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Industrial pollution

DETERMINING THE IMISSIONS OF OZONE AND NITROGEN OXIDES IN THE VICINITY OF OVERHEAD ELECTRIC LINES

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Abstract. The main environmental negative impacts of the overhead electric lines (OHLs) are of the following types: physical, electromagnetic, visual, mechanical, sonorous and chemical (by generating ozone and nitrogen oxides due to corona phenomenon). With reference to the assessment of the 'environmental externalities', 'Transelectrica' has initiated a systematic action for determining the concentration of O_3 and NO_x (imissions) in the atmosphere in the vicinity of the own OHLs. The epidemiological studies evidenced some acute effects (irritations of eyes, nose and throat) due to exposure of the young people to more than 200 μg/m^3 hourly concentrations of O_3 in the atmosphere. The combinations of O_3 with NO_2, SO_2 or powders in suspension have stronger synergic effects upon human beings and environmental factors. This work presents the results of O_3 and NO_x measurement made for the first time in Romania in between 2001-2002, by means a specialised mobile laboratory. The measurements were performed in two conditions (cold and warm seasons) at OHLs with various voltages (110, 220 and 400 kV) both below the conductors and in the area of their supporting towers (poles) under various weather conditions. Estimation of OHL contribution to O_3 and NO_x generation in the air next door was made based on the difference between the values of measurement below the OHL and the reference ones (away from OHL).

Keywords: overhead electric line, 'corona' phenomenon, ozone and nitrogen oxides imissions.

AIMS AND BACKGROUND

IMPACTS OF THE POWER GRIDS UPON THE ENVIRONMENT

The power grids mainly consisting of power lines (over head/underground) and electric substations (transforming/connection) have positive impacts upon the environment as follows:

- creation of work places all along their whole life cycle: civil engineering/ erection, operation/maintenance, replacement/dismantling;
- enabling electricity flow from generators to distributors/users considering its beneficial role played in any human activity;

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• facilitating the electricity users' access to the 'green' power plants (hydro-, solar- and wind power plants).

Although they are not major polluting sources as other energy installations are considered such as the thermal power plants[1], the power grids have certain negative impacts upon the environment during their whole life cycle.

The main negative impacts of the OHLs are of the following types:

• *physical* by occupying the land, land clearing, fragmenting the habitats, blocking the flight of birds;

• *electromagnetic* by the effects of the electric and magnetic fields upon the living bodies and upon the voice, radio and TV systems;

• *visual* by affecting the landscape;

• *mechanical* by the possibility of flying machines crash, the danger of collapsing at crossing of roads, railways, waters, etc., and the danger of fire when being accidentally touched by objects or dry vegetation;

• *sound* by noises caused by items of the grid operation/vibration or by corona phenomenon;

• *chemical* by generating ozone and nitrate oxides due to 'corona' phenomenon[2].

'CORONA' PHENOMENON

During the power grid operation, both in the vicinity of OHLs and below the bus bars of the transforming/connection substations, mostly at the ones over 220 kV and under high air humidity conditions, the so called 'corona' phenomenon occurs featured by independent and incomplete discharges concentrated round the live item. The 'corona' phenomenon manifests itself by[3]:

• audible noises in a wave band ranged between 20 and 20 000 Hz;

• visual phenomenon in a wave band ranged between 10^{14} and 10^{15} Hz;

• radio disturbances in a wave band ranged between 0.5 and 1.6 MHz;

• disturbances of the TV facilities in a wave band ranged between 24 and 216 MHz;

• disturbances of the high frequency voice facilities with carrying currents;

• emissions of ion 'species' or free radicals (O_3 and NO_x).

IMPACTS OF OZONE AND NITROGEN OXIDES UPON THE ENVIRONMENT

Impacts upon human health. Except the atmosphere ozone which retains a huge part of the harmful ultraviolet radiation in the top atmospheric layers, the tropospheric ozone is accountable for 16% of planet heating and had negative effects upon human beings, animals and plants.

Ozone is a strong oxidiser which may react with class of biological matters, inclusively with the cellular membranes consisting of proteins and lipids. The epidemiological studies evidenced some acute effects (irritations of eyes, nose and throat) due to exposure to more than 200 μg/m^3 hourly concentrations of O_3 in the atmosphere. At hourly concentrations ranged between 160 and 300 μg/m^3, lung functions problems were identified mainly concerning children and young people.

Nitrogen oxides and nitric acid resulted from this process are extremely harmful for the human body. They attack the mucous, the breathing system, turn the oxihaemoglobin into methemoglobin which causes paralyses. The combinations of O_3 and NO_2 or powders in suspension have stronger synergic effects upon human beings.

Impacts upon vegetation. Up to certain concentrations (harmful thresholds), nitrogen oxides are beneficial for plants as they contribute to their growing. Nevertheless, in these cases they have an increased sensitiveness when attacked by insects or considering the climate conditions (frost, for instance). Beyond the harmful thresholds, the nitrogen oxides have evident fito harmful effects. Numerous studies pointed out the negative synergetic effect of the following combinations: O_3 with NO_2 or NO_2 with SO_2 upon vegetation. Based on these studies, an annual protection guideline value of 30 μg/m^3 is recommended for NO_2 imission in the presence of 30 μg/m^3 for SO_2 and 60 μg/m^3 for O_3.

Impacts upon water and soil. The influence of atmospheric pollution upon changing of water physical and chemical parameters is caused by dry and wet deposits and it is mainly traced in the ground steady waters (lakes).

At the contact air-water limit, the acid gases (SO_2 and NO_2) are turned into strong acids which increase water acidity (lowering of pH) and its content of sulphates and nitrates. Decreasing the pH accelerates the dissociation of the heavy metal compounds, and the related ions become free with an increased mobility.

The harmful influence of all these elements acts directly upon the aquatic flora and fauna, upon the spontaneous and planted flora (by irrigations) and upon human beings by ingestion of water and contaminated food.

By wet deposits (precipitations) the pollutants existing in the thick and large layers of air lay down on the water surface, modifying the pH, conductivity and loading with sulphates, nitrates, chlorides, metals, etc.

The soil is the environmental factor which ingests all consequences of the pollution. Therefore, both air and water pollution inevitably leads also to soil pollution eventually.

Impacts upon buildings and equipment. Out of the whole NO_x amount, more than 95% is under the form of NO_2 and 5% under the form of NO.

Eliminated in the air, NO in the presence of oxygen in the air and influenced by the ultraviolet light turns quickly enough into NO_2 which is very harmful. Under certain conditions, NO_2 and water form the nitric acid according the relation: $2NO_2 + H_2O = HNO_3 + HNO_2$.

The nitric acid resulted leads to some corrosion processes. It can, therefore, attack metallic constructions. These processes may occur even in the case of very low concentrations of nitrogen oxides in the atmosphere (0.08 ppm).

It has been proved the impact of NO_x upon some special construction materials in the carbonate category, such as marble. The nitrogen oxides penetrate the micro-cracks of these materials where they form nitrates which, through crystallisation, increase the cracks and ruin the construction[4].

EXPERIMENTAL

ENVIRONMENTAL POLICY OF C.N. 'TRANSELECTRICA' S.A.

The National Power Transmission Company – 'Transelectrica' S.A. ensures the power transmission (internal and cross border) and dispatch, owing 8795 km of OHLs with voltages of 110, 220, 400 and 750 kV and 76 power transforming/connection substations.

The main goal of the environmental policy of the company is to mitigate the negative impacts of its main equipment upon the environment up to the applicable requirements and regulations.

One of the actions taken for reaching this goal is the measurement/monitoring of impacts upon the environmental factors. For the environmental factor 'air', measurements of noise were performed inside and outside the power substations, measurements of pollutant emissions at the thermal power plants and in their own automobile fleet.

In between 2001-2002, the concentrations of ozone and nitrogen oxides in the atmosphere were measured in the vicinity of high voltage OHLs by means of specialised device and for the first time in Romania.

MEASUREMENT CONCEPTION AND THE EQUIPMENT UTILISED

The measurements were intended to pinpoint the OHL contribution to the increase of O_3 and NO_x imission. As these pollutants may occur in the atmosphere also for other causes than the 'corona' phenomenon, also the parameters needed for results interpretation were measured, such as the meteorological ones (temperature, humidity, wind speed and direction, solar radiation). There were also measured some pollutants such as: SO_2, CO and inhalable particulates (PM10) considering that they can, by their presence, amplify the harmful effect of O_3 and NO_x.

Estimation of OHL contribution to O_3 and NO_x generation in the air next door was made based on the difference between the values of measurement below the OHL and the reference ones (away from OHL).

For not having two identical facilities, it was not possible to simultaneously measure the imissions below the OHL and in the reference area. The measurements were performed in two conditions (cold and warm seasons) at OHL with various voltages (110, 220 and 400 kV) in the area of the power substation of Lacul Sarat (Braila county), both below the conductors and in the area of their supporting towers (poles) under various weather conditions. Six determinations of 30 min each were performed for each OHL and each parameter was acquired in 3 min (Ref. 5).

A mobile HORIBA laboratory owned by the Inspectorate for Environmental Protection in Constantza town (Fig. 1) was utilised. This mobile laboratory equipment is shown in Table 1.

Table 1. Main characteristics of HORIBA mobile lab equipment

Equipment	Type	Measuring principle	Measuring range	Detection limit
Analyser of O_3*	APOA-360	absorbtion in UV	0-0.1/0.2/0.5/1 ppm	0.40 ppb
Analyser of NO_x*	APNA-360	chemiluminescence	0-0.1/1/5/10 ppm	0.50 ppb
Analyser of SO_2*	APSA-360	fluorescence in UV	0-0.2/0.5/1/10 ppm	1.00 ppb
Analyser of CO*	APMA-360	IR, non-dissipative absorbtion	0-5/10/20/50/ 100 ppm	0.05 ppm
Particulates monitor (MP 10)	FH 62 IR	beta-radiation absorbtion	0-2400 $\mu g/m^3$	0.5 $\mu g/m^3$
Sensor for wind speed and direction	263AA4	sensors: anemometer, weathercock	speed: 0-60 m/s direction: 0-360°	+/- 0.5 % (accuracy)
Sensor for air temperature/humidity	hygrometer MP400A	sensors: RTDPt100, Rotronic hygrometer-C94	temperature: 40-60°C humidity: 5-100% RH	+/- 0.3 °C (accuracy)
Sensor for solar radiation (direct and diffuse)	starpyrometer 8102	sensor: determining the global illumination	0-1500 W/m^2	+/- 3.0% (accuracy)

*Calibration is made with standard gas stored in tanks.

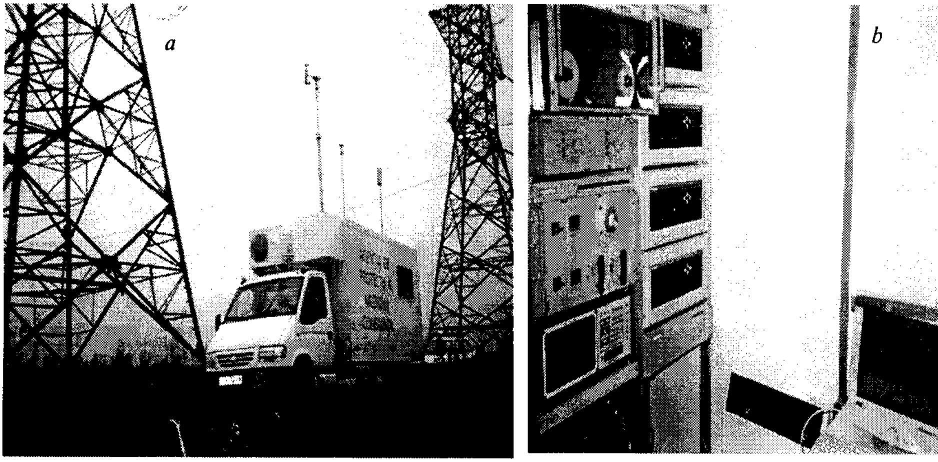

Fig. 1. Mobile laboratory meant for imission measurement: *a* – outside view, *b* – inside view

RESULTS AND DISCUSSION

MEASUREMENT RESULTS

The measured values of the atmospheric parameters in the area of OHL with voltages of 110, 220 and 400 kV, per seasons (cold and warm) compared to the measured reference values are shown in Tables 2, 3 and 4.

It is worth mentioning that the applicable regulations at the measuring date (STANDARD 12574/87) included the following values for the maximum admitted concentration:

– for ozone: 0.03 mg/m^3 (for the average per 24 h) and 0.10 mg/m^3 (for an average per 30 min);

– for nitrogen oxides (NO_2): 0.10 mg/m^3 (for the average per 24 h) and 0.30 mg/m^3 (for an average per 30 min).

Table 2. Measurements at the 110 kV OHL Lacu Sarat-Urleasca

Season	Measurement	NO (mg/m^3)	**NO_2 (mg/m^3)**	NO_x (ppm)	CO (mg/m^3)	SO_2 (mg/m^3)	**O_3 (mg/m^3)**	Temp. (°C)	Radiation (W/m^2)
Cold	reference	0.003	**0.009**	0.006	0.199	0.014	**0.028**	13.6	341
	near pole	0.005	**0.012**	0.008	0.302	0.034	**0.053**	12.4	252
	+/- reference	0.002	**0.003**	0.002	0.103	0.020	**0.025**	−1.2	−89
	between poles	0.003	**0.009**	0.006	0.257	0.026	**0.047**	13.5	423
	+/- reference	0.000	**0.000**	0.000	0.058	0.009	**0.019**	−0.1	82
Warm	reference	0.002	**0.002**	0.002	0.066	0.011	**0.043**	24.4	327
	near pole	0.005	**0.013**	0.010	0.238	0.046	**0.099**	25.7	582
	+/- reference	0.003	**0.011**	0.008	0.172	0.035	**0.056**	1.3	255
	between poles	0.003	**0.004**	0.003	0.187	0.028	**0.067**	25.8	455
	+/- reference	0.001	**0.002**	0.001	0.121	0.017	**0.024**	1.4	128

Table 3. Measurements at the 220 kV OHL Lacu Sarat-Filesti

Season	Measurement	NO (mg/m³)	**NO_2 (mg/m³)**	NO_x (ppm)	CO (mg/m³)	SO_2 (mg/m³)	**O_3 (mg/m³)**	Temp. (°C)	Radiation (W/m²)
Cold	reference	0.002	**0.016**	0.009	0.189	0.014	**0.027**	12.9	2
	near pole	0.005	**0.021**	0.013	0.404	0.035	**0.069**	13.2	8
	+/- reference	0.003	**0.005**	0.004	0.215	0.021	**0.042**	0.3	6
	between poles	0.003	**0.019**	0.011	0.297	0.032	**0.055**	14.0	114
	+/- reference	0.001	**0.003**	0.002	0.108	0.018	**0.028**	1.1	112
Warm	reference	0.002	**0.001**	0.002	0.101	0.008	**0.053**	22.9	529
	near pole	0.007	**0.015**	0.011	0.405	0.038	**0.108**	24.4	689
	+/- reference	0.005	**0.014**	0.009	0.304	0.030	**0.055**	1.5	160
	between poles	0.004	**0.005**	0.004	0.279	0.028	**0.106**	24.2	542
	+/- reference	0.002	**0.004**	0.002	0.178	0.020	**0.053**	1.3	13

Table 4. Measurements at the 400 kV OHL Lacu Sarat-Gura Ialomitei

Season	Measurement	NO (mg/m³)	**NO_2 (mg/m³)**	NO_x (ppm)	CO (mg/m³)	SO_2 (mg/m³)	**O_3 (mg/m³)**	Temp. (°C)	Radiation (W/m²)
Cold	reference	0.001	**0.003**	0.002	0.074	0.013	**0.024**	6.5	39
	near pole	0.002	**0.012**	0.007	0.167	0.036	**0.079**	7.3	84
	+/- reference	0.001	**0.009**	0.005	0.093	0.023	**0.055**	0.8	45
	between poles	0.002	**0.006**	0.004	0.085	0.035	**0.059**	6.6	40
	+/- reference	0.001	**0.003**	0.002	0.011	0.022	**0.035**	0.1	1
Warm	reference	0.002	**0.005**	0.004	0.171	0.016	**0.056**	25.1	208
	near pole	0.003	**0.027**	0.015	0.467	0.036	**0.131**	26.3	677
	+/- reference	0.001	**0.022**	0.011	0.296	0.020	**0.075**	1.2	469
	between poles	0.002	**0.012**	0.007	0.449	0.033	**0.129**	27.3	776
	+/- reference	0.000	**0.007**	0.003	0.278	0.017	**0.073**	2.2	568

CONCLUSIONS

• The maximum values resulted for measurements for the average concentration per 30 min were:

– for ozone: 0.079 mg/m³ in the cold season and 0.131 mg/m³ in the warm season;

– for nitrogen oxides: 0.021 mg/m³ in the cold season and 0.027 mg/m³ in the warm season.

• In the cold season the admitted limits were not exceeded (the averages per 30 min). In the warm season the limits were exceeded only at the 220 and 400 kV OHLs.

• The OHL contribution to the increase of ozone and nitrogen oxides concentrations in the atmosphere were strongly influenced by the meteorological factors and specially by air humidity and solar radiation. In order to increase the results accuracy, it is necessary to perform a long time monitoring of the air in the vicinity of OHL and simultaneously make measurements below OHL and away from it (reference).

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