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THE MEANING OF AIR QUALITY AND FLUE GAS EMISSION STANDARDS FOR PUBLIC ACCEPTANCE OF NEW THERMAL POWER PLANTS

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For the time being only 30–40% of the electric energy supply in Croatia comes from burning fossil fuel. New capacities of 800–1400 MW for the next decade will have to rely on the exclusive use of fossil fuels in thermal power plants (TPP). Public opinion will probably have a decisive influence on the issuing of construction permissions. The potential adverse effects on air seem to be the main argument against construction of TPPs. The priority is therefore to unambiguously state what air quality is warranted in the influenced area for the whole operation period of a TPP. It is important that the public should understand the real meaning of current air quality standards and emission limits. The only known way to do it today is through comparison with the corresponding standards and limits accepted worldwide. This paper discusses some important aspects of such comparison.

Key words:
legislation, limit values, mathematical model, NIMBY syndrome, warranted air quality, warranted emission values

Contemporary approach to design and construction requires all environmental protection measures to maximally reduce unfavourable influences. Environmental Protection Act stipulates in Article 4 that »Actions in the environment should not influence the level of the life quality, human health and sustainable development of the nature« (1). All other Croatian acts, ordinances, and directives which concern environmental protection are based on the quoted clause.

Croatian legislation on recommended values (RV), limit values (LV) (2), and emission limit values (ELV) in the air from stationary sources (3) draws from the practices of the most demanding European and world regulations. Its implementation exclusively relies on the Best Available Technology Not Entailing Excessive Costs (BAT/BATNEEC) principle. The application of »clean technologies« seems to be inevitable in the

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construction of a new thermal power plant (TPP). BAT/BATNEEC principle has been accepted as a general criterion for estimation and implementation of environmental stipulations, especially those related to air quality requirements as a prerequisite to construction of a TPP. The observance of prescribed environmental terms, especially the ones related to air quality requirements, is a prerequisite for starting a new TPP construction.

The public opposition to construction of new TPPs is often based on lay or ill-intended arguments pretending to prove their inevitably catastrophic environmental impacts. Fear and distrust of government and experts who support those projects are heavily drawn upon in forming public opposition, which stimulates the appearance of Not In My Back Yard (NIMBY) and Locally Unwanted Land Use (LULU) syndromes (4).

It is a duty of experts to raise the general level of safety culture and to inform the public about the decision-making process for the intended project (5). It is very important to give the public clear definitions and proofs that elucidate the real meaning of a TPP »lifetime warrant« of environmental conditions.

Conditions defined by legislation on air protection

It seems that air protection is in the focus of unprofessional and biased arguments about the »inevitable« dangers of TPPs to the environment. This is why the public deserves clear answers as to what kind of air quality is warranted in the closer and further surrounding of a TPP throughout its operational lifetime (usually 30–45 years). That is strictly stipulated by the Air Protection Act (6). The Act distinguishes three categories of air quality for a certain area:

1. *The first category air quality*: clean or slightly polluted air (RV not exceeded).
2. *The second category air quality*: moderately polluted air (RV exceeded, LV not exceeded).
3. *The third category air quality*: excessive air pollution (LV exceeded).

Croatian Ordinance on Air Quality Recommended and Limit Values defines RV and LV (2).

The Air Protection Act in articles 25 and 38 stipulates that:

(i) *In the area with the first category air quality*, precautionary measures are to be taken to prevent the RV from being exceeded as a result of building and development of the area.

(ii) *In the area with the second category air quality*, measures for air pollution reduction are to be undertaken so as to achieve the RV.

(iii) *In the area with the third category air quality*, restoration measures are to be undertaken so as to achieve the LV as a short-term and the RV as a long-term goal.

(iv) *In the third category air quality area* no location and building permit and no inspection certificate shall be issued either for a new air pollution source or for reconstruction of the existing one, unless the new construction or reconstruction are to ensure:

- the replacement of the existing inappropriate facility with a new one which reduces air pollution,

– that the increase of air pollution near the facility shall not exceed 1% of the LV, provided that the rehabilitation programme for the existing pollution sources is in the process of implementation.

To understand a concept of air quality lifetime warranty, one should understand the meaning of RV and LV with respect to pollutants and fuel which are characteristic for a TPP. Emission limit values (ELV) are the highest air emissions allowed by the Croatian legislation and they are the basis of air quality protection. They ensure the use of the best available and applicable technologies, the best solutions and measures, as well as immediate environmental protection and protection against distant or transboundary air pollution (7).

The air quality of all sites planned for construction of power plants in Croatia is of the first category (8). According to the Air Protection Act (6), it would be possible to relocate power plants only to areas where air quality is of the second category. In the first case RV should not be exceeded and in the second case levels below RV are to be reached in the near future (short-term goals) by implementing rehabilitation measures. The Croatian Ordinance on Emission Limit Values in the Air from the Stationary Sources (3) particularly prescribes ELV for air pollutants characteristic for large stationary combustion plants, including TPPs. However, it is important to underline that legislation authorises (6) the Croatian Government to set more restrictive ELV for certain areas, which depends on the sensibility of the eco-system, transmission over long distances, and the actual air quality. Furthermore, local government can set even more restrictive ELV when requesting proposals for a rehabilitation programme or when it foresees activities which may affect the environment and which require environmental impact assessment (as is the case with TPPs) (8).

Ideal categorisation and the meaning of the existing air quality standards

Air quality can be categorised by the effects of pollutants on the respective receptors. Starting from that premise, a general/basic risk function R should be determined for each particular pollutant ξ(9, 10):

$$R = R\{S(I(t))\}\ ,\ R \in [0,\ 1] \qquad /1/$$

Function /1/ takes into consideration the order of importance of the receptor groups as well as the order of countable sets of effects assigned to each receptor group, where S[I(t)] is the immission indicator denoting the space and time content of the pollutant ξ in the air. The immission/concentration indicator S[I(t)] is a set of properties which reliably signal the presence a significant presence of a pollutant in the air in a given space and time. Function $R\{S(I(t))\}$ is a model scale of air quality (regarding to pollutant ξ) from which further categorisation may develop.

MODEL DEVELOPMENT AND INPUT DATA

Necessary interpretation of air quality standards

Contemporary methods for the assessment and categorisation of air quality are based on air quality limit values as very simplified approximations of the model method (11).

With this in mind, air quality limit values should be viewed as ordered quadruplets – information vectors:

$$G = < T, \tau, p, X_{\tau p} >; \qquad \tau \subset T, \qquad p \in [0,\ 1] \qquad /2/$$

where T – monitoring period, τ – averaging time, p – quantile level, $X_{\tau p}$ – value compared with the concentration value $c_{\tau p}$, during averaging time τ and quantile level p of the »relevant« distribution function. It follows that:

$$\text{for } \tau = T : X_{\tau p} = X_{T1} = \overline{X} \text{ (average value)} \qquad /3/$$

$$\text{for } p = 1 - \tau / T : X_{\tau p} = X_{\tau, 1-\tau/T} = X_{\max}; \quad \text{for } p = 1 - 2\tau / T : X_{\tau p} = X_{\tau, 1-2\tau/T} = X_{\max 2} \qquad /4/$$

Table 1 *Air quality standards for* SO_2 (T=8760 h)

	Mark	τ(h)	p	$X_{\tau p}$ (μg/m³)	Remark	Reference
Croatia (RV)	1	24	1–τ/T	125	a	2
	2	1	1–τ/T	350	–	2
	S	8760	–	50	b	2
Croatia (LV)	1	24	0.98	250	c	2
	1_{50}	24	0.50	80	d	2
	2	24	0.98	350	e	2
	2_{50}	24	0.50	120	f	2
World Health Organisation (WHO)	1	1/6	1–τ/T	500	–	12
	2		WHO2 ≡ RV2		g	12
	3		WHO3 ≡ RVS		–	13
Switzerland (CH)	1	½	0.95	100	–	19
	2	24	1–2τ/T	100	–	19
	S	8760	–	30	–	19
(USA) (primary – ' and secondary – " standards)	'	24	1–2τ/T	365	–	18
	S'	8760	–	80	–	18
	"	3	1–2τ/T	1300	–	18
Germany (GER)	–	½	0.98	400	–	20
	S	8760	–	140	–	20
Japan (JAP)	1	1	1–τ/T	260	–	21
	2	24	1–τ/T	110	–	21

a) Recommended values $X_{\tau p}$ of European Community for the same T, τ, p read: 100–150 μg/m³ (12)
b) Recommended values $X_{\tau p}$ of European Community for the same T, τ, p read: 40–60 μg/m³ (12)
c) If standard S/P is exceeded (see Table 4)
d) If standard S/P_{50} is exceeded (see Table 4)
e) If standard S/P is not exceeded (see Table 4)
f) If standard S/P_{50} is not exceeded (see Table 4)
g) Recommended value of the WHO for Europe

Each quadruplet (eq. /2/) is actually a point in hypersurface R=*const* of the general risk function R (eq. /1/). Generally, the air quality standards are set up using a system consisting of a minimum of two limit values, that is, two quadruplets G (eq. /2/). One refers to possible short-term effects and the other to possible long-term effects. Ideally, these quadruplets should correspond to the same value of the function R. Considering the degree of possible unfavourable immission effects, the limit air quality values can be refered to as desirable (recommended) or limit (»endurable«) air quality levels. These levels are determined by quantities RV and LV in the Croatian Ordinance (2).

To evaluate an air quality lifetime guarantee of a TPP design one needs to determine the meaning of RV and LV, that is, to compare the corresponding quadruplets (eq. /2/) of RV and LV with those of the representative air quality standards used worldwide. Tables 1–4 show Croatian (RV, LV) and international air quality limit values for SO_2, NO_2, O_3 and suspended particles.

Table 2 *Air quality standards for* NO_2 (T=8760 h)

	Mark	τ(h)	p	$X_{\tau p}$ (μg/m³)	Remark	Reference
Croatia (RV)	–	24	0.98	60	–	2
	S	8760	–	40	–	2
Croatia (LV)	1	24	0.98	120	–	2
	2	1	0.98	200	–	2
	S	8760		60	–	2
World Health Organisation (WHO)	1	1	$1-\tau/T$	400	–	12
	2	24	$1-\tau/T$	150	–	12
	3	1	$1-\tau/T$	200	a	13
Switzerland (CH)	1	1/2	0.95	100	–	19
	2	24	$1-2\tau/T$	80	–	19
	S	8760	–	30	–	19
European Community (EU)	1	1	0.98	135	b	12
	1_{50}	1	0.50	50	b	12
	2		EU ≡ GV2		–	12
United States of America (USA)	S	8760	–	100	–	18
Germany (GER)	–	1/2	0.98	200	–	20
	S	8760	–	80	–	20
Japan (JAP)	–	24	$1-\tau/T$	120	c	21

a) Recommended value of the WHO for Europe
b) Recommended value
c) Originally, for $X_{\tau p}$ an interval is quoted: 80–120 μg/m³

Table 3 *Air quality standards for O_3 (T=8760 h)*

	Mark	τ(h)	*p*	$X_{\tau p}$ (μg/m³)	Remark	Reference
Croatia (RV)	–	24	0.98	110	–	2
Croatia (LV)	1	24	0.98	150	–	2
	2	1	0.98	180	–	2
World Health Organisation (WHO)	1	1	$1-\tau/T$	175	a	12
	2	8	$1-\tau/T$	110	b	12
	3	1	$1-\tau/T$	150	–	13
	4	8	$1-\tau/T$	120	c	13
Switzerland (CH)	1	1	$1-2\tau/T$	120	–	19
	2	1/2	0.98	100	d	19
European Community (EU)	1	8	$1-\tau/T$	110	health protection	12
	2	1	$1-\tau/T$	200	vegetation protection	12
	3	24	$1-\tau/T$	65	vegetation protection	12
	4	1	$1-\tau/T$	180	population information	12
	5	1	$1-\tau/T$	360	population warning	12
(USA)	–	1	$1-2\tau/T$	235	–	18
Japan (JAP)	–	1	$1-\tau/T$	120	–	21

a) Originally $X_{\tau p}$ is from the domain 150–200 μg/m³
b) Originally $X_{\tau p}$ is from the domain 100–120 μg/m³
c) Recommended value of the WHO for Europe – moving averaging time
d) *T*=1 month=720 h

Table 4 *Air quality standards for suspended particles* (*T*=8760 h)

	Mark	τ(h)	*p*	$X_{\tau p}$ (μg/m³)	Remark	Reference
Croatia (RV)	–	24	0.98	120	–	2
	S	8760	–	75	–	2
Croatia (RV – S/P)	1	24	$1-\tau/T$	120	a	2
	2	1	$1-\tau/T$	300	a	2
	S	8760	–	75	a	2
Croatia (LV)	–	24	0.98	350	–	2
	S	8760	–	150	–	2
Croatia (LV – S/P)	S/P	24	0.98	350	b	2
	S/P_{50}	24	0.50	150	b	2
World Health Organisation (WHO)	–	24	$1-\tau/T$	120	–	12
Switzerland (CH)	–	24	0.95	150	–	19
	S	8760	–	70	–	19
Germany (GER)	–	1/2	0.98	300	–	20
	S	8760	–	150	–	20

a) Standard quoted with RV for SO_2 (Table 1)
b) Standard which determines LV for SO_2 (Table 1)

Establishing the model

If each quadruplet G_i had value R_i of the basic risk function R, the comparison between air quality standards would be clear and very simple. However, experience shows that the comparison is possible only if necessary simplifications are acceptable, for instance, using the model described by Barbalić et al. (14): (i) there is a known functional dependence on averaging time of distribution functions over the concentration field of the monitored area, that is, of parameters of those distribution functions, (ii) the distribution functions are all (approximately) log-normal. In that case, (only one) »comparator« function $A(b)$ corresponds to each quadruplet G (14):

$$G \rightarrow \{b, A(b)\}: \quad A(b) = \exp\left\{0{,}5 \cdot \log\left(\frac{T}{\tau}\right) - y_p \cdot \sqrt{b} \cdot \sqrt{\log\left(\frac{T}{\tau}\right)} + \log X_{\tau p}\right\}, \qquad (b \geq 0) \quad /5/$$

where b is air quality parameter (conditional concentration indicator) independent of averaging time τ; y_p is a parameter of standard normal distribution for quantile level p; and log is the logarithm (base e).

The standard's system N, which encompasses several limit values such as G' and G'', with comparator functions A' and A'', respectively, agrees with the comparator function:

$$\Phi(b) = \inf\{A', A'', ...\} \qquad /6/$$

The below relations apply for systems N_i and N_j with comparator functions Φ_i and Φ_j, respectively:

$$\Phi_i < \Phi_j \rightarrow N_i \prec N_j; \quad \Phi_i = \Phi_j \rightarrow N_i = N_j; \quad \Phi_i > \Phi_j \rightarrow N_i \succ N_j \qquad /7/$$

($<$ – less than, $\prec$ – more stringent than, $>$ – greater then, $\succ$ – less stringent than). If Φ_M is a comparator function of the given system of standards N_M, and Φ_i a comparator function of the comparative system of standards N_i, then

$$RO(b) = \frac{\Phi_i - \Phi_M}{\Phi_M} \qquad /8/$$

is the relative difference between system N_i and system N_M, depending on air quality parameter b. In accordance with relations /7/:

$$RO(b) < 0 \rightarrow N_i \prec N_M; \quad RO(b) = 0 \rightarrow N_i = N_M; \quad RO(b) > 0 \rightarrow N_i \succ N_M \qquad /9/$$

The total relative difference between systems N_i and N_j within the range (b_1, b_2) of values b, for which the use of air quality standards is expected is:

$$ROI(b_1, b_2) = \int_{b_1}^{b_2} RO(b)\,db \qquad /10/$$

The described procedure was applied to compare the Croatian RV and LV air quality levels with a selection of respective air quality standards elsewhere. Figure 1 represents the comparison with graphical interpretations of the function /8/ based on data from Table 1 for SO_2, where

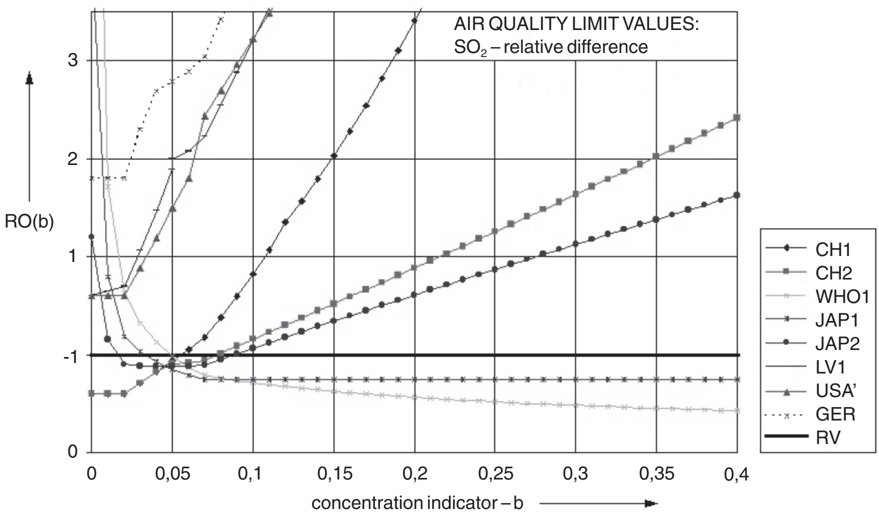

Figure 1 *Comparison of SO_2 – air quality standards (reference level ≡ RV; for abbreviations see Table 1)*

$$\Phi_M(b) = \inf \{A_{RV1}(b),\ A_{RV2}(b),\ A_{RVS}(b)\} \qquad /11/$$

and Φ_i are infima of air quality standards compared with RV. The identical procedure can be applied to particules, NO_2, and O_3.

A complete comparison of air quality standards requires calculation of integral in the equation /10/ for various air quality standards where the integration domain (b_1, b_2) should encompass common realisations of values b. In such case, the order between air quality standards N_i and N_j is determined by the following relations:

$$ROI_i(b_1, b_2) < ROI_j(b_1, b_2) \rightarrow N_i \prec N_j, ... \qquad /12/$$

RESULTS

Comparison of air quality standards

The below selection of integration domains facilitates comparison air quality standards quoted in Tables 1–4:

(i) long-term standards (in Tables 1–4, or τ=8760 h or p=0.5):
   – the lower limit b_1=0,
   – the upper limit b_2 is determined as the abscissa of intersection points of the comparator functions $A(b)$ corresponding to the long-term and short-term standards. On the average, $b_2 \cong 0.05$, i.e.: $(b_1,\ b_2) \equiv (0;\ 0.05)$.

(ii) short-term standards:

Table 5 *National and international air quality standards by stringency*

Rank of standards			1	2	3	4	5	6	7	8	9	10	11	12	13
SO_2 (marks as used in Table 1)	long-term	standard	CH	RV/WHO	JAP	USA	LV	GER	–	–	–	–	–	–	
		ROI	-0.015	0	0	0.030	0.043	0.051	0.109	–	–	–	–	–	–
	short-term	standard	WHO1	JAP1	RV	JAP2	CH2	CH1	USA	LV	GER	–	–	–	–
		ROI	-0.071	-0.051	0	0.072	0.105	0.435	0.904	1.030	1.334	–	–	–	–
NO_2 (marks as used in Table 2)	long-term	standard	CH	RV	JAP	EU	LV	WHO	GER	–	–	–	–	–	–
		ROI	-0.002	0	0.006	0.037	0.042	0.054	0.073	–	–	–	–	–	–
	short-term	standard	JAP	CH2	WHO1	RV	WHO2	EU2	LV1	CH1	GER	LV2	EU1	–	–
		ROI	-0.062	-0.030	0.021	0	0.059	0.162	0.201	0.207	0.317	0.337	0.393	–	–
O_3 (marks as used in Table 3)	$(b_1. b_2) \equiv (0 ; 0.25)$	standard	JAP	WHO1	EU4	EU2	EU3	WHO2/EU1		USA	EU5	CH1	RV	LV2	LV1
		ROI	-0.196	-0.171	-0.169	-0.168	-0.166	-0.156	-0.156	-0.128	-0.087	-0.070	0	0.085	0.091
Suspended particles (marks as used in Table 4)	long-term	standard	WHO	RV	CH	JAP	GER	LV	EU	–	–	–	–	–	–
		ROI	-0.008	0	0.011	0.013	0.052	0.067	0.070	–	–	–	–	–	–
	short-term	standard	WHO	JAP	RV	CH	GER	LV	EU	–	–	–	–	–	–
		ROI	-0.096	-0.027	0	0.011	0.188	0.383	0.531	–	–	–	–	–	–

– the lower limit b_1 equals the upper limit of long term standards b_1=0.05

– the upper limit can be well estimated only on the base of experience. According to a representative literary corpus dealing with air quality data the acceptable upper limit is b_2=0.25, i.e.: $(b_1, b_2) \equiv (0.05; 0.25)$.

The above procedure served to calculate $ROI(b_1, b_2)$ values as an approximate measure of the total relative difference from RV standards. It was then possible to establish the order of various air quality standards according to their stringency (Table 5).

With respect to various national and international environmental policies, air quality standards can generally be divided in »desired« air quality standards (Table 1 for SO_2: RV, JAP1, JAP2, WHO1,CH1) and »endurable« air quality standards (Table 1 for SO_2: LV, USA, GER).

It is clear that RV and LV should be evaluated in this framework. From relations between RV/LV and other standards for SO_2, NO_2, O_3, and suspended particles in Table 5, one may see that:

(i) RV and LV for SO_2, NO_2, and particulates, are »more stringent or approximately equal« to air quality standards, recommendations, or limit values known worldwide as the »respectable model«;

(ii) RV and LV for O_3 are evidently more tolerant than the model standards.

Taking into account minor contribution of TPPs to the ozone content in the environmental air (in comparison with other sources such as motor vehicles)(8), it can generally be concluded that the guaranteed life-time air quality standards for a new TPPs in Croatia would comply with the most respected criteria worldwide.

Evaluation of ELV and the meaning of commonly guaranteed emission values for new TPP constructions in Croatia

It is common that the regulation of limit values of emissions from stationary combustion plants depends on the thermal capacity of the plant and of the type of fuel. In 1988, the European Community issued a directive setting emission limits for new stationary combustion plants with a thermal capacity of more then 50 MW (15). To comply with those limit values means in practice to follow the BAT/BATNEEC approach. Many countries, including Croatia, have adopted emission limit values from that directive (15) and introduced even more stringent values. Therefore, the requirements concerning emissions in the air established by Croatia are in line with the most stringent emission standards.

Having in mind the discussion in the previous section, it is important to stress the difference in formal interpretation between emission limit values and air quality (immission) values. A comprehensive and expert interpretation of air quality standards takes into account that they combine several properties. Emission limit values are also a combination of properties, although that fact is regularly neglected. With the exception of the basic concentration value, additional data necessary for comprehensive interpretation of emission standards surely are the period of estimation, averaging time, and corresponding quantile levels: Relevant components may also be operating characteristics and measuring conditions, usually determined by a series of regulations and directives which define the procedure of emission measurements (it is enough to note specific differences between continuous emission measurements and random sample measurements).

The fact is that emission concentration is a component that influences emission levels the most and is considered almost identical to it. However, the real differences between them can be considerable (17), i.e. for the comparison of various emission standards the mentioned additional components have to be taken into consideration. For instance, the averaging times of the Croatian (3), Swiss (19), and German ordinances (20) are different.

Generally, an emission standard (precisely defined with respect to the type, class, size, and capacity of the source) limiting the release of a certain air pollutant is a set of many emission limit values (24). Furthermore, emission limit values are defined as multivalent magnitudes consisting of several components. The full meaning of emission standards is determined by the included emission limit values and the full meaning of each emission limit value is determined by all of its components. The most important components of emission limit values are (24): concentration value – EX; averaging time – τ; quantile level – p; monitoring period – T; humidity of flue gases – r_v; standard condition of flue gases – (p_n, T_n) or standard density of flue gases – ρ_n; and oxygen content in flue gases – $r(O_2)$. In other words an emission limit value is a combination of seven components:

$$GE = \left\langle T, \tau, p, EX_{\tau p}, r_v, \rho_n, r(O_2) \right\rangle \qquad /13/$$

In practice, though, to be able to define a category of an emission source it is enough to interpret it as a combination of four components, that is, a quadruplet,:

$$GE = \left\langle T, \tau, p, EX_{\tau p} \right\rangle \qquad /14/$$

Table 6 shows the comparison between models of limit values for particulates, SO_2, and NO_x (15, 16, 19, 22) and the Croatian ELV standards (3) in the category of coal-fired plants with the greatest power capacity. It is worth noticing that usual TPP construction design requirements are more stringent than the Croatian ELV standards (23).

An attempt to estimate the corresponding levels of stringency of various emission standards/limit values may seem senseless unless the parameters of the distribution function of the emission concentration values are known. Without the support of empirical data on emission concentration characteristics, the described model served only to obtain a rough estimate of differences in stringency between the selected emission standards/limit values.

DISCUSSION

Taking into consideration that quadruplets G (eq. /2/) and EG (eq. /14/) are analogous, the described mathematical model can be applied using relations /3/–/12/. However, the following needs to be pointed out:

Table 6 *Representative emision limit values of coal-fired combustion plants for particulates*, SO_2, and NO_x in the *category of plants with the greatest thermal capacity*(>500 MW_t):
r_v=0, T=7000 h, p_n=101,3 kPa, T_n=0 °C, $r(O_2)$=6%

Emission standard	**Mark** **–**	**τ** **H**	**p** **–**	**$EX_{\tau p}$** **mg/m^3_n**	**Reference** **–**
			Particulates		
European Community (EU)	1 2	24 x 30 48	1–τ/T 0.97	50 55	15
Germany (GER)	1 2 3	24 ½ ½	1–τ/T 0.97 1–τ/T	50 60 100	22
Switzerland (CH)	1 2 3	24 1 1	1–τ/T 0.97 1–τ/T	54* 64* 107*	19
Croatia (ELV)			Identical as Germany		3
Requested (RQ)	1	½	1–τ/T	50	23
			SO_2		
European Community (EU)	1 2	24 x 30 48	1–τ/T 0.97	400 440	15
Germany (GER)	1 2 3	24 1/2 1/2	1–τ/T 0.97 1–τ/T	400 480 800	22
Switzerland (CH)	1 2 3	24 1 1	1–τ/T 0.97 1–τ/T	429* 514* 857*	19
Croatia (ELV)			Identical as Germany		3
Requested (RQ)	1	½	1–τ/T	400	23
			NO_x		
European Community (EU)	1 2	24 x 30 48	1–τ/T 0.95	650 715	15
Germany (GER)	1 2 3	24 1/2 1/2	1–τ/T 0.97 1–τ/T	200 240 400	22
Switzerland (CH)	1 2 3	24 1 1	1–τ/T 0.97 1–τ/T	214* 257* 429*	19
Croatia (ELV)	1 2 3	24 1/2 1/2	1–τ/T 0.97 1–τ/T	650 780 1300	3
Requested (RQ)	1	1/2	1–τ/T	400	23

* Recalculated value: $r(O_2)$=7%→$r(O_2)$=6%

(i) The ratio between corresponding concentration values of the emission limit values for both particulates and SO_2 does not change (Table 6):

$$\frac{EX_{\tau p}(EU1,\ SO_2)}{EX_{\tau p}(EU1,\ particulates)} = \frac{EX_{\tau p}(EU2,\ SO_2)}{EX_{\tau p}(EU2,\ particulates)} = ...$$

$$... = \frac{EX_{\tau p}(CH3,\ SO_2)}{EX_{\tau p}(CH3,\ particulates)} = \frac{EX_{\tau p}(RQ,\ SO_2)}{EX_{\tau p}(RQ,\ particulates)} = 8$$

Therefore, it is advisable to analyse only one quantity for both particulates and SO_2. Let us suppose that it is a comparative indicator *Y:*

$$Y = \frac{EX_{\tau p}(M\,,particulates)}{50\,mg\,/\,m_n^{\ 3}} = \frac{EX_{\tau p}(M\,,SO_2)}{400\,mg\,/\,m_n^{\ 3}}$$

where *M* denotes the mark of the emission standards (for instance, EU1, EU2, GER3, and so on) from Table 6.
The emission limit values for NO_x have to be separately analysed.

(ii) It is impossible to select with confidence the upper integration limit in the equation /10/ without using a representative set of empirical data. Therefore, a comparison in accordance with relation /12/ is biased and should limit itself to analysing relative differences *RO(b)* (eq. /8/). Figures 2 and 3 showing *RO(b)* for the comparative indicator *Y* of particulates, SO_2, and NO_x are based on the above described mathematical model and include the above considerations.

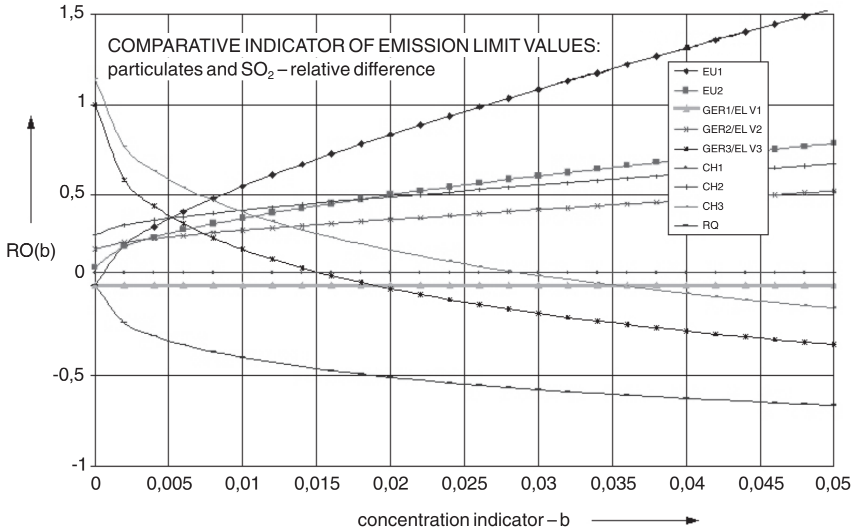

Figure 2 *Comparison of particulates and SO_2 emission standards* (*reference level* ≡ *GER1/EL V1; for abbreviations see Table 6*)

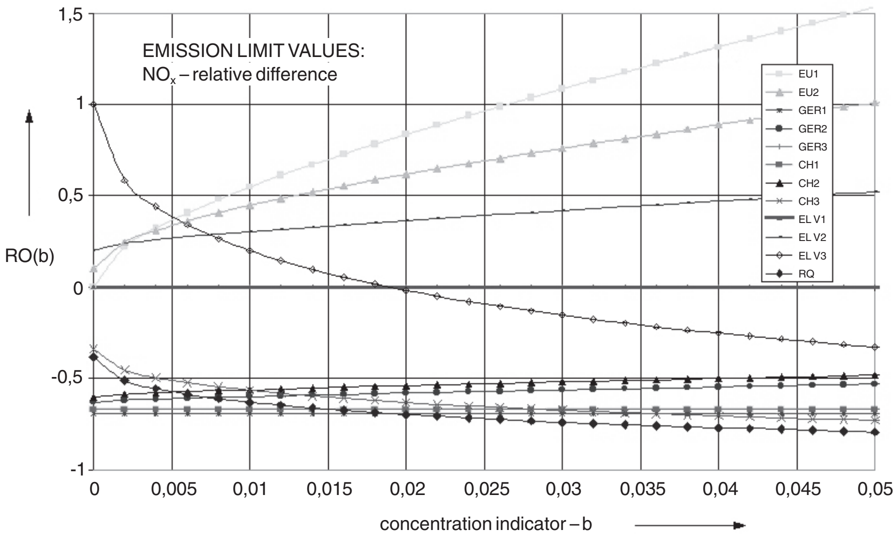

Figure 3 *Comparison of NO_x emission standards* (*reference level* ≡ *GER1/ELV1; for abbreviations see Table 6*)

It is evident that: (i) all limit values are more stringent than those prescribed by the EU; (ii) Croatian ELV for particulates and SO_2 are visibly stringent; (iii) there is very little possibility that the ELV prescribed for quantile level 97% will be exceeded; (iv) the exceptional stringency of the emission limits imposed on new TPP constructions in Croatia could be explained only by the common misinterpretation of emission standards which neglects the complexity of the ELV as a combination of components.

To conclude, Croatian emission standards (for particulates and SO_2) are sufficiently stringent. This fact should help to create better public attitude toward new TPPs. For the time being, the more convincing argument for broader acceptance of new TPP constructions is the fact that contemporary TPPs emit half or less pollutants than prescribed by emission standards (particulates – 20 mg/m_n^3, SO_2 – 200 mg/m_n^3, NO_x – 300 mg/m_n^3) and that contractors are able to guarantee those levels in their bids.

CONCLUSION

Judging by the Croatian Air Protection Act, a new TPP should not deteriorate the air quality of the surrounding areas. In terms of the first and the second category of air quality, it means that the respective RV and LV will not be exceeded. Therefore, with regard to public acceptance of the construction of a new TPP, it is very important to clarify the real meaning of RV and LV, as well as of the maximal emission values guaranteed for the lifetime of a TPP.

Air quality standards differ a lot from country to country. The differences can be noticed only if the standards are viewed through all of their components: concentration value, monitoring period, quantile level, and averaging time. As the differences are almost impossible to compare directly, it is necessary to apply formalised mathematical models. The mathematical model proposed in this study was able to that and we were able to determine the order of selected air quality standards (WHO, EU, Switzerland, Germany, Japan, and USA) for significant pollutants (SO_2, NO_2, O_3, and suspended particles) according to their stringency. In practice, emission standards are usually evaluated only on the basis of concentration values, while other components are neglected. However, those other components essentially determine the real character of emission standards, especially in continuous measurements.

The same mathematical model which we used to compare air quality standards can be adapted for comparison of ELV. The comparison of emission standards, including the Croatian ELV for most important pollutants, shows significant differences between the emission standards (national and international), depending on the source (thermal plants, incineration plants, and so on).

Finally, the Croatian recommended and limit air quality standards and the emission limit values are among the most demanding standards used worldwide.

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Sažetak

ZNAČENJE TUMAČENJA GRANIČNIH VRIJEDNOSTI KAKVOĆE ZRAKA I EMISIJA U ZRAK ZA PRIHVAĆANJE GRADNJE TERMOELEKTRANA U JAVNOSTI

Zasad se u Hrvatskoj samo 30–40% proizvodnje električne energije osigurava s pomoću izgaranja fosilnih goriva. Ipak, u nastupajućem desetljeću moraju se izgraditi novi proizvodni kapaciteti koji će se temeljiti na fosilnim gorivima, ukupne snage 800–1400 MW. Međutim, otpor javnosti tijekom postupka odobravanja izgradnje bilo kakve nove termoelektrane može bitno utjecati na konačnu odluku o njezinoj izgradnji. Pretpostavljeni nepovoljan utjecaj termoelektrana na kakvoću zraka je, čini se, prostor glavnih napada i protivljenja namjeravanim gradnjama termoelektrana. Zbog toga, vrlo veliku važnost imaju iskazi o kakvoći zraka koja se jamči za cjelokupno radno razdoblje termoelektrane, u svim područjima u kojima se, zbiljski, može očekivati njezin utjecaj na kakvoću zraka. Takvi iskazi mogu se postaviti na temelju razumljivog objašnjenja stvarnog značenja postojećih graničnih vrijednosti kakvoće zraka i emisijskih graničnih vrijednosti u zrak koje se zakonski moraju zadovoljiti. Na temelju današnjih aktualnih znanja, jedini način za takva tumačenja značenja graničnih vrijednosti jest njihova usporedba s odgovarajućim graničnim vrijednostima koje se u svijetu uzimaju kao uzor u području zaštite kakvoće zraka. Predložak koji se temelji na pretpostavci o logaritamskoj normalnoj raspodjeli koncentracija onečišćujućih tvari omogućava uspostavu poretka među graničnim vrijednostima kakvoće zraka i procjenu poretka među graničnim vrijednostima emisije. S pomoću takvog predloška izvršena je usporedba hrvatskih i uglednih svjetskih normi kakvoće zraka i emisijskih graničnih vrijednosti. Na temelju usporedbe slijedi da će kakvoća zraka kojoj će udovoljiti nove termoelektrane u Hrvatskoj biti na razini najzahtjevnijih svjetskih mjerila.

Ključne riječi:
jamstvo kakvoće zraka, jamstvo emisijskih vrijednosti, matematički model, sindrom NIMBY, usporedba graničnih vrijednosti, zakonodavstvo

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