Modelling and Evaluation of Impact on Population due to Continuous Emissions from the Severonickel Smelters (Kola Peninsula)

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Abstract

This study is devoted to evaluation of total deposition and loading patterns for population of North-West Russia and Scandinavian countries due to continuous emissions (following "mild emission scenario") of sulphates from the Cu-Ni smelters (Severonickel enterprise, Murmansk region, Russia). The Lagrangian long-range dispersion model (Danish Emergency Response Model for Atmosphere) was run in a long-term mode, and results were integrated and analyzed in GIS environment. Estimation was performed on annual and seasonal scales, including depositions, impact on urban areas and calculating individual and collective loadings on population in selected regions of Russia and Scandinavian countries.

Pollution from Cu-Ni Smelters

There are several major locations in the Russian Arctic associated with large amounts of sulphur dioxide (SO2) and heavy metals emissions and known as the largest Cu-Ni smelters. These are three Russian enterprises: Norilsk Nickel (Krasnoyarsk Krai), Pechenganickel (cities of Zapolyarny and Nikel, Murmansk region) and Severonickel (city of Monchegorsk, Murmansk region). According to the plans of Kola Mining and Metallurgical Company a reduction of emissions had been performed in recent years. For example, at the beginning of the last decade (year of 2000), the SO_2 emissions from the Severonickel and Pechenganickel enterprises reached 45300 and 151200 tonnes, respectively (*Ekimov et al., 2001*).

Long-Term Modelling and Analyses

To estimate potential impact on population due to continuous emissions, the Lagrangian-type Danish Emergency Response Model for Atmosphere (DERMA; *Sorensen, 1998; Baklanov et al., 2008*) in a long-term mode was employed to perform long-term simulations of air concentration, time integrated air concentration (TIAC), dry (DD) and wet (WD) deposition patterns (Fig. 1) resulting from continuous emissions of the Severonickel smelters located on the Kola Peninsula (Murmansk region, Russia). To perform such simulations the European Center for Medium-Range Weather Forecasts (ECMWF) 3D meteorological fields for the year 2000 were used as input. For simplicity, it has been assumed that the daily unit releases of sulfates from smelters location occurred at a constant rate of 10^9 µg/sec (i.e. 86.4 ton per day). Then, for each daily release the followed atmospheric transport, dispersion, and deposition on the underlying surface due to dry and wet removal processes were estimated on intervals ranging from 0.5 to 10 days. Moreover, it should be noted that output from such long-term simulations is an essential input for evaluation of impact, doses, risks, and short- and long-term consequences, etc.

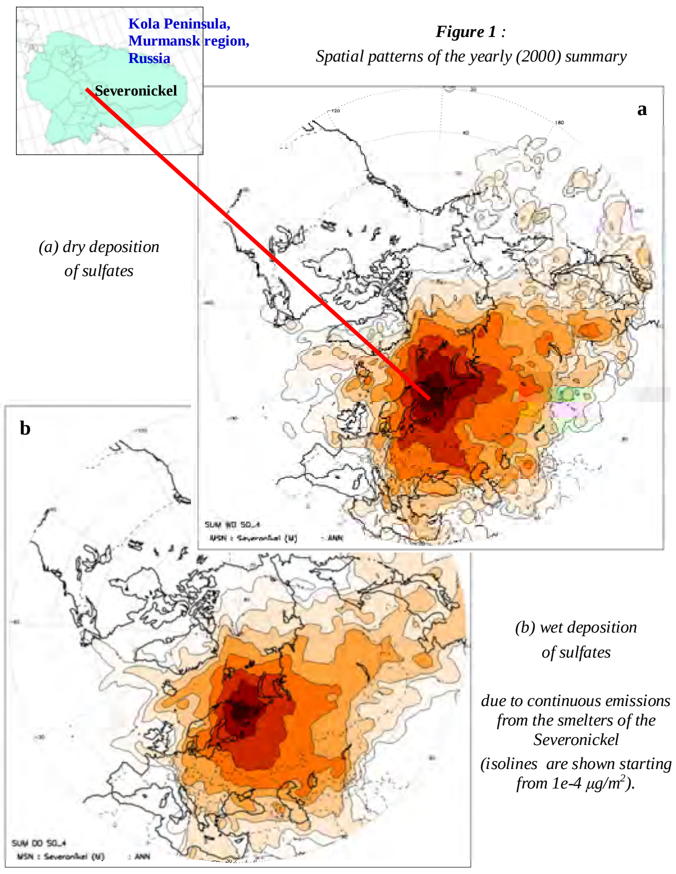

***Figure 1**: Spatial patterns of the yearly (2000) summary*

(a) dry deposition of sulfates

(b) wet deposition of sulfates

due to continuous emissions from the smelters of the Severonickel

(isolines are shown starting from 1e-4 µg/m²).

The modeled DD and WD fields were analyzed as a function of monthly variability (Fig. 2) and regional distribution (Table 1). Deposition data were also integrated into GIS environment (Fig. 3a) taking into account standard administrative division of the North-West Russia and bordering countries (Fig. 3a), population density (Fig. 3b) overlapped with modelling results and administrative boundaries data (Fig. 3c). The estimation of deposited amounts (loadings) of sulfates for selected regions of Russia and border countries has been performed (Fig. 4). The Atlas of potential impact from all locations of the Cu-Ni smelters was elaborated (Fig. 5) which included temporal (monthly) variability of both summary and averaged types of the TIAC, DD and WD fields. Results of this study are summarized in *Mahura et al.* (2012).

Monthly Variability of Deposition Patterns

For the "mild scenario emissions" (i.e. approx. 31.6 ths. ton), for the Severonickel smelters, on annual scale, daily dry deposition is about 6 t with the highest (10 t) - in September (Figure 2). The wet deposition is 23 t (maximum 50 t - in February), and it is dominating in total deposition. On average, 33% of emissions could be deposited on the surface during 10 days of atmospheric transport from the smelters with the highest (65%) and lowest (14%) deposited amounts observed in February and July, respectively.

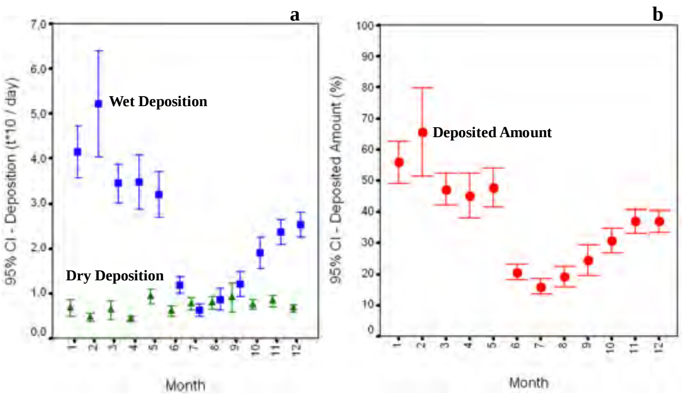

***Figure 2**: Month-to-month variability at 95% confidence interval of averaged dry and wet deposition patterns (in tonnes per day) and (b) deposited amount (in %) resulted from the Severonickel continuous emissions.*

Regional Distribution of Deposition Patterns

The Murmansk region of Russia, where the smelters are located, is the most impacted, followed by Karelia Republic and Arkhangelsk region (with total deposition more than order of magnitude lower compared with the Murmansk region) (Tab. 1). Among administrative units of the Scandinavian countries - Lapland (Finland), Norrbotten (Sweden) and Finnmark (Norway) - have the highest depositions. On average, it is higher in fall for all three Scandinavian countries; and lower in summer (for Finland) and winter (for Norway). For Russian regions, on average, deposition is higher in spring (except, Arkhangelsk and Nenets regions), and it is lower in summer and winter. The maximum deposition is observed for the northern, central, and southern territories of Finland in spring, fall and winter, respectively. For Sweden, it occurs in fall. For northernmost part of Norway it takes place in spring, and for other territories – in fall. For Russia, the largest maxima are linked with spring and fall for territories southerly and easterly of the Severonickel smelters, respectively.

Country	Region/ County/ Province	Total Deposition (µg/m²)									
	Seasons	Spring		Summer		Fall		Winter		Year	
	Statistics	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max
Finland											
	Lapland	623	2263	230	571	940	2219	392	2117	2185	7170
	Oulu	282	792	61	180	802	1344	297	594	1442	2910
	Eastern Finland	70	122	21	38	316	698	160	354	567	1200
	Western Finland	30	40	8	17	131	573	37	64	205	640
	Southern Finland	42	73	9	18	48	105	85	137	183	332
Norway											
	Finnmark	826	3218	307	760	909	2242	197	889	2239	6730
	Troms	26	49	40	91	126	235	10	29	202	403
	NordLand	4	11	3	11	18	31	3	7	28	50
Russia											
	Murmansk	11228	56495	2279	7849	4369	11124	10406	46667	28282	122000
	Karelia	581	2181	198	611	542	1476	447	1677	1768	5050
	Arkhangelsk	112	578	115	1185	282	1651	42	148	551	3030
	Nenets	161	376	11	36	249	702	21	193	442	1250
	Vologda	107	391	26	216	66	243	15	47	214	864
	Leningrad	83	221	19	45	28	67	66	102	196	309
Sweden											
	Norrbotten	16	67	19	75	92	268	11	65	138	397
	Vesterbotten	2	7	1	2	15	31	12	29	30	69
	* Maximum - HIGH vs. LOW										

***Table 1**: Regional distribution of total deposition (annual and seasonal) due to continuous emissions of the Severonickel smelters.*

Atlas of Potential Impact from Anthropogenic Sources

MSN: Monchegorsk (Severonickel)

AVG TIAC AVG DD AVG WD SUM TIAC SUM DD SUM WD

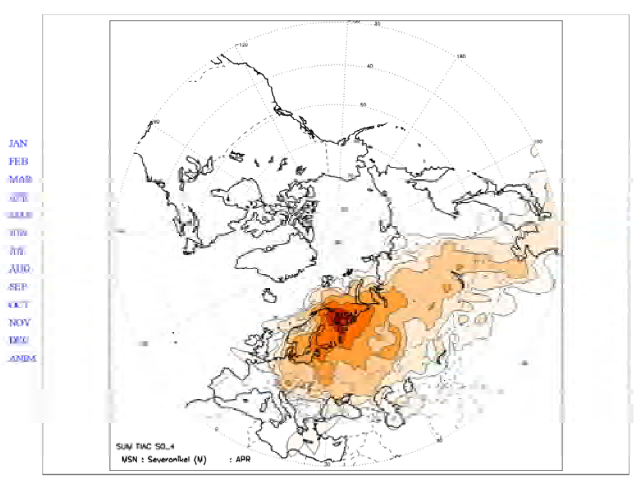

***Figure 5**: Snapshot of Atlas showing spatial representation of the summary time integrated air concentration field during April resulted from Severonickel continuous emissions.*

GIS Integration of Modelling, Population and Administrative Boundaries

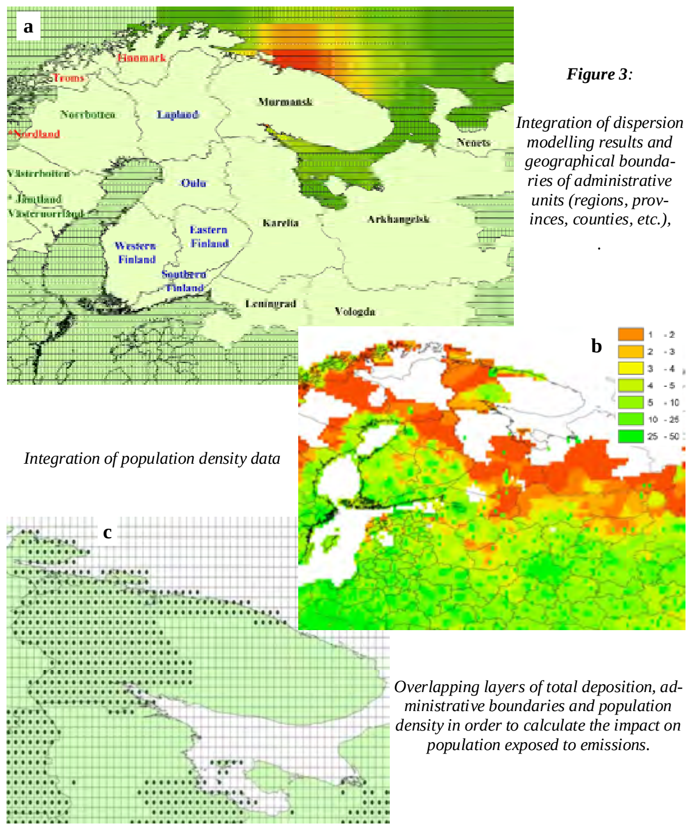

***Figure 3**: Integration of dispersion modelling results and geographical boundaries of administrative units (regions, provinces, counties, etc.),*

Integration of population density data

Overlapping layers of total deposition, administrative boundaries and population density in order to calculate the impact on population exposed to emissions.

Individual and Collective Loadings on Population

The yearly ***individual loading*** can be up to 120 kg/person for the most populated urban areas of the Murmansk region (Figure 4). For bordering territories with this region such loadings are less than 5 kg/person for territories of eastern Finland, Karelia Republic, and Arkhangelsk region; and not greater than 15 kg/person – for Finnmark county of Norway. There exists seasonal variability (with lowest loadings in summer), which is less pronounced for Scandinavian countries. The percentage contribution into such loading is higher in winter-spring for Russia (in sum 85%), in spring for Norway (34%), in fall for Finland and Sweden (32 and 41%, respectively).

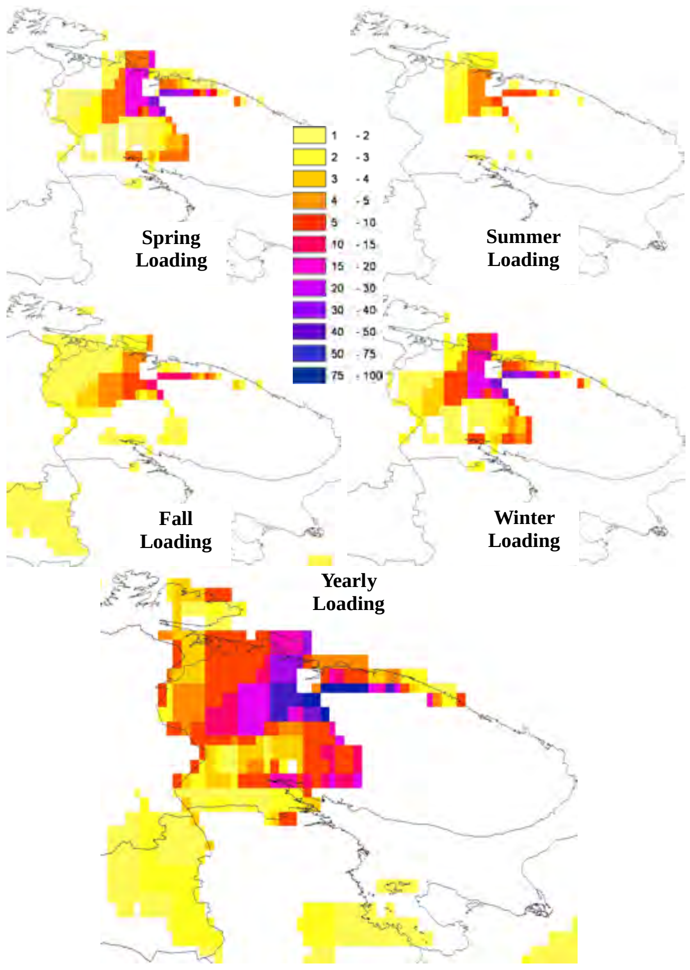

***Figure 4**: Seasonal variability of individual loadings for population (in kg/person) from deposited sulfates resulted from the Severonickel smelters continuous emissions (mild scenario).*

The yearly **collective loading** is the highest (2403 tonnes) for the Murmansk region. Both Karelia Republic and Arkhangelsk region have the second largest loadings (83 and 77 t). These three regions account for 97.5% of yearly value. For populated territories of bordering countries with the Murmansk region such loadings are 140.4, 13, and 10.7 t for Finland, Norway and Sweden, correspondingly.

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