

CONTENTS

1.	INTRODUCTION	1
1.1.	World nuclear energy situation	1
1.2.	Motivation for partitioning and transmutation	2
1.3.	Purpose and structure of this report	3
2.	POTENTIAL IMPACT OF PARTITIONING AND TRANSMUTATION ON RADIOACTIVE WASTE MANAGEMENT	4
2.1.	Radiotoxicity evolution, hazard and risk	4
2.1.1.	Spent light water reactor fuel	4
2.1.2.	Spent light water reactor MOX fuel	7
2.1.3.	Spent fast reactor MOX fuel	7
2.1.4.	Radiotoxicity of fission products	8
2.1.5.	Advanced conditioning of minor actinides	8
2.1.6.	Transmutation of minor actinides	8
2.1.7.	Natural and archaeological analogues	9
2.2.	Technical issues related to partitioning and transmutation ...	10
2.3.	Effects of changes in long term policy on waste management	12
2.4.	Decision requirements for introduction of partitioning and transmutation	14
2.4.1.	Aqueous processing	14
2.4.2.	Pyrochemical reprocessing and recycling of transuranic elements	16
2.4.3.	Neptunium processing and transmutation issues	16
2.4.4.	Americium and curium processing and transmutation issues	18
2.4.5.	Transuranic element processing and transmutation issues	19
3.	NON-PROLIFERATION ASPECTS OF PARTITIONING AND TRANSMUTATION	21
3.1.	Proliferation potential of neptunium and americium	21
3.2.	Monitoring schemes for neptunium and americium	22

3.3.	Impact of partitioning and transmutation on nuclear non-proliferation	24
3.3.1.	Short and medium term impact	25
3.3.2.	Long term impact	25
3.3.2.1.	Impact on institutional arrangements	25
3.3.2.2.	Impact on safeguards implementation	26
3.3.2.3.	Safeguards implementation at future partitioning and transmutation cycle facilities	26
3.4.	Development of proliferation resistant partitioning and transmutation technology	27
3.4.1.	Proliferation resistance measures	27
3.4.2.	Proliferation resistant strategies for partitioning and transmutation development	28
3.4.3.	Intrinsic technological measures	28
3.5.	Technical aspects of proliferation control	29
3.5.1.	Partitioning	30
3.5.2.	Proliferation resistance of advanced aqueous processing	30
3.5.3.	Safeguardability of advanced aqueous partitioning ...	31
3.5.4.	Partitioning by pyroprocessing	32
3.5.4.1.	Safeguardability of pyroprocessing	33
3.6.	Safeguards and proliferation issues of transmutation	34
3.6.1.	Proliferation resistance of transmutation reactors ...	34
3.6.2.	Safeguardability of transmutation reactors	35
4.	FUEL CYCLES	36
4.1.	Introduction	36
4.1.1.	Once through fuel cycle	36
4.1.2.	Plutonium recycling in light water reactor MOX	37
4.1.3.	Plutonium recycling in light water reactor MOX and fast reactor MOX	39
4.1.3.1.	Associated MOX fuel fabrication and refabrication problems	40
4.1.4.	Plutonium and minor actinide recycling in light water reactor UO ₂ and MOX and in fast reactor burner transuranic elements	42

4.1.4.1.	Metal fuel fabrication for advanced liquid metal reactors and advanced fuels for burner reactors	43
4.1.5.	Plutonium and minor actinide recycling in light water reactor UO ₂ and MOX and accelerator driven system transuranic elements	43
4.1.6.	Plutonium and minor actinide recycling in a combined double strata strategy scenario	45
4.1.7.	Generation IV	47
4.2.	Dual purpose conditioning for transmutation and/or disposal	48
4.2.1.	Fuel/target fabrication of minor actinides	48
4.2.1.1.	Zircon	49
4.2.1.2.	Zirconia inert matrix	50
4.2.1.3.	Rock-like yttria stabilized zirconia and spinel	50
4.2.1.4.	Yttria stabilized zirconia based inert matrix fuel	50
4.2.1.5.	Americium and curium incorporation into zirconia based materials	51
4.2.2.	Current research and development studies on inert matrix fuels	51
5.	PARTITIONING	51
5.1.	Partitioning of minor actinides from aqueous reprocessing streams	51
5.1.1.	Partitioning of neptunium	52
5.1.2.	Partitioning of americium and curium from high level liquid waste resulting from spent light water reactor fuel	53
5.1.3.	Status of partitioning processes	56
5.1.3.1.	TRUEX process	56
5.1.3.2.	DIAMEX process	56
5.1.3.3.	TRPO process	57
5.1.3.4.	An(III)–Ln(III) separation	57
5.1.3.5.	Americium and curium separation	59
5.1.4.	Comparative testing of advanced aqueous processes	60
5.1.5.	Conditioning of separated minor actinides and fabrication of irradiation targets	62
5.2.	Pyrochemical reprocessing	64

5.2.1.	Principles of pyroprocessing	65
5.2.2.	Pyroprocessing in the USA	66
5.2.3.	The European Union roadmap	70
5.2.4.	Russian development programme	71
5.2.5.	Japanese research and development programme	72
5.2.6.	Other activities	74
5.3.	Separation of long lived fission and activation products	74
5.3.1.	Fission products	74
5.3.2.	Activation products	77
5.3.3.	Other radionuclides	77
6.	TRANSMUTATION	78
6.1.	Transmutation efficiency	78
6.2.	Fuel concepts for transmutation	79
6.2.1.	Solid fuel	79
6.2.1.1.	Oxide fuels and targets	80
6.2.1.2.	Non-oxide fuels and targets	82
6.2.2.	Liquid fuel	83
6.3.	Transmutation potential of various reactor types	84
6.3.1.	Light water reactors	84
6.3.1.1.	Minor actinide recycling in light water reactors	85
6.3.1.2.	Irradiation of neptunium.....	86
6.3.1.3.	Irradiation of americium.....	88
6.3.1.4.	Conclusions on thermal neutron irradiation of minor actinides.....	90
6.3.2.	Fast reactors	91
6.3.2.1.	Transmutation-incineration of neptunium... ..	92
6.3.2.2.	Transmutation of americium	92
6.3.2.3.	Multiple recycling of plutonium and minor actinides in critical fast reactors	94
6.4.	Accelerator driven systems	95
6.4.1.	Spallation target	96
6.4.2.	Subcritical core	96
6.5.	Transmutation issues of long lived fission products	97
6.5.1.	Iodine-129	99
6.5.2.	Techneium-99	99
6.5.3.	Caesium-135	100
6.5.4.	Zirconium-93	100
6.5.5.	Tin-126	100

6.5.6.	Carbon-14	100
7.	ADDITIONAL WASTE MANAGEMENT CONSIDERATIONS	101
7.1.	Impact of improved reprocessing	102
7.1.1.	Residual plutonium	102
7.1.2.	Neptunium	102
7.1.3.	Iodine	102
7.1.4.	Technetium	103
7.2.	Impact of advanced processing	103
7.2.1.	Pyrochemical processing	104
7.3.	Impact of transmutation on waste management and disposal	105
8.	CONCLUSIONS	109
9.	RECOMMENDATIONS TO DECISION MAKERS	110
	REFERENCES	111
	ANNEX I: NATURAL AND ARCHAEOLOGICAL ANALOGUES ...	119
	ANNEX II: CURRENT STUDIES ON INERT MATRIX FUEL	122
	ABBREVIATIONS	125
	CONTRIBUTORS TO DRAFTING AND REVIEW	127