COMPARATIVE ANALYSIS OF ISOTOPE COMPOSITION OF VVER 1000 WESTINGHOUSE AND TVEL SPENT FUEL

Y. Kovbasenko

State Scientific and Technical Centre on Nuclear and Radiation Safety (SSTC NRS), Kyiv, Ukraine

Spent fuel characteristics important to safety are determined primarily by isotopic composition formed during burnup of this fuel. Determination of isotope composition of spent fuel is necessary to solve the tasks related to:

- **Account and control of quantity of nuclear hazardous material;**
- **Determination of source terms during analysis of criticality, thermal and radiation safety;**
- **Using burnup as the nuclear safety parameter while substantiating safety of spent fuel management systems ("burnup credit" principle).**

Isotope composition of spent fuel is determined by not only of its burnup level, but also those conditions, or, more exactly to say, by that neutron spectrum under which this burnup occurred.

The more hard was neutron spectrum, the more U238 is involved into the burnup process (mainly, due to generation of Pu239), and the more U235 is remained in spent fuel under the same burnup level. Therefore, this work considers those operational parameters, which changes are capable of influencing upon in-core neutron spectrum hardening.

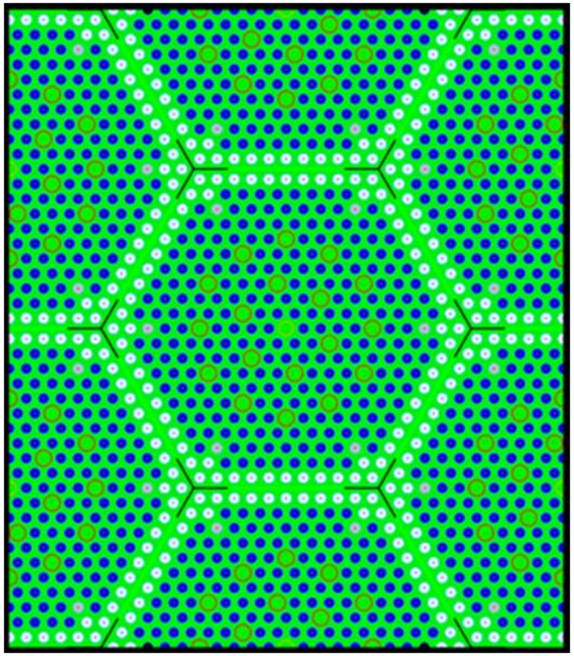
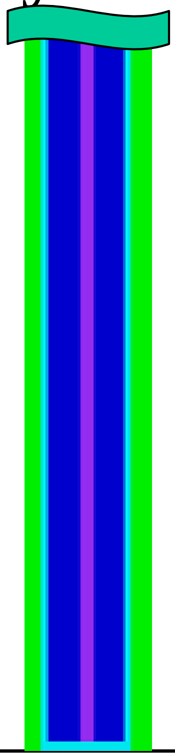
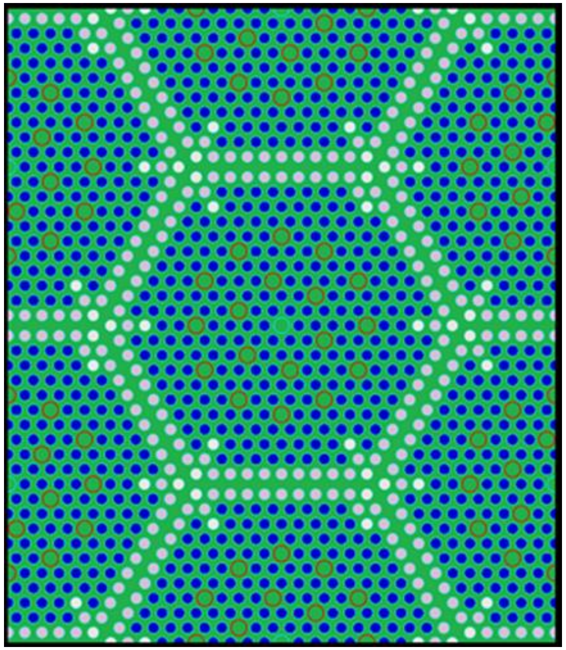
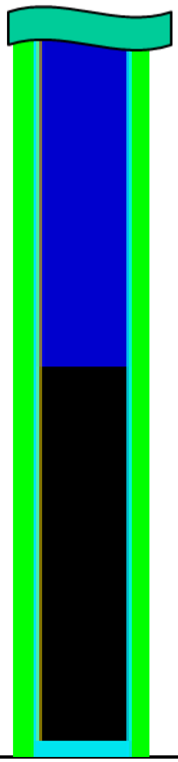
Therefore the impact on VVER 1000 spent fuel multiplication properties and isotope composition caused by the different operational conditions, such as the presence or absence of absorber-rods – control rods claster (CR) in guide tubes, oscillating the concentration of boric acid, dissolved in the moderator (water) during the campaign, water density, fuel and/or moderator temperature has analyzed.

Also, impact caused by technological allowances applied while manufacturing fuel assembly was analyzed by weight of fuel and by its enrichment.

To determine the isotopic composition of spent VVER 1000 fuel SCALE code package was selected. The SCALE code package includes computer modules, which combining programs and libraries to calculate one or another problem (criticality analysis, heat transfer, isotopic composition distribution depending on burnup, etc.).

For our calculations we used the TRITON module of SCALE, which allow to model fuel burnup processes in complex 3D geometry. The calculations were performed with the use of standart 44GROUPNDF5 library of neutron-physical constants.

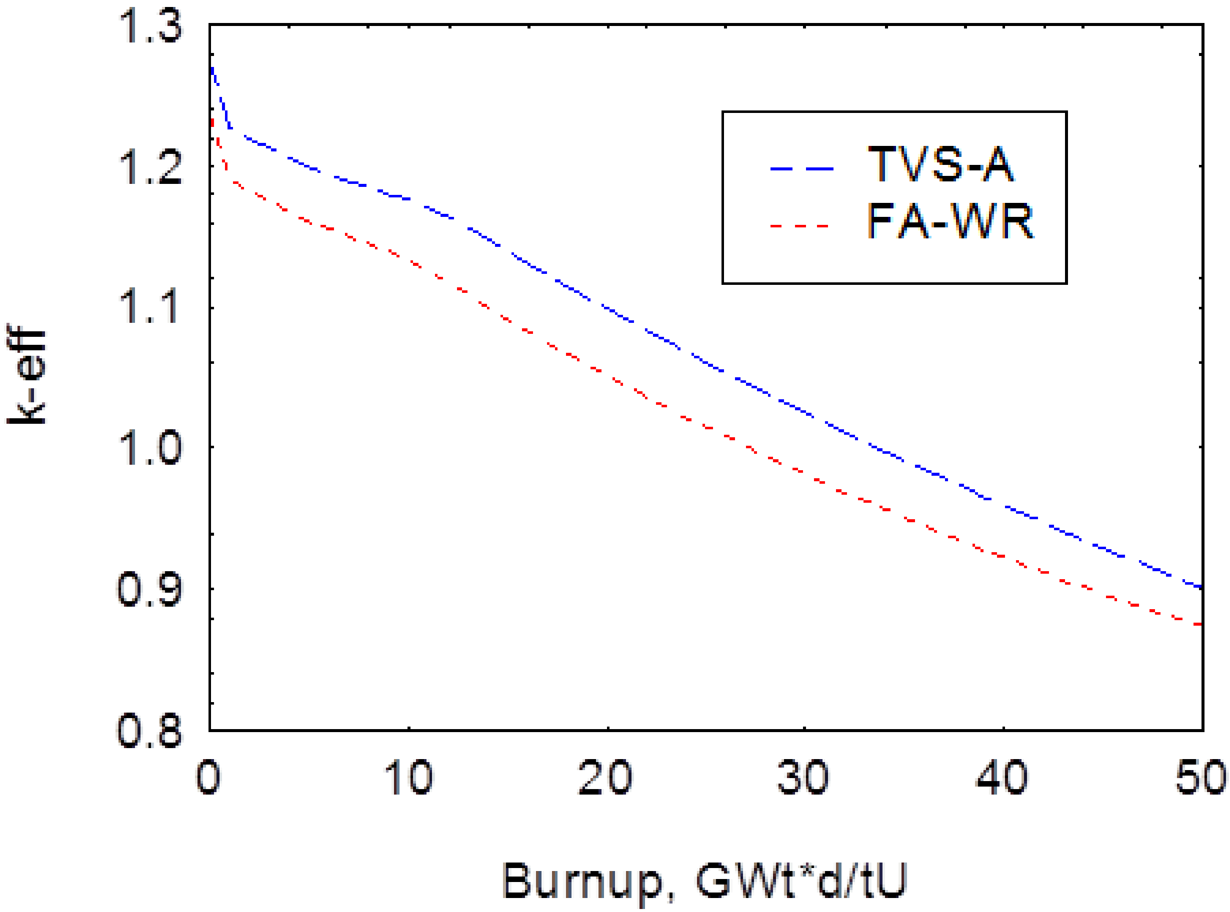
Reviewing reactor cells of VVER-1000 were composed of the typical modern fuel assemblies TVS-A of Russian TVEL suppliers and new FA-WR of Westinghouse company under the burnup level up to 50 GWt*day/tU in 4 year fuel cycle

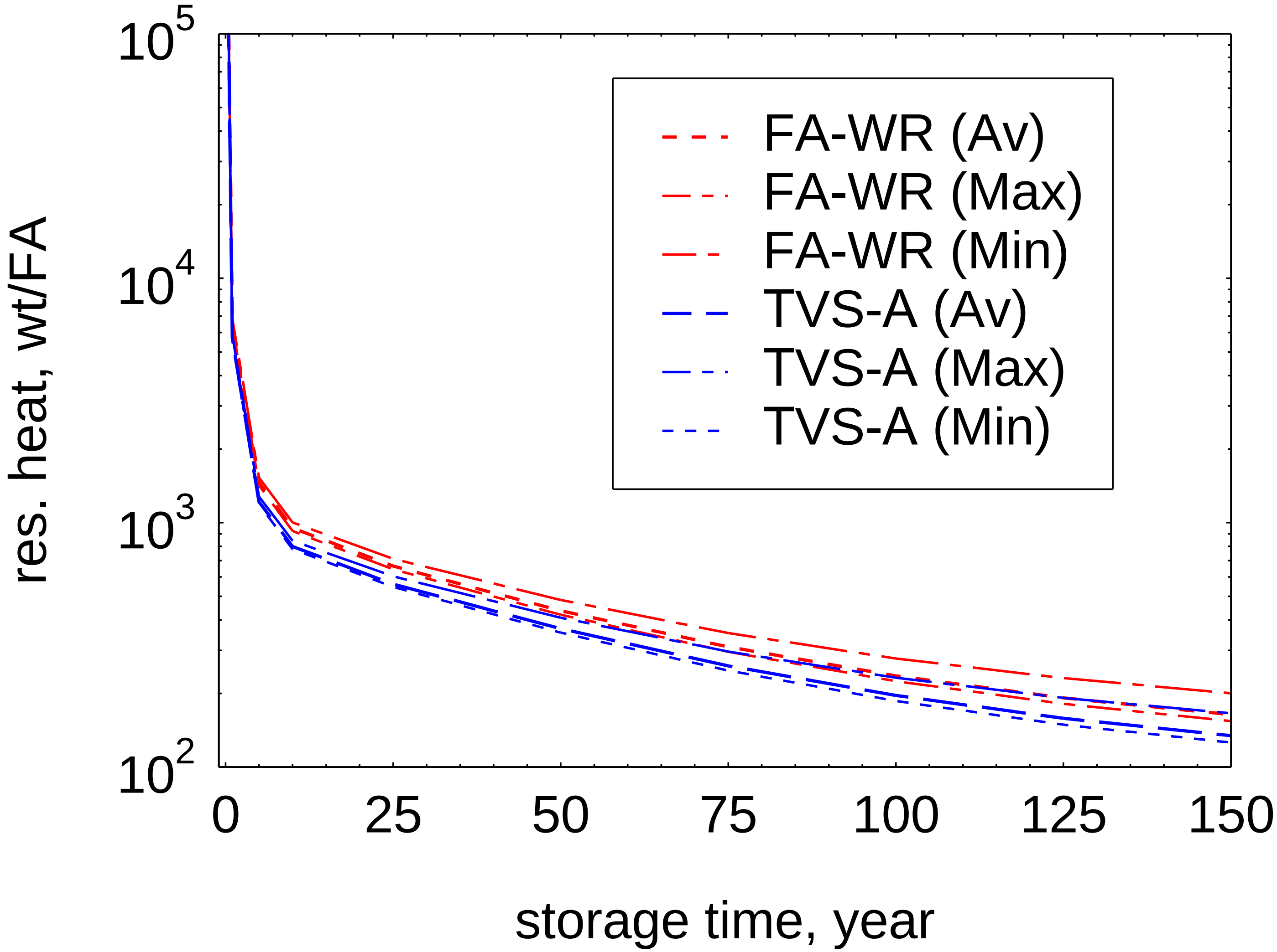





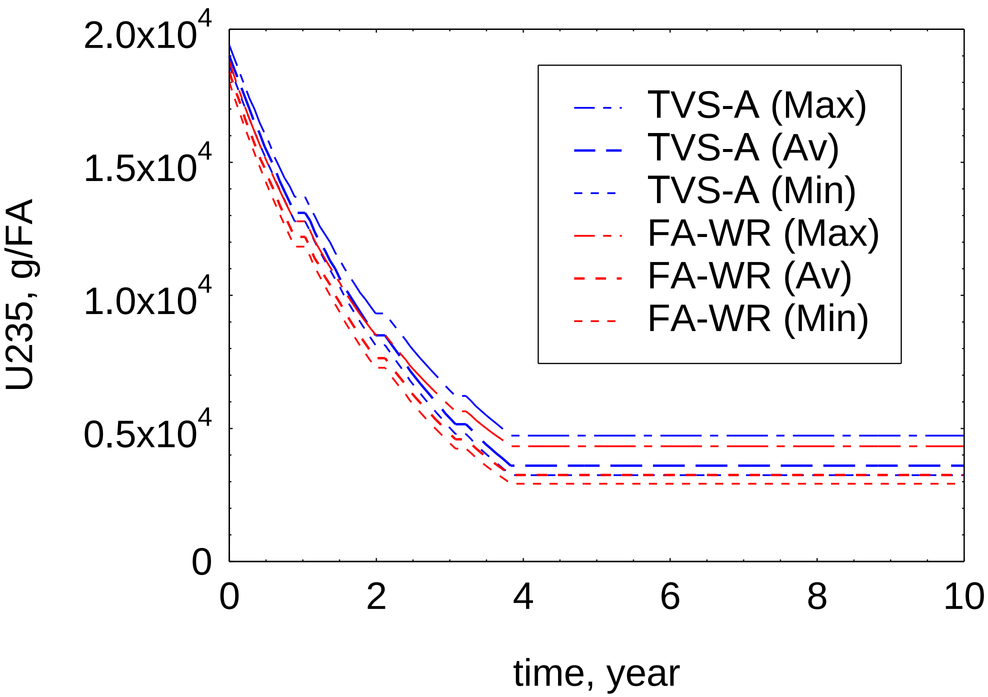
Parameter	TVS-A (TVEL)	FA-WR (Westinghouse)
Fuel stack length	3530 mm	3530 mm
Central Zone length (nom.)	3530 mm	3225.2 mm
Axial Blanket length (nom.)	-	2 zone x 152.4 mm
Fuel mass (UO2), kg	494.5±4.5	550.6 ± 5.0
Fuel pin (312 pieces)		
Enrichment, wt%	306*4.4%+ 6*3.6%(BA)	240*4.2%+60*3.9%+6*3.6%+ 6*3.0%(BA), 0.714% (blanket)
Pellet ID/OD, mm	1.4/7.57	-/7.84
Cladding ID/OD, mm	7.73/9.1	8.0/9.14
Cladding material/ density, g/ccm	alloy Э110 / 6.45	alloy ZIRLOTM / 6.55
Central tube		
ID/OD, mm	11.0/13.0	11.0/12.6
Material / density, g/ccm	alloy Э635 / 6.45	alloy ZIRLOTM / 6.55
Guide tube (18 pieces)		
ID/OD, mm	10.9/12.6	11.0/12.6
Material	alloy Э635	alloy ZIRLOTM
Spacer grid (13 pieces in fuel zone)		
Mass, g	550	830
Material / density, g/ccm	alloy Э110 / 6.45	alloy 718 / 8.18
Ribs (6 stiffener corners)		
Width / thickness, mm	52 / 0,65	-
Material	alloy Э635	-

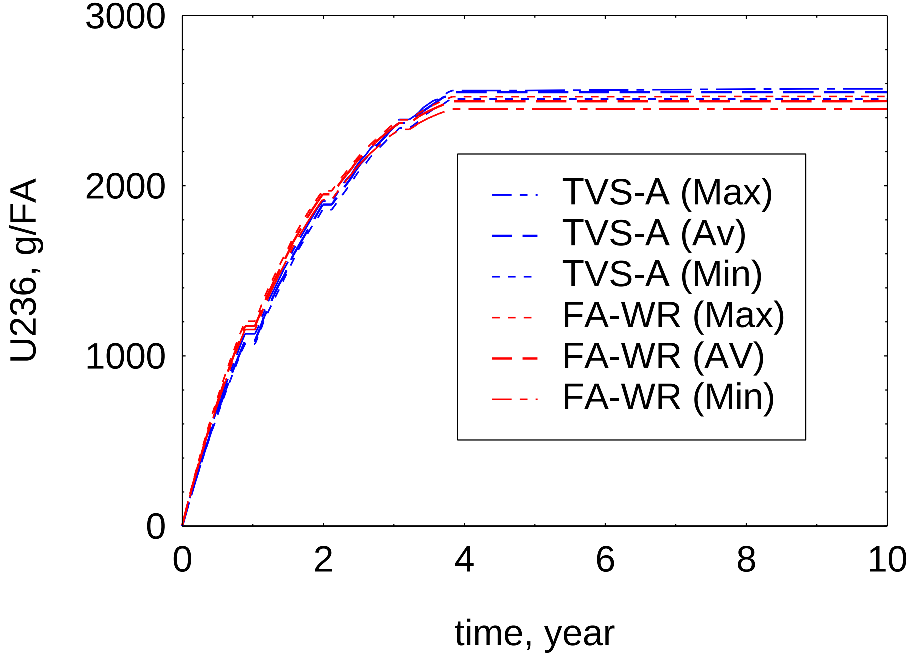
Operational parameters that were used while performing isotope composition calculation

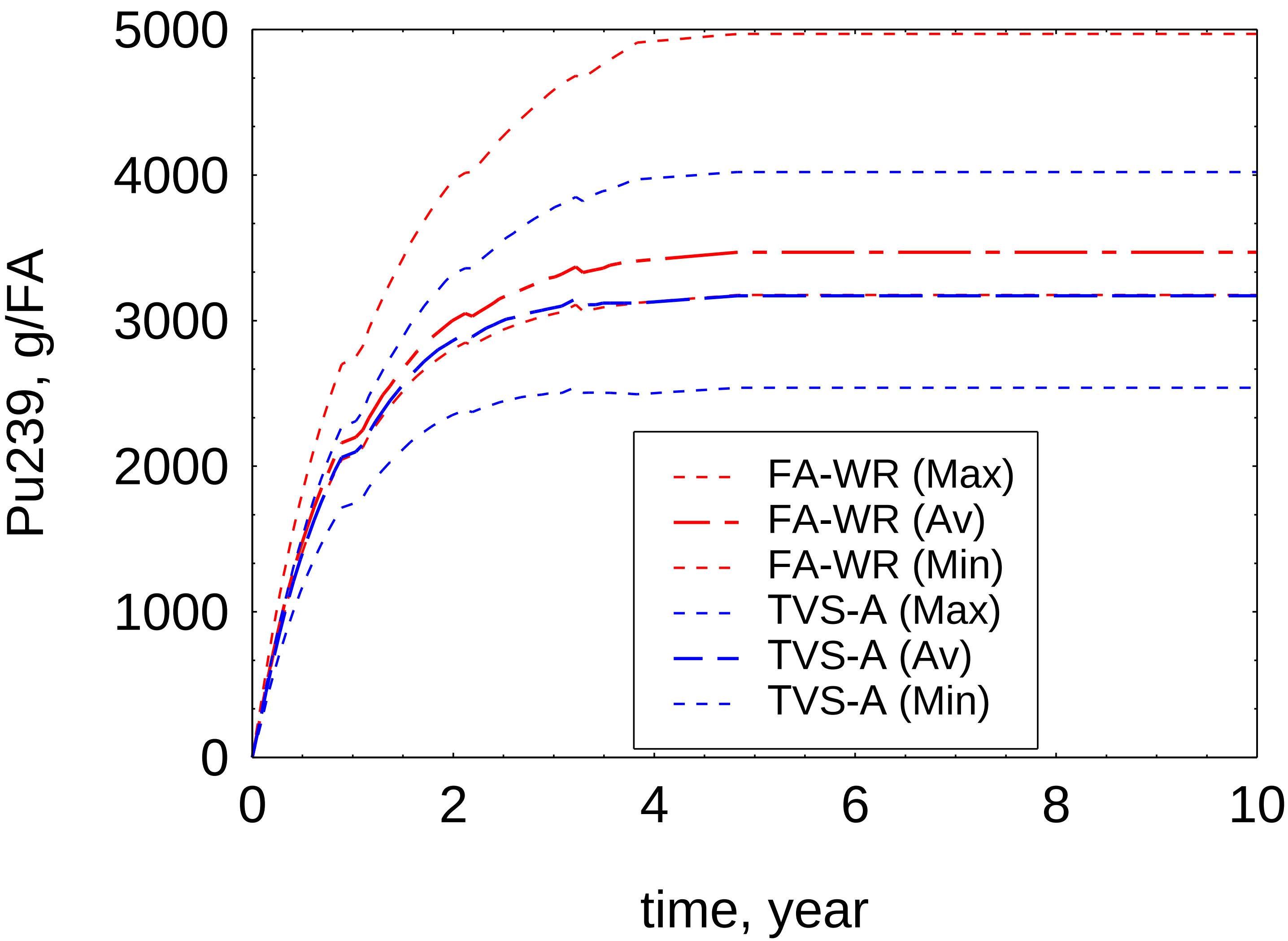
Set of parameters	Av.	Max.	Min.
Enrichment, wt%	Av	+0.5	-0.5
Weight, kg/FA	Av.	+4.5/+5.0	-4.5/-5.0
CR in guide tubes	-	+	-
Boric acid concentration, ppm	525	1050	0
Water density, g/	0.72	0.70	0.74
Water temp., grad K	578	600	500
Fuel temp., grad K	1005	1100	900

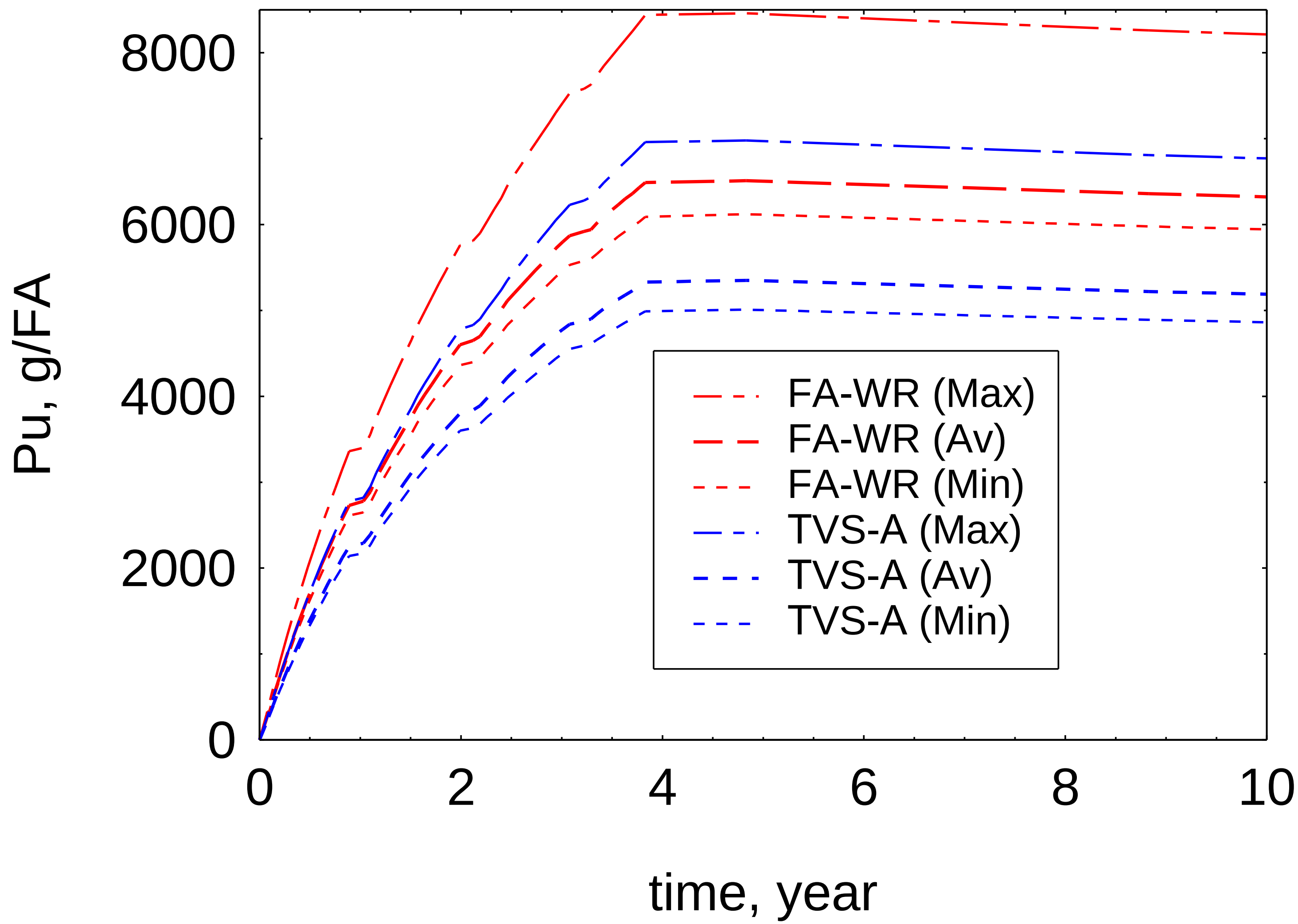

1.3
1.2
1.1
1.0
0.9
0.8
k-eff
0
10
20
30
40
50
Burnup, GWt*d/tU
TVS-A
FA-WR

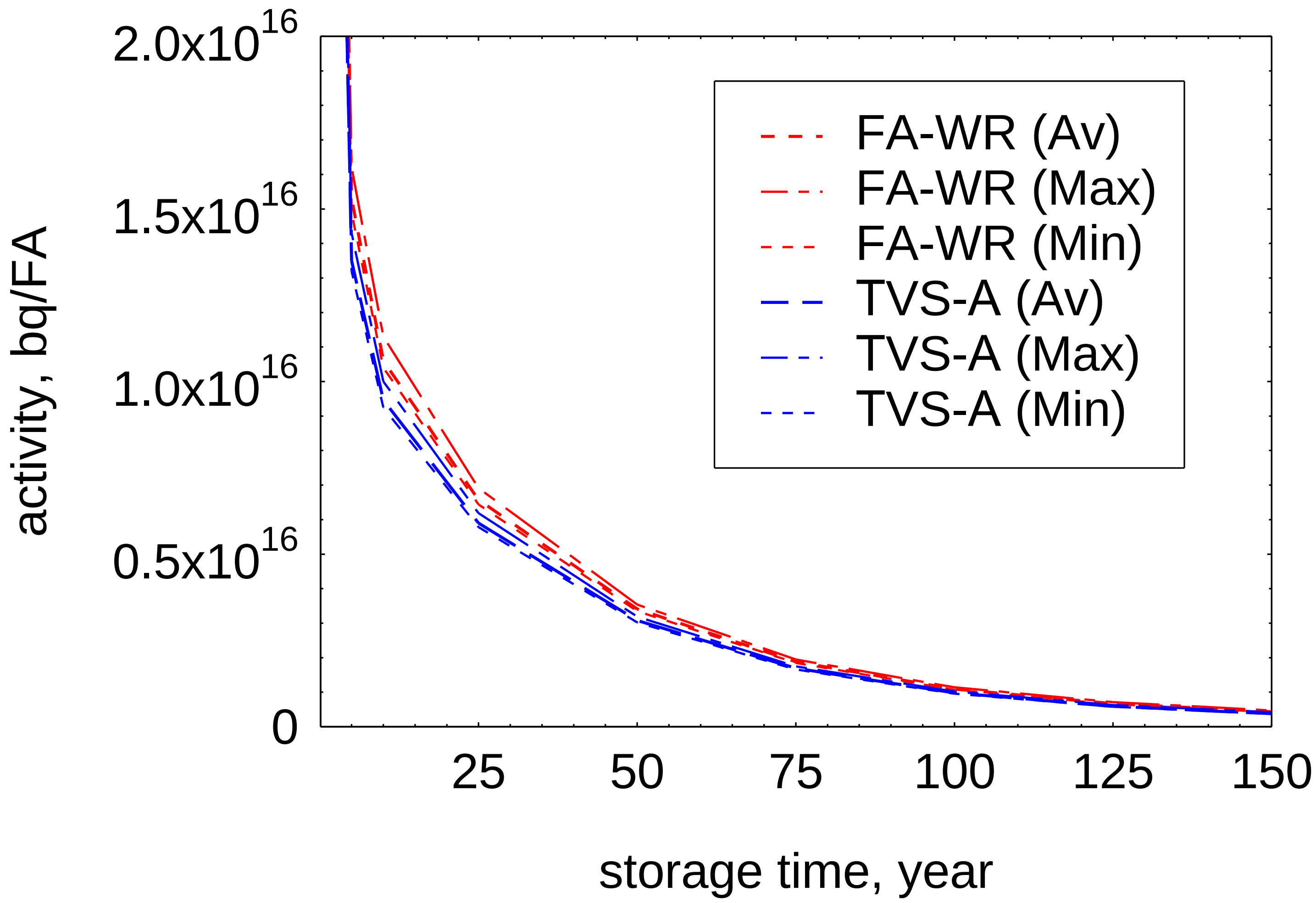

res. heat, wt/FA
storage time, year
FA-WR (Av)
FA-WR (Max)
FA-WR (Min)
TVS-A (Av)
TVS-A (Max)
TVS-A (Min)
10^5
10^4
10^3
10^2
0
25
50
75
100
125
150


U235, g/FA
2.0x10^4
1.5x10^4
1.0x10^4
0.5x10^4
0
0
2
4
6
8
10
time, year
TVS-A (Max)
TVS-A (Av)
TVS-A (Min)
FA-WR (Max)
FA-WR (Av)
FA-WR (Min)


U236, g/FA
3000
2000
1000
0
0
2
4
6
8
10
time, year
TVS-A (Max)
TVS-A (Av)
TVS-A (Min)
FA-WR (Max)
FA-WR (AV)
FA-WR (Min)


5000
4000
3000
2000
1000
0
Pu239, g/FA
0
2
4
6
8
10
time, year
FA-WR (Max)
FA-WR (Av)
FA-WR (Min)
TVS-A (Max)
TVS-A (Av)
TVS-A (Min)


8000
6000
4000
2000
0
Pu, g/FA
0
2
4
6
8
10
time, year
FA-WR (Max)
FA-WR (Av)
FA-WR (Min)
TVS-A (Max)
TVS-A (Av)
TVS-A (Min)


2.0x10^16
1.5x10^16
1.0x10^16
0.5x10^16
0
activity, bq/FA
25
50
75
100
125
150
storage time, year
FA-WR (Av)
FA-WR (Max)
FA-WR (Min)
TVS-A (Av)
TVS-A (Max)
TVS-A (Min)

Set of parameters	TVS-A		FA-WR		TVS-A vs FA-WR
	Max. /Av.	Max. /Min.	Max. /Av.	Max. /Min.	
Residual heat	1.23	1.31	1.22	1.30	1.22 (FA-WR/TVS-A)
U235 concentration	1.32	1.46	1.34	1.48	1.12 (TVS-A/FA-WR)
U236 concentration	1.05	1.08	1.05	1.07	1.02 (TVS-A/FA-WR)
Pu239 concentration	1.45	1.59	1.44	1.57	1.25 (FA-WR/TVS-A)
Pu concentration	1.31	1.39	1.30	1.38	1.24 (FA-WR/TVS-A)
Activity	1.10	1.13	1.10	1.13	1.14 (FA-WR/TVS-A)
Eu154 concentration	1.26	1.35	1.24	1.33	1.38 (FA-WR/TVS-A)
Cs134 concentration	1.18	1.24	1.17	1.22	1.33 (FA-WR/TVS-A)
Cs concentration	1.06	1.08	1.06	1.08	1.11 (FA-WR/TVS-A)

CONCLUSIONS 1

Only for three characteristics “Activity”, “U236 concentration” and “Cs concentration” the calculated changes depend on manufactory tolerances and operational conditions are negligible (less than 10%).

Other characteristic varies within the limits from 20 to 50 %%. Especially strong dependence within 50% both TVS-A and FA-WR are observed for Pu-239 concentration. For the remaining considered characteristics it is significantly lower and does not exceed 40%.

CONCLUSIONS 2

As regards all considered spent fuel characteristics obtained values determined for average rated operational parameters are not average values and are closer to the minimum possible values. Such results are connected with the presence of control rods clasters within assembly, which has the significant influence on spent fuel isotope composition.

CONCLUSIONS 3

In general, obtained results allow making conclusion that from the viewpoint of safe spent fuel management and storage implementing new alternative fuel of Westinghouse company at VVER-1000 does not require modifications of current conditions and procedures. For the majority of considered spent fuel characteristics the differences between TVS-A (TVEL) and FA-WR (Westinghouse) are less than total changes of these characteristics depending on production tolerance and operation conditions.

THANK YOU FOR YOUR ATTENTION