An atmospheric emission inventory of anthropogenic and biogenic sources for Lebanon.

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A temporally-resolved and spatially-distributed emission inventory was developed for Lebanon (where data on air pollution are sparse and inexistant) to provide quantitative information for air pollution studies as well as for use as input to air quality models. This inventory covers major anthropogenic and biogenic sources in the region with 5 km spatial resolution for Lebanon and 1 km spatial resolution for its capital city Beirut and its suburbs. Furthermore, monthly, daily and hourly temporal profiles were developed for several emission sources.

Methodology

Emissions were calculated using the methodologies stated in the EMEP guide book (EMEP/EEA, 2009). Anthropogenic emission sources include transport, energy production, industrial, waste generation and agriculture sectors, while the biogenic emission sources include biomass burning and the emissions from forests and grasslands. The pollutants or pollutant categories include CO, NO_x, SO_2, NMVOC, ammonia NH_3, PM_{10}, and $PM_{2.5}$.

A bottom-up approach was used where possible, in particular, for the on-road transport sector as well as for the power and industrial plants using activity data for individual sources (number of vehicles, annual production in GJ for a power plant ...), because these sectors are believed to be major contributors of air pollution in Lebanon. For other sources, a top-down approach was adopted using regional activity data.

Annual Results

The total estimated anthropogenic and biogenic emissions by source category as well as major source contributors are presented in Table 1.

Table 1. Annual results.

Pollutants	Gg/year	Major contributor	Value(%)
CO	563	Road transport	93
NO_x	75	Road transport	52
SO_2	62	Industrial plants	73
NMVOC	83	Road transport	55
NH3	4	Agriculture	98
PM_{10}	12	Industrial plants	62
$PM_{2.5}$	9	Industrial plants	59

- The contribution of on-road mobile sources to total CO, NO_x and NMVOC emissions (Figure 1) is related to the fact that in Lebanon personal vehicles are the prevailing mode of transport and public transport is dominated by passenger cars and shared taxis with the absence of a rail transport system.

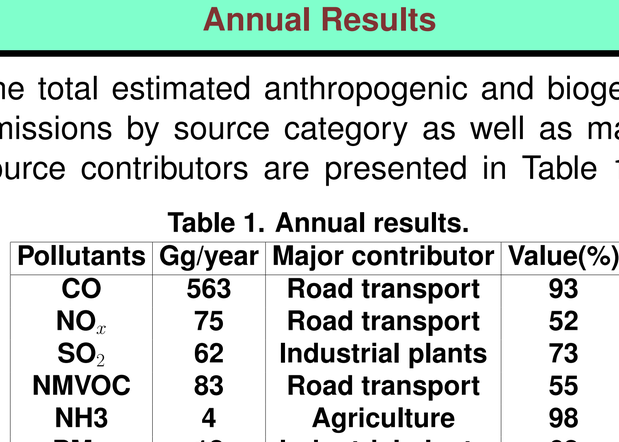

Figure 1. Category contribution by source

- For PM, the large contribution of industrial plants mainly cement plants is related to the fact that the annual production of cement in Lebanon is the highest when compared to other manufacturing industries (lime, fertilizers..).
- For SO_2, the reason is due to the fact that the fuel used for the production of 42 percent of the energy is heavy fuel oil (CAS, 2009), which has a sulphur content of 25000 to 30000 ppm by weight (MoE, 2005).

Spatial emissions

The annual anthropogenic and biogenic emissions were spatially allocated to 5 km x 5 km grid cells for Lebanon (Figure 2) and to 1 km x 1 km grid cells for Beirut with its suburbs (Figure 3).

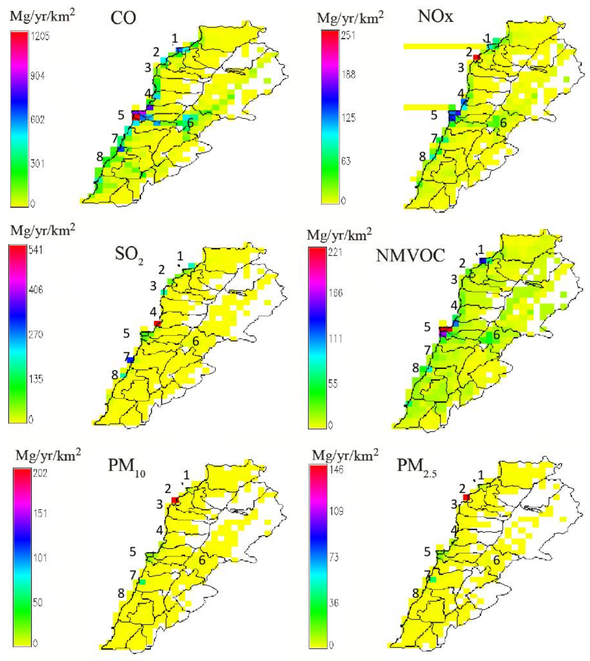

Figure 2. Spatial distribution of emissions for Lebanon

- CO emissions are mainly distributed over the grid cells of Beirut and its suburbs (5), Tripoli (1) and Saida (8) because these locations encounter the majority of road transport in terms of vehicle-km travelled. CO emissions are also distributed over the grid cells of line sources (highways and major roadways)
- For SO_2 emissions, major contributing areas include the regions of Zouk Mikael (4) and Jieh (7), where the power plants are located as well as the region of Seelata (fertilizers and sulphuric acid industry)
- PM emissions are highest in the region of Chekka (2) (location of the cement plants).

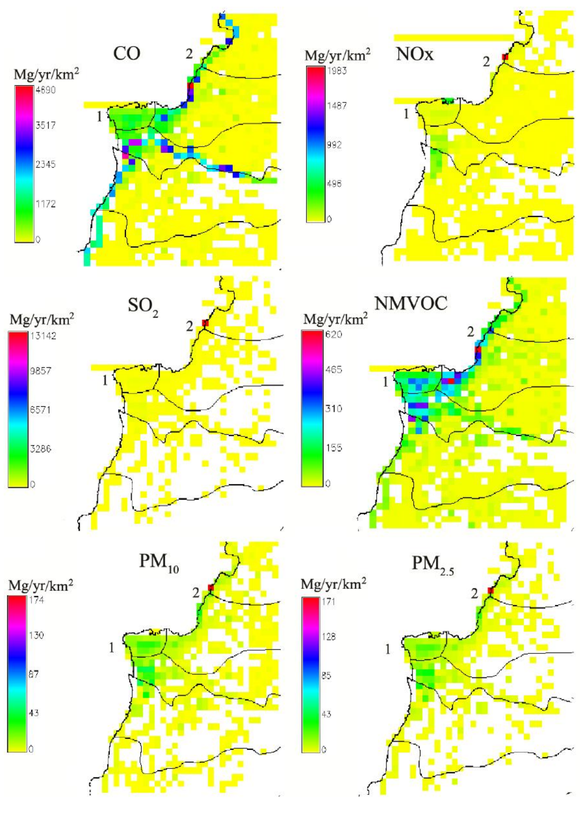

Figure 3. Spatial distribution of emissions for the inner domain

- For the inner domain, major contributions for CO emissions are from the city of Beirut (1), from the highways and roadways near the coast and from the area between Beirut and the Bekaa region, where there is dense population, heavy traffic flow and numerous point sources.
- The area near the coast line where heavy traffic flow, dense populations and a lot of small industries are located contributes significantly to NMVOC emissions.
- The power plant of Zouk Mikael (2) contributes mainly to NO_x, SO_2 and PM emissions.

Temporal profiles

- For power plants (Figure 4) energy consumption increases during July-August and December-January because a supplement of energy is needed for air conditionning in summer and for heating in winter.
- For on-road mobile sources, an increase in the number of vehicles is observed in the months of December and January and a decrease in the months of August and September.
- The diurnal variations in the urban areas of both weekdays and weekends show a morning peak (7 am - 10 am) and an evening peak (4 pm - 6 pm) for weekdays. On Saturdays, one peak is observed from 11 am to 2 pm. On Sundays, the morning peak is from noon to 1 pm and the evening peak is from 5 to 7 pm.

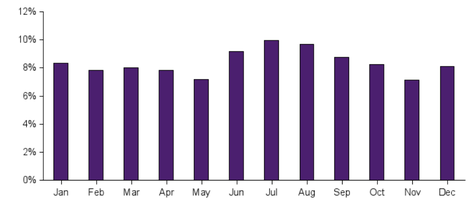

Figure 4. Monthly variations of emissions from power plants

Conclusion

An atmospheric emission inventory of anthropogenic and biogenic sources for Lebanon was developed. The major contributor to total CO, NO_x and NMVOC emissions is the road transport sector while the major contributors to total PM and SO_2 emissions are the power and industrial plants.The spatial distribution of emissions shows that CO, NO_x, and NMVOC emissions are mostly over Beirut and its suburbs, Tripoli and Saida. Large power plants and industrial plants in the regions of Zouk Mikael, Jieh, Chekka and Selaata are the major contributors to concentrations of SO_2, PM_{10} and $PM_{2.5}$.

Prospects

Future improvements of the emission inventory should focus on (1) refinements of the activity data for the identified major sources (on-road traffic, power plants, large industrial plants) as well as the development of Lebanon-specific emission factors for on-road transport and (2) the addition of potentially missing important natural sources of coarse PM emissions (sea salt and desert dust).

References

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- MoE, 2005. National environmental action plan, Ministry of Environment, Beirut - Lebanon.