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WASTE DISPOSAL BY SHALE FRACTURING AT ORNL*

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ABSTRACT

Shale fracturing is a process currently being used at the Oak Ridge National Laboratory for the permanent disposal of locally generated waste solutions. In this process, the waste is mixed with a solids blend of cement and other additives; the resulting grout is then injected into an impermeable shale formation at a depth of 700 to 1000 ft. A description of the process, the monitoring techniques that have been developed, the leach rates that have been observed, and some considerations of the impact on the environment are discussed.

PROCESS DESCRIPTION

Shale fracturing is a process currently being used at the Oak Ridge National Laboratory for the permanent disposal of locally generated intermediate-level waste solutions. These solutions are alkaline, contain about 1 M $NaNO_3$, and have a radionuclide content (predominantly ^{137}Cs) of about 1 Ci/gal. In this process, the waste solution is mixed with a solids blend of cement and other additives;

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DISCLAIMER

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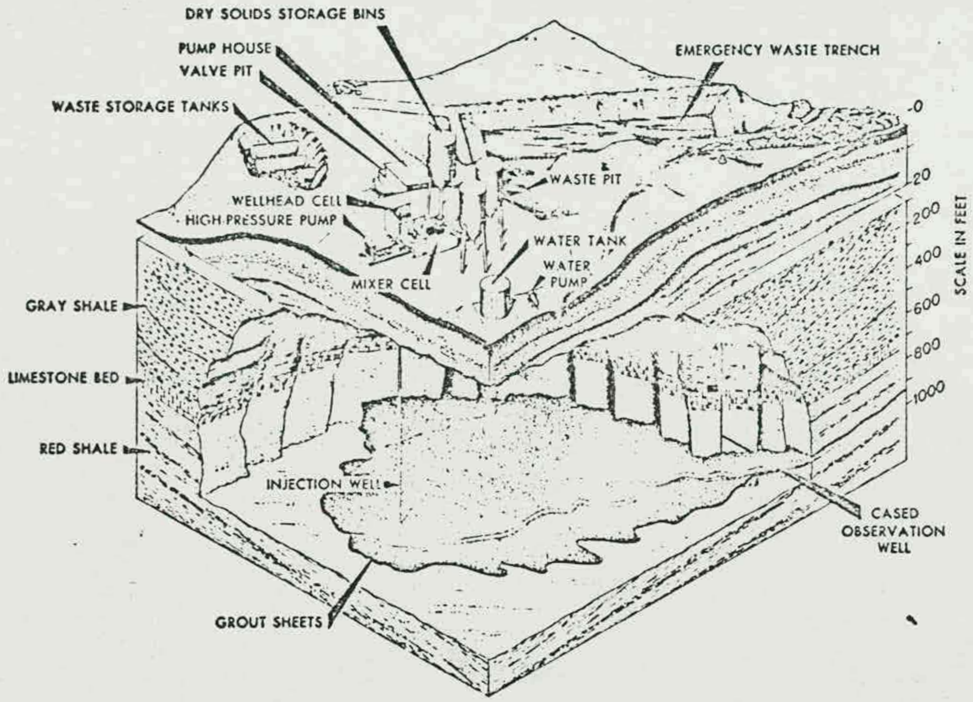

~~ORNL FRACTURING DISPOSAL PILOT PLANT~~

The Shale Fracturing Disposal Plant at ORNL

the resulting grout is then injected into an impermeable shale formation at a depth of 700 to 1000 ft (200 to 300 m), well below the level at which groundwater is encountered. During the course of the injection, the grout forms a thin, approximately horizontal grout sheet that measures several hundred feet across. A few hours after the injection has been completed, the grout sets and thus permanently fixes the radioactive waste in the shale formation.

The process was developed in a series of experiments conducted between 1959 and 1965. The experimental facility was modified in 1966 for the routine disposal of intermediate-level waste solutions generated at ORNL. Since then, this facility has been used for 17 operational injections. More than 2 million gal of waste grout containing over 600,000 Ci of radionuclides have been injected. There have been some operational problems, but most have been comparatively minor and none have been truly serious; the general experience has been quite good (1).

Each injection disposes of approximately 1 year's accumulation of waste solution. Prior to the injection, the waste solution is pumped to the waste storage tanks at the injection site. The dry solids are blended and stored in bins at the injection facility. During the injection, the waste solution is pumped to the mixer, continuously mixed with the preblended solids, and then discharged into the surge tank. From the surge tank, the grout is pumped down the tubing string in the injection well and out into the shale formation. The injection pressure is about 3000 psi. The normal grout injection rate is about 250 gal/min; an injection requires about 8 hr to complete.

The rock formations underlying the fracturing site are bedded shale which extend to a depth of about 1000 ft. Beneath the shale is a bed of dense sandstone. All injections have been made into the lower part of the shale beds. No circulating groundwater has been observed at a depth greater than 150 ft, and several other findings (detailed core examinations, the presence of salt and gas in the shale, etc.) support this observation. A two-part test procedure has been developed to verify the absence of any significant communication between the disposal zone and the surface. A test injection is made with water, and the rate of the subsequent pressure decay is noted; a slow rate of decay indicates the absence of surface communication. A grout test injection is made and the fracture orientation is determined; the existence of a horizontal fracture indicates that the formation fractures preferentially in this orientation and that the subsequent injections will remain within the disposal zone.

The solids blend developed for this process consists of Portland cement, fly ash, drilling clay, pottery clay, and a retarder. The retarder delays the setting time of the grout, the pottery clay fixes cesium, the drilling clay retains excess water, the fly ash fixes strontium, and the cement serves as the overall binder.

The leach rates of radionuclides from a set grout are quite low (i.e., approximately equivalent to those from a borosilicate glass). The leach behavior of the set grout has been determined for cesium, strontium, plutonium, and curium (2). A modification of the proposed IAEA test method was used in these studies. The leach rates were found to be diffusion controlled and followed the relationship:

$$\frac{\Sigma a_n}{A_o} \left(\frac{V}{S}\right) = 2 \left(\frac{D_e \, t_n}{\pi}\right)^{1/2},$$

where

$\frac{a_n}{A_o}$ is the fraction of the radionuclide leached in time t_n (sec);

v is the specimen volume, cm^3;

s is the surface area exposed to leaching, cm^2; and

D_e is a diffusion coefficient, cm^2/sec.

Observed values of the diffusion coefficient for cesium leached from grouts containing one of the better cesium fixers were between 10^{-12} and 10^{-14} cm^2/sec. A typical diffusion coefficient for strontium was 5×10^{-12}; coefficients for curium and plutonium were approximately 10^{-16} and 10^{-17}, respectively.

The injection pressure and the radiation exposure of the operating crew are regularly monitored during each injection. A few days after the injection, the orientation of the grout sheet is determined by logging the network of observation wells which surrounds the facility. After several injections have been completed, the cumulative surface uplift around the injection well is determined and the continued impermeability of the shale overlying the disposal zone is verified.

The essential feature of the shale fracturing process is the fixation of the radionuclides in a geological formation that is known to be isolated from contact with the surface environment. The process also has some additional features that would provide continued containment of the radionuclides even if the isolation of the disposal formation were lost. For example, the leach rates of significant radionuclides from the set grout are quite low. In addition, any radionuclides that might be leached from a grout sheet would be retained in the disposal zone by the high ion exchange capacity of the shale. Therefore, this process offers an exceptionally favorable approach to permanent disposal of radioactive wastes.

A new shale fracturing facility is being designed and built. This new facility will have improved shielding and containment so that wastes of higher specific activity can be handled. Process instrumentation and the dry solids handling equipment will also be improved.

REFERENCES

1. H. O. Weeren, "Waste Disposal by Shale Fracturing at ORNL," Nuclear Engineering and Design, 44, 291-300 (1977).

2. J. G. Moore, H. W. Godbee, A. H. Kibbey and D. S. Joy, "Development of Cementitious Grouts for the Incorporation of Radioactive Wastes," U.S. D.O.E. Rep. ORNL-4962, Oak Ridge National Laboratory, Oak Ridge, Tennessee, p. 116, April 1975 (available from NTIS).