

## CONTENTS

1.	INTRODUCTION .....	5
2.	BALTIC SEA .....	10
2.1.	Main environmental problems .....	11
2.2.	HELCOM .....	12
2.3.	Baltic Sea Action Plan .....	14
2.4.	Sub-basins of the Baltic Sea.....	16
3.	EMEP MSC-W MODEL .....	20
3.1.	Development of the EMEP model .....	20
3.2.	Model domain and vertical structure .....	21
3.3.	Basic equations and numerical solutions.....	25
3.3.1.	Continuity equation .....	26
3.3.2.	Advection .....	26
3.3.3.	Diffusion .....	27
3.3.4.	Convection .....	27
3.4.	Dry deposition .....	27
3.4.1.	Dry deposition of gases .....	28
3.4.2.	Dry deposition of aerosols .....	28
3.5.	Wet deposition .....	29
3.5.1.	In-cloud scavenging .....	29
3.5.2.	Below-cloud scavenging .....	29
3.6.	Chemistry .....	30
3.7.	Input data for the EMEP MSC-W model .....	32
3.7.1.	Emissions .....	32
3.7.2.	Meteorology.....	34
3.7.3.	Land use data .....	35
3.8.	Model output .....	36
3.8.1.	Concentrations and depositions .....	37
3.8.2.	Source-receptor matrices .....	38
3.9.	Uncertainty of the model results .....	40
3.9.1.	Model results versus measurements in the EMEP domain .....	40
3.9.2.	Model results versus measurements in the Baltic Sea region ...	44
4.	NITROGEN EMISSION .....	48
4.1.	Historical nitrogen emissions.....	49
4.1.1.	Land sources .....	49
4.1.2.	Shipping emissions .....	51
4.2.	Annual EMEP emissions in 2011 .....	51
4.2.1.	Total and sector emissions for the model run .....	52
4.2.2.	Spatial distributions of nitrogen emissions .....	56
4.3.	Annual nitrogen emissions in the period 1985-2011 .....	58
4.3.1.	Emissions in the EMEP domain.....	59
4.3.2.	Emissions from the HELCOM Contracting Parties .....	60
4.3.3.	Ship emissions on the Baltic Sea.....	62
4.4.	Future nitrogen emissions .....	66

4.4.1. Nitrogen oxides emissions up to 2050 .....	64
4.4.2. Emissions in 2020 according to Gothenburg Protocol.....	66
4.4.2. Future ship emissions.....	69
<b>5. NITROGEN DEPOSITION.....</b>	<b>71</b>
5.1. Previous estimates of nitrogen deposition .....	72
5.2. Nitrogen depositions in 2011 .....	74
5.2.1. Annual depositions to the Baltic Sea basin.....	74
5.2.2. Annual depositions to individual sub-basins .....	78
5.2.3. Monthly depositions in 2011 .....	78
5.3. Nitrogen depositions in the period 1995-2011.....	80
5.3.1. Annual depositions to the Baltic Sea basin.....	80
5.3.2. Annual depositions to individual sub-basins .....	81
5.3.3. Seasonal variation of nitrogen deposition.....	82
5.4. Influence of meteorology on nitrogen deposition .....	83
5.5. Reductions of nitrogen deposition between 1995 and 2011.....	85
5.6. Comparison of changes in nitrogen emissions and nitrogen depositions .....	87
5.7. Estimation of future nitrogen deposition.....	88
<b>6. SOURCE ALLOCATION BUDGET FOR NITROGEN DEPOSITION .....</b>	<b>89</b>
6.1. Source allocation budget for 2011 .....	89
6.1.1. Contributions to the Baltic Sea basin .....	89
6.1.2. Contributions to sub-basins.....	91
6.2. Source allocation budget for the period 1995-2011 .....	95
<b>7. NORMALISED DEPOSITION.....</b>	<b>97</b>
7.1. Normalisation procedure .....	97
7.1.1. Contributions from individual sources.....	98
7.1.2. Source-receptor matrices .....	100
7.1.3. Calculation of normalised deposition .....	101
7.2. Calculated normalised depositions for the period 1995-2011....	102
7.3. Comparison of emissions and normalised depositions .....	102
<b>8. EFFECTS OF THE REVISED GOTHENBURG PROTOCOL .....</b>	<b>105</b>
8.1. Method for calculating 2020 depositions.....	105
8.2. Reductions of nitrogen depositions in 2020.....	106
8.3. Results for the HELCOM Contracting Parties .....	109
8.3.1. Reductions from all HELCOM sources .....	109
8.3.2. Reductions from individual HELCOM Contracting Parties.....	113
<b>9. SUMMARY AND CONCLUSIONS .....</b>	<b>116</b>
<b>10. REFERENCES.....</b>	<b>120</b>
Appendix A .....	129
Appendix B.....	132