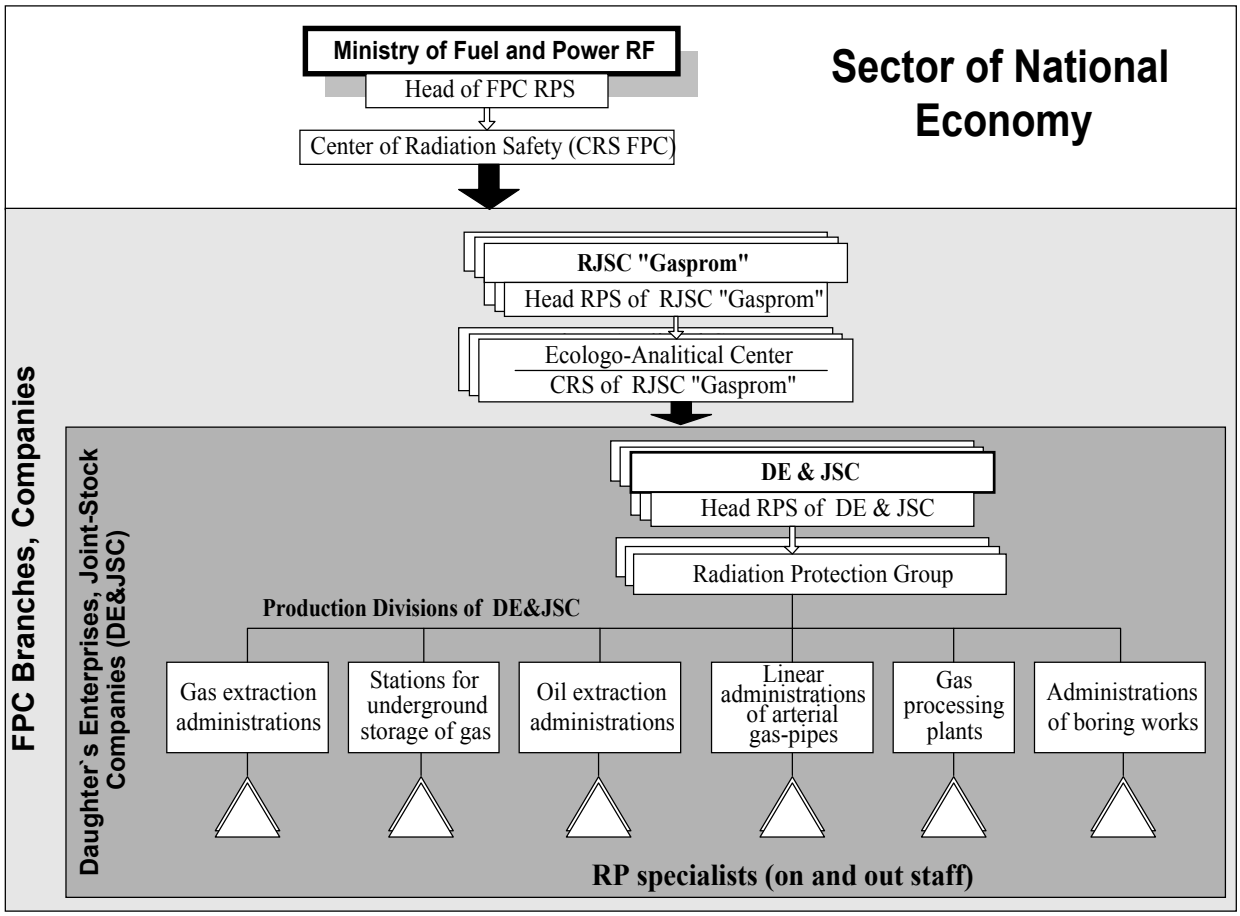

Fig 1. Administrative vertical for ensuring proper radioactive waste control and management in OGI

3. Technologies and techniques for radioactive waste management and environmental restoration in OGI

Practical activities and R&D in the areas of decontamination, waste storage/disposal and environmental restoration of OGI sites are realized in rather intensive and integral manner.

For decontamination of pipes (removal of NORM-contaminated inner scales) there were developed and tested a number of technologies including (6):

An ultrasonic method. Decontamination factor comes to 75–90%

Method of zonal overheating. Decontamination factor is 70–90%

An alkaline boiling extraction. Decontamination factor comes to 95–99%.

An acid washing. The decontamination factor is 90–99%.

An electrohydraulic method: As a result of the blast effect, originating at a high-voltage discharge in a fluid, there is a loosening and the partial destruction of hard deposits. Pipes are not damaged.

The last method was considered as the most prospective one, and special industrial plant for decontamination of well tubulars have been designed for this purpose (7-9).

Small components (couplings, ends, pipe sockets) are planned to be transported to the special facility "**Ecomet-S**" for decontaminating remelting (10). Melting plant consists of an induction furnace, an exhaust ventilation, gas cleaning system, and units for flux preparation, charging the furnace and

casting metal into moulds. Metal is melted under a layer of refining fluxes. After melting and contaminated slag removal metal is cast into ingot moulds. Contaminated slag, dust and filter elements together with the secondary waste from the decontamination site are sent to near surface repository.

In February 2002 this plant was approved for operation by the Governmental Commission, and at present it is in operation to process metallic radioactive waste accumulated in Leningrad NPP.

Large-gabarit contaminated equipment of compound configuration (e.g. pumps) and some components not subject to renewal are intended to be disposed of without decontamination. Some variants of disposal are already realized in practice.

Thus, for example, more than 24000 m^3 of solid waste of total activity 1.92 TBq have been disposed of in underground cavern created in 1966 by the nuclear explosion in a salt dome "Big Azgir" for the storage of gas condensate (11). These waste involve around 20000 m^3 of soil contaminated with both NORM (mostly ^{226}Ra) and man-made radionuclides (mostly ^{137}Cs and ^{90}Sr); 7000 m of string tubes of 40–400 mm diameter; 2200 m of armored cables, and other materials. Environmental restoration works were finished in 1994, and the site was prepared for unrestricted use (11, 12).

Another project of on-site disposal of contaminated equipment is at the final stage of development in the "Lukoil-Permoil" company (13): it is planned to dispose of large-gabarit equipment pumps without decontamination into decommissioned boreholes.

Both technologies are applied mostly for contaminated equipment, tubes, tools, etc., that is to say – for the waste of a relatively small volume. Management of NORM-contaminated sludges with the total volume of a few tens millions tons requires another approach. Presently three main alternatives are under considerations and developments:

1) landspreading or storage of sludges (without pretreatment) in a specially constructed storage facilities/sites (8,14,15);
2) decontamination of sludges with subsequent disposal of water streams in a plugged and abandoned wells, and utilization of decontaminated solids (1);
3) dissolution of sludges with subsequent disposal of liquid waste into deep geological formations (8, 9).

Technology of safe storage of radioactive oil sludges and contaminated soil (as a waste of environmental restoration activity in OGI) is already realized in practice (15).

Technology of decontamination treatment of NORM-containing sludges, generated in gas-condensate production, has been developed by Ukhta State University and Russian Academy of Natural Science, and tested in the "Northgasprom" Company (1). More than 500 tons of sludges with initial specific activity of about 10 kBq/kg have been processed. Liquid product of sludges treatment had an activity less then 10 Bq/kg; solid product, containing practically insoluble compounds of radium – 1,5 kBq/kg. Liquids were pumped in geological formation at the depth of 3400 m, solids can be used for construction of interfield roads out of populated localities. Annual throughput of the pilot facility exceeds 2000 tons, estimated cost of treatment comes to 200–250 $ per ton (1).

Potential attractiveness of the third option (dissolution of sludges) is based on the positive results of laboratory trials of technologies on dissolution of mineral components and long experience in underground disposal of radioactive liquid waste in geological formations (16).

Conclusion

At present topicality of the problem of radiation safety ensuring in oil and gas industry is widely recognized. Working out all necessary components of the state radiation safety system (including creation of legal framework, development of effective mechanisms of regulation and financial support, etc.) is realized rather integratedly and dynamically.

However, there is much scope for further development, co-ordination of efforts of all the parties involved, and settlement of still existing uncertainties and contradictions. In a series of urgent tasks one could mention:

- lack of commercially available technologies for decontamination of processing and production equipment, and for NORM-contaminated industrial waste handling and treatment;
- deficiency of capacities for waste storage and final disposal;
- uncertainties of the procedures of licensing and responsibilities of regulatory bodies;
- lack of clearly defined mechanisms of funding the projects related to NORM-containing waste management and environmental restoration of contaminated oil-fields.

In general, today it is more or less clear "**what must be done**" to provide guarantees of radiation safety for employees and population, but apparently it is necessary to devote serious energies in order to define "**how it can be done**".

References

1. Ryjakov V.N., Krapivskiy E.I. New Decontamination Technologies of Radioactive Sludges, Scales and Contaminated Soils at Hydrocarbons' Fields. Proc. 5-th International Conference on Radiation Safety (St. Petersburg, Russia, 24–27 Sept. 2002), SPb: RESTEC p. 330–337, (2002).
2. Norm of Radiation Safety (NRB-99), Ministry of Health, (1999).
3. Information on Underground Nuclear Explosions on Osinskiy, Gezhsky, Astrakhansky and Orenburgsky Oil-Gas Deposits. Federal Board on Medical, Biological and Emergency Problems, Ministry of Health, presented at Parliament Hearings, Dec. (1997).
4. The Basic Sanitary Rules of Radiation Safety Ensuring (OSPORB-99), Ministry of Health, (1999).
5. Sanitary Rules of Radioactive Waste Management (SPORO-2002), Ministry of Health, (2002).
6. Gorbunov V.A., Lysenko A.A. Ensuring of Oil-Field Equipment Purification From Scales Containing Natural Radionuclides. Proc. Fuel and Power Complex of Russia Forum (St. Petersburg, Russia, 8–11 April 2003), SPb: RESTEC, p. 245–247, (2003).
7. Vekilov E.H., Tchernikov V.S., Shubin E.F., et.al., An Experience of "RosOil-StavropolOilGas" in Ensuring of Radioecological Safety. Proc. Seminar Modern Problems of Radiation and Radioeclogical Safety in Oil and Gas Industry of Russia (Ramenskoe, Russia, September 22–23 1999), MFP, p. 7, (1999).
8. Chechetkin Yu.V., Sokolov Ye.I., Ulyushkin A.M., Management of Radioactive Waste at Oil Production Plants. Proc. 3-th International Conference on Radiation Safety, (St. Petersburg, Russia, Oct. 31–Nov. 4 2000), SPb: RESTEC, p. 279–280, (2000).
9. Takhautdinov T.F., Sizov B.A., Diyashev R.H., Zaytzev V.I., Problem of Radioactive Precipitations in Processing Equipment. Labour Protection in Industry, **5**, p. 39–37, (1995).
10. Agapov A.M., Buntushkin V.P., Troshev A.V., Shamov V.P., Cheremisin P.I., Voronkov M.S. Joint-Stock Company "Ecomet-S" Activities in the Field of Solving Problem of Metal Radwaste Management in Russian Federation. Proc. Fuel and Power Complex of Russia Forum (St.Petersburg, Russia, 8–11 April 2003), SPb: RESTEC, p 271–275, (2003).
11. Dubasov Yu.V., Sokolov V.A., Creation of the 1-st World Repository of Radioactive Waste in the Nuclear Explosion Cavern". Proc. 2-nd International Conference on Radiation Safety, (St. Petersburg, Russia, 9–12 Nov. 1999), SPb, RESTEC, p. 155–159, (1999).
12. Graschenko S.M., Dubanov Yu.V., Katsarov V.I., et.al., Results of Radiation Control Performed by the Specialists of Radium Institute at the Objects of Gas Industry. Proc. 3-th International Conference on Radiation Safety, (St. Petersburg, Russia, Oct. 31–Nov. 4 2000), SPb: RESTEC, p. 288–290, (2000).
13. Melenev V.G., Disposal of Oil Production Equipment Contaminated by Natural Radionuclides, Proc. 2-nd International Conference on Radiation Safety, (St. Petersburg, Russia, 9–12 Nov. 1999), SPb, RESTEC, p. 82–83, (1999).
14. Popova A.A., Forming and Implementation of the Program of Radiation Safety Ensuring in Osinsky Oil Deposit After Underground Nuclear Explosions. Proc. 2-nd International Conference on Radiation Safety, (St. Petersburg, Russia, 9–12 Nov. 1999), SPb, RESTEC, p. 27–28, (1999).
15. Popova A.A. Operation of Radwaste Storage Facility in JSC "Lukoil-PermOil". Proc. 3-th International Conference on Radiation Safety, (St. Petersburg, Russia, Oct. 31–Nov. 4 2000), SPb: RESTEC, p. 287–288, (2000).
16. Lipaeva A.V., Ulyushkin A.M., Geological Conditions as a Safety Basis for Liquid Radioactive Waste Disposal. Litology and Natural Resouses, **5**, p. 470–483, (1997).