Spent nuclear fuel management in Kozloduy NPP.

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Basic information
The project of building a Nuclear Power Plant in Bulgaria started in 1969.

Kozloduy NPP consists of 6 units:

1 - WWER 440 built and commissioned in 1974;
2 - WWER 440 built and commissioned in 1975;
3 - WWER 440 built and commissioned in 1980;
4 - WWER 440 built and commissioned in 1982;
5 - WWER 1000 built and commissioned in 1987 (licensed for operation by 2028 after PLEX);
6 - WWER 1000 built and commissioned in 1991 (licensed for operation by 2029 after PLEX);
To fulfill the engagements resulting from joining the EU, the Government of Bulgaria shut down the first 4 units type WWER 440:

Unit 1 and 2 at the end of 2002;
Unit 3 and 4 at the end of 2006;

Now these four units are in process of decommissioning.

For 45 years Kozloduy NPP produced 625 644 667 MWh.

Now, with only units 5 and 6 in operation, Kozloduy NPP have 32 % part from energy production in Bulgaria.
Management of SNF
For the period 1979 – 2014, generated SNF is 2150 t HM. 58 % from this SNF is transported for reprocessing in Russia.

According to the strategy of SNF management, in the period 2015 – 2030 from unit 5 and 6 (WWER 1000) is expected to be generated 1600 SNF assemblies.

Bulgaria have a strong legislation framework concerning nuclear fuel cycle and SNF management.
Strategy for management of SNF 2015 – 2030
The strategy considers 3 options (alternatives) for SNF management

1. Transport of SNF for reprocessing (minimum 50 t HM per year).
2. On site storage of SNF:
   - Wet storage of SNF
   - Dry storage of SNF
3. Consideration of on site storage of high level radioactivity waste generated during reprocessing.

The Strategy pointed out that for now the most acceptable option is the transport of minimum 50 t HM per year for reprocessing.
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Nuclear power reactors

Wet storage of SNF

Dry storage of SNF

Transport for reprocessing
A Spent Nuclear Fuel Storage Facility (Wet type) for short term storage located at Kozloduy NPP site was built and started operating in 1990.
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Spent Nuclear Fuel Storage Facility (Wet type)
A Dry Spent Nuclear Fuel Storage Facility for long term storage (50 years) located at Kozloduy site was built and started operating in 2011.
Dry Spent Nuclear Fuel Storage Facility
Kozloduy NPP maintains necessary documentation concerning nuclear fuel data during whole life cycle on the NPP site. Data and record are reliably stored and periodically analyzed. Kozloduy NPP has built a system for control and monitoring of records.

The collected data are about:
Nuclear fuel.
Fuel assemblies.
Transport containers.
Storage containers.
Transport.
Basic and auxiliary equipment used for handling and transport.
Data for NF is calculated with validated programs:
For Database
- Smart Fuel
For Calculation and modeling.
- SCALE 6.1
Also alternatively, various measurements are made to confirm the fuel integrity and calculated data:
- Continuous reactor control during fuel campaign.
- Measurements of leakage of the fuel assemblies.
- Visual control of the assembly.
- Measuring of burn up during loading of containers for dry storage.
- Non destructive analysis.
Main data records for SNF:
Assembly type, number and place of storage.
Physical status, dimension, weight
Enrichment.
Leakage status (hermetic, non hermetic). Fuel integrity.
Irradiation history. Storage time.
Cooling time.
Nuclide inventory.
Burn up. Homogeneity of burn up.
Residual heat. Temperatures.
Activity. Radiation dose.
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Example of database program:
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Calculated activity of main nuclides in the spent fuel pool for selected moment.

Activity Bq
The required nuclide inventory calculations are performed using the computer code system SCALE 4.4a [1]. A specific ORIGEN-S library developed at the Kozloduy NPP for typical irradiation conditions is used for each different fuel assembly type.

According to the procedures for spent fuel transportation across the border, beside the residual heat release in each cask, there is a requirement to report the concentrations of selected major fuel isotopes. These are $^{235}$U, $^{236}$U, $^{238}$U, $^{239}$Pu, $^{240}$Pu, $^{241}$Pu, $^{242}$Pu. As well as the total amounts of $^{235}$U+$^{236}$U+$^{238}$U and of $^{239}$Pu+$^{240}$Pu+$^{241}$Pu+$^{242}$Pu.

The burn up dependent concentrations of uranium and plutonium isotopes calculated using ORIGEN-S are compared with data submitted by the fuel supplier.
Furthermore, a comparison is made between the ORIGEN-S calculated concentrations (of all major U and Pu isotopes, as well as of $^{237}$Np, $^{241}$Am and $^{243}$Am) and corresponding results obtained using the HELIOS-1.5 lattice code.

Burnup dependence of the $^{235}$U concentration (ORIGEN-S vs TVS-M)
To improve the quality of fuel and fuel assemblies the collected data are analyzed and discussed with manufacturing companies.

During 45 years of experience of management of nuclear fuel, Kozloduy NPP have a significant contribution of improvement of quality of used fuel.

The results are proved by continuous technological and environmental control of radiation parameters.

Nuclear safety and radiation protection of workers, population and environment, reaching a high level of safety culture are the basic principles for management of Kozloduy NPP.
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Radiation protection

0.20 manSv/unit – personnel collective dose for 2018 as per the number of reactors in operation

0.44 manSv/unit - 2018 WANO performance indicators for PWR reactors
A model evaluation of public exposure in the area around the plant, resulting from the radioactive discharges to the atmosphere and hydrosphere, was carried out using computer codes based on the adopted by the European Union CREAM methodology.

The maximal individual effective dose for the public, taking into account the contribution of 14C and 3H, was estimated at 5.46 μSv/a, which makes up 0.2% of the exposure resulting from the natural radiation background typical for the region – 2.4 mSv/a.
Radioecological monitoring
Gamma-radiation equivalent dose rate (\(\mu\text{Sv/h}\)), in the 30-km zone in the populated areas in the 30-km zone, AISRM, 2018.

- Background gamma radiation in the 30-km zone – 0,05 \(\div\) 0,19 \(\mu\text{Sv/h}\), within the limits of the natural radiation background for the area
- Doses to the public in the 30-km zone - 4 \(\div\) 7 \(\mu\text{Sv/a}\) (1 mSv radiation protection normative basis)
- Radioactivity in the monitored sites - corresponds to the normative basis
- Radiation conditions - stable and unaffected by the operation of Kozloduy NPP
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Average values of background in Bulgaria

![Graph showing average values of background in Bulgaria with city names on the x-axis and μSv/h on the y-axis. The graph includes error bars and a line indicating the mean value.]
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Records
SNF assembly stored at Kozloduy NPP site have a file where is stored the history and the whole known data.

The special attention is hold on those parameters that have a main role in calculation of the nuclear safety and radiation protection.

Nuclear fuel and records are object of continuous control.
Conclusion

In wet type storage
Continuous environmental radiation control and radiation control of the parameters of water pools of storage facility proves that the storage conditions ensure the integrity of the fuel.

In dry type storage;
Continuous environmental radiation control and control of outgoing temperature proves that the applied technology for dry storage is suitable to ensure nuclear safety and radiation protection.
Thank You

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