Emissions from Diesel Non-Road Vehicles: A Case Study of Murmansk Region

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Outline

- Overview of black carbon project;
- Objectives of the inventory;
- BC emissions results (focus on off-road transport);
- Emissions standards;
- Conclusions.

What is Black Carbon?

- A component of particulate matter (PM) formed by incomplete combustion of fossil fuels and biomass;
- The impacts of fine particles ($PM_{2.5}$), including black carbon, may result in premature deaths and risks to the cardiovascular system;
- Black carbon (BC) is the most strongly light-absorbing component of particulate matter;
- Major contributor to current global warming following carbon dioxide and methane.

Diesel BC Emissions in the Russian Arctic: Why it is Important?

- Russia makes up a large share of the Arctic;
- Russia has very little data on its black carbon emissions;
- Diesel emissions from within the Russian Arctic contribute substantially to total Arctic concentrations of BC;
- The Arctic Council, including Russia, works on BC emission reductions in the Arctic.

"Arctic Black Carbon: Reduction of Black Carbon from Diesel Sources" Project

- Sponsored by the U.S. Department of State and supported by the U.S. Environmental Protection Agency
- Project Objectives:
  - Assess primary sources of black carbon in the Russian Arctic;
  - Develop a targeted baseline emission inventory for black carbon from diesel sources in key areas;
  - Establish policy recommendations and financing options for reducing black carbon diesel sources.

Main Results of Black Carbon Emissions Inventory from Diesel Sources in Murmansk Region

$PM_{2.5}$, BC and OC Emissions in Murmansk Region (tons)

Activity	$PM_{2.5}$	BC	OC
On-road transport	98.9	53.7	36.2
Mines	450.5	279.3	83.8
Locomotives	30.5	22.3	4.5
Construction	15.6	12.0	2.4
Agriculture	5.0	3.9	0.8
Diesel generators	35.2	27.1	5.4
Fishing (in Russian waters)	16.5	5.1	1.0
Total	**652.3**	**403.4**	**134.1**

Diesel Consumption in Murmansk Region, 2012: Top-Down and Bottom-Up Approaches

Activity	Diesel use (tons)
On-road transport *	65,100
Mines	139,000
Locomotives	21,200
Construction	4,100
Agriculture	1,300
Diesel generators, including:	8,800
Small generators for commerce and services	7,100
Off-grid generators *	1,700
Fishing (in Russian territorial waters) *	3,000
Total	**242,500**

* - bottom-up calculations

On-Road Transport

- Data sources on vehicle fleet and activity: registry, parking lot surveys, vehicle inspection station, video surveys, GPS logger data, municipal data.
- Highlights:
  - Share of diesel cars – 12%;
  - The share of vehicles with emissions controls is higher than shown in the registry;
  - Only 40-50% of vehicles are in use in Murmansk City;
  - Euro 0 trucks are the major source of BC emissions.

Off-Road Sources of Black Carbon Emissions

- Off road vehicles:
  - Mining industry;
  - Construction and road management vehicles, including snow plows;
  - Locomotives;
- Diesel generators;
- Fishing ships.

Mining Industry

- There are 4 big mining companies in Murmansk Region;
- Diesel consumption:
  - top-bottom approach -139,013 tons
  - bottom-up approach – 138,554 tons
- Sources of BC emissions:
  - mining haul trucks;
  - shovels, bulldozers, excavators;
  - supplementary vehicles;
  - drilling equipment.

Mining Trucks

- Mining vehicles consume 85% of diesel in the industry;
- An average truck consumes more than 1 ton of diesel per day or about 500 tons per year;
- BELAZ trucks dominate the market of large mining trucks and constitute 70% of the mining fleet;
- Most BELAZ trucks are equipped with Cummins engines.

BC Emissions from Mining

- 88 percent of Cummins engines in Murmansk region are Tier 0 (do not have emissions controls);
- 12 percent of Cummins engines are Tier 1;
- Emission factor for mining trucks :
  - Tier 0: 3.551 g $PM_{2.5}$/kg fuel;
  - Tier 1: 0.967 g $PM_{2.5}$/kg fuel
- Caterpillar and Komatsu mining trucks might have cleaner engines;
- Total BC emissions by mines ~ **280 tons** per year.

Locomotives

- The most popular diesel locomotives are Soviet- or Russian-made with a power output of 882 or 1,500 kW;
- Locomotives do not have any emission controls and are old;
- Emission factor for locomotives: 1.44 g $PM_{2.5}$/kg fuel;
- BC emissions by locomotives -

  22.3 tons per year.

Construction and Road Management

- Off-road vehicles in the construction industry used 3,205 tons diesel fuel;
- Road management companies used 865 tons of fuel;
- We used EMEP-EEA emission factors:

  - 4.038 g $PM_{2.5}$ /kg fuel for construction vehicles without controls;

  - 3.551 g $PM_{2.5}$ /kg fuel for road management equipment without controls;

  - 0.967 g/kg fuel for equipment with controls.

- Total BC emissions – **12.0 tons** per year.

Emission Standards for Off-Road Vehicles

Off-Road Diesel Engine PM Emission Standards, g/kWh

	United States		European Union	
130<kW<560	Tier 1	0.54	Stage I	-
	Tier 2	0.20	Stage II	0.20
	Tier 3	0.12	Stage III A	0.20
	Tier 4i	0.02	Stage III B	0.025
	Tier 4f	0.02	Stage IV	0.025
kW>560	Tier 1	0.54	Stage I	-
	Tier 2	0.20	Stage II	-
	Tier 3	0.12	Stage III A	-
	Tier 4i	0.10	Stage III B	-
	Tier 4f	0.04	Stage IV	*

* Proposed from 2016

Off-Road Diesel Engine PM Emission Standards

- **United States:** 450 ≤ kW < 560 Tier 1 standard in 1996; Tier 2 in 2002; Tier 4i in 2011
- >560 kW: Tier 1- 2000, Tier 2 – 2006.
- **Canada**: U.S. Tier 3 standard in 2006 (450≤ kW<560), Tier 2 emission in 2006 (>560 kW)
- **European Union**: Stage I standard (130 ≤ kW ≤ 560) in 1999; Stage II in 2002; Stage IIIa in 2006, Stage IIIb in 2011, Stage IV in 2014
- **China**: Stage I in 2007, Stage II in 2009 (130 ≤ kW ≤ 560)
- **Japan**: similar to Tier 3 / Stage IIIa in 2008, Tier 4 in 2013
- **Brazil**: similar to Tier 3 / Stage IIIa standard in 2015-2017.

Emissions Regulations for Off-Road Vehicles in Russia

- GOST R 41.96-2011 “Uniform provisions on engines in agricultural and forestry tractors and in non-road mobile machinery” was developed in 2011 and approved by the Federal Agency on Technical Regulation and Metrology in 2013;
- It set the standard for PM emissions for off-road engines with power output between 130-560 kW at 0.2 g/kWh (equivalent of Tier 2/Stage II). It did not come into force;
- Russia does not have emissions regulations of off-road vehicles. Technical regulation to control PM emissions should be approved by the Eurasian Economic Commission.

Off-Road Transport Plays an Important Role in Total Diesel Emissions in Russia (2010)

Sector	Diesel, million tons	BC emissions, tons
On-road transport *	17.3	31,100
Agriculture and forestry**	2.8	8,200
Industry	2.6	5,600
Other sectors	2.9	11,800
Total	**25.6**	**56 700**

* 5,181,200 diesel vehicles.

** ~300,000 tractors in agriculture.

Policy Conclusions

- Off-road vehicles represent an important opportunity for additional emission reductions;
- Regulation is required to achieve these reductions;
- The costs of meeting higher emission standards is 1-3 percent of the purchase price of typical new non-road diesel equipment (EPA);
- Emissions reductions bring benefit to local communities and environment;
- Better air quality monitoring system is needed.