ENVIRONMENTAL IMPACT ESTIMATION OF SOME DISINFECTION TREATMENTS APPLIED FOR A FINAL ZOO-TECHNICAL EFFLUENT USING THE GLOBAL POLLUTION INDEX

ESTIMAREA IMPACTULUI DE MEDIU AL UNOR TRATAMENTE DE DEZINFECȚIE APLICATE UNUI EFLUENT FINAL ZOOTEHNIC FOLOSIND INDICELE DE POLUARE GLOBALĂ

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Abstract. *This paper discusses some disinfection treatments (i.e. chlorination with sodium hypochlorite, advanced oxidation with hydrogen peroxide and ferrous ions, and UV irradiation) applied in the case of a real zoo-technical effluent in terms of legal and approved quality of final effluent discharged directly in a watercourse nearby. The environmental impact of these disinfection treatments against the local natural aquatic environment (natural receptor – watercourse) estimated by the global pollution index (I^*_{GP}) is within or over admissible limits but with potential effect of discomfort or even stress against organisms (application of different disinfection treatments) in comparison with the direct discharge of un-treated zoo-technical effluent that produced an 'aquatic environment highly affected, dangerous for organisms'.*
Key words: *zoo-technical effluent, chemical treatment, disinfection, environmental impact assessment, global pollution index*

Rezumat. *Această lucrare discută câteva tratamente de dezinfecție (i.e. clorinarea cu hipoclorit de sodiu, oxidarea avansată cu apă oxigenată şi ioni feroşi, iradierea cu radiație UV) aplicate în cazul unui efluent real dintr-o fermă zootehnică în termeni de calitate certă şi legală a efluentului final evacuat direct într-un curs de apă din apropiere. Impactul acestor tratamente de dezinfecție asupra mediului acvatic natural (receptor natural local – curs de apă) exprimat prin indicele de poluare globală (I^*_{PG}) este în sau depăşeşte limitele admisibile (aplicarea tratamentelor de dezinfecție) dar cu efect pronunțat de disconfort sau chiar stres asupra organismelor, în comparație cu evacuarea directă în emisar a efluentul final neepurat care generează un 'mediu acvatic puternic afectat, dăunător pentru organismele existente'.*
Cuvinte cheie: *efluent zootehnic, epurare chimică, dezinfecție, evaluare impact de mediu, indice global de poluare*

INTRODUCTION

Disinfection is known as a procedure of removal or killing of viruses and organisms present in water (final individual or mixed effluent). In general, more than 96-99% of the organisms in water are mostly removed by coagulation, flocculation, oxidation, sedimentation and filtration (complex wastewater technol-

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ogical process), but the quality norms for natural water resources and treated wastewater require that in case of them used for drinking or bathing/swimming proposes to be lacking of coliform organisms and to meet the conditions of microbiological quality for human, sportive and social consumption (Yen, 2007). The important removals in the physico-chemical treatment steps are useful, but these are not complete. That is why, the supplementary chemical and non-chemical disinfection is necessary in order to fulfil these demands.

The organisms (procaryotic and eucaryotic organisms, simple invertebrates), and also different viruses from drinkable water and wastewater, were at the origin of some diseases with mass transmission (*i.e.* typhoid fever, cholera, infectious hepatitis, dysentery, etc.) namely pathogenic agents (Zaharia, 2011a). The bacteriological analysis being long-time consuming, the preventive water disinfection actions for human, industrial, sportive consumption are imposed with priority. Thus, disinfection becomes an important step in treatment of water resources because is a threat for public health or causes tastes, smells and unwanted increasings of organisms and pollutants concentration in conduits and basins.

The disinfection mechanism depends of desinfectant type (*i.e.* halogens, chloroamines, ozone, oxidizing agents, UV radiation, etc.) but also of organism type. The disinfectant based on halogen acts by penetration in cell and disactivation of essential enzime (produced by cell as spores, fungi, etc.) important being the oxidation potential directly correlated with disinfecting capacity. Numerous disinfection procedures are available: (*i*) *chemical disinfection* – with chemicals as: halogens – chlorine and derivates containing chlorine, chloroamine, bromine, iodine, ozone, other oxidizing agents (H_2O_2, H_2O_2/Fe^{2+}, Fe^{3+}, $KMnO_4$,etc.) and (*ii*) *non-chemical disinfection* – with heat (stream, hot air) and UV, ionizing radiation, which have also an important role.

The disinfecting mechanism (killing of pathogenic agents) is not very well known being expressed by empirical equations determined by kinetic models of diffusion and chemical transformations (*e.g.*, Chick law). Also, the disinfecting mechanism depends of contact time, temperature, pH, concentration of disinfectant, concentration of microorganisms (especially, total coliforms-TC, E-coli, total fecal coliforms) and presence of any interferring substances.

The diagnosis of environmental impact due to effluent treatment is one of the first stages in complete evaluation of sustainability of a technological treatment process of individual or mixed effluents. This is the reason for why the environmental impact assessment caused by final effluent treatment is always necessary, considering mainly the impact against natural aquatic environment (*i.e.* direct discharges in natural receptor of improper treated or even untreated final effluent). This is the principal target of this paper which evaluates the disinfection treatments applied to a final effluent from a zoo-technical farm in order to follow the development strategy for environmental protection adoptable/easily adopted by the farmer. Moreover, the study proposes the emphasizing of a practice tool for cumulative impact (CIA) based on application of alternative methodology of

global pollution index (I^*_{GP}), considered as a revision or initial evaluation of cumulative effects and local impact (Zaharia, 2011b, 2012).

MATERIAL AND METHOD

1. Data collection and analysis of different effluent quality indicators

Data collection, sampling and analysis of potential pollution produced by different effluent disinfection treatments from the studied zoo-technical farm against the natural aquatic environment (watercourse nearby) were performed, and achieved in the environmental analysis laboratory. The principal specific quality indicators of untreated and treated analyzed effluent are: pH, color, suspended solids - SS, chemical oxygen demand - COD_{Cr}, biochemical oxygen demand - BOD_5, chlorides, sulfates, ammonia, total nitrogen, total phosphorus, phenol index, fixed residues, total coliforms (TC), total fecal coliforms (TFC), etc. For analysis were used different individual analyzers or multifunctional apparatus (*i.e.* HACH One-Laboratory pH-meter; DRELL DR/2000 spectrophotometer - HACH Company, SP-830 Plus spectrophotometer - Metertech Inc., autoclave, microscope etc.) and, also, different volumetric (titrimetric) and gravimetric analysis methods internationally approved (analytical and microbiological methods) in accordance with the standards in force.

The application of preventive treatment of zoo-technical effluent (disinfection) is always indicated in each farm for ensuring a proper quality of all discharges in aquatic environment, based mainly on different mixed treatments (disinfection treatments), such as (Zaharia and Suteu, 2007; Zaharia and Surpateanu, 2009):

- *treatment **I**: coagulation (*bentonite - 3 g/L, ferric sulfate - 57.50 mol/L or aluminium sulfate - 5.85 mmol/L, 2 min of rapid agitation, 10 min of lent agitation, 50 rpm) – *sedimentation* (30 min of sedimentation or settlement),
- *treatment **II**: coagulation* (the same as the treatment I) – *sedimentation – simple oxidation (H_2O_2)* (36.76 mmol/L H_2O_2, min 3 h, or 24 h of oxidation) – *adsorption* (contact filter with active carbon - AC, for residual H_2O_2 removal),
- *treatment **III**: coagulation* (the same as treatments I-II) – *sedimentation – advanced oxidation* (H_2O_2 / Fe^{2+}, VIS radiation) (pH 3-4.5, 0.176 M H_2O_2, 1.44 M Fe^{2+}, 120 min of advanced oxidation) – *adsorption* (contact filter with AC),
- *treatment **IV**: coagulation*(as treatments I-III)– *sedimentation– chlorination* (pH=7.50, 1h, room temperature, 17.60 mg/L Cl-NaOCl, residual chlorine < 0.11 mg Cl_2/L),
- *treatment **V**: coagulation* (as treatments I-IV) – *sedimentation – UV Disinfection* pH=7.50, time of 1h, UV mercury lamp of medium pressure – length of 0.12 m, diameter of 0.020 m and tubular reactor of 0.3 L capacity, height of 0.45 m).

2.2. Environmental impact evaluation – Alternative methodology of I^*_{GP} index

Some analyzed quality indicators of the investigated zoo-technical effluent were used for calculation of an effluent quality index, EQ_i (Eq.1), and also of an evaluation score, ES_i, expressed by a mark between *1* and *10* attributed based on evaluation scale (Zaharia C., 2011b, 2012).

$$EQ_i = C_{i,measured} / CMA_i \quad (1)$$

in which, *i* – identification of the specific quality indicator; $C_{i,measured}$ – measured/analyzed value of the quality indicator and MAC_i – maximum admissible concentration of the quality indicator in accordance with the imposed limits of local environmental authority.

The cumulative effect of different potential polluting components is expressed by the average arithmetic value (EQ_{water} *or* ES_{water}) of all quality indicators (EQ_i) or evaluation scores (ES_i). For quantification of the environmental impact is calculated

the global pollution index (I^*_{GP}). The correlation between the global pollution index (I^*_{GP}), real state of aquatic environment and impact of effluent disinfection treatments is characterized in table 1 (Zaharia, 2011b, 2012).

Table 1

Correlation (I^*_{GP}) – local pollution status of aquatic environment in the alternative methodology of global pollution index

I^*_{GP} values	Real pollution status of natural aquatic environment
$I^*_{GP}=1$	Natural aquatic environment, unaffected by the effluent disinfecting treatment
$1 < I^*_{GP} < 2$	Aquatic environment modified by disinfecting treatment in admissible limits
$2 \leq I^*_{GP} < 3$	Aquatic environment modified by disinfecting treatment, with generation of discomfort effects
$3 \leq I^*_{GP} < 4$	Aquatic environment modified by disinfecting treatment, with stress generation against organisms
$4 \leq I^*_{GP} < 6$	Aquatic environment modified by disinfecting treatment, dangerous for organisms
$I^*_{GP} \geq 6$	Polluted aquatic environment (degraded), improper for organisms

RESULTS AND DISCUSSIONS

The disinfection performances and removals of different polluting components from zoo-technical effluent are good and sustain the necessity of its treatment (Zaharia and Suteu, 2007; Zaharia and Surpateanu, 2009). But, the principal quality indicators of untreated and disinfected zoo-technical effluent (table 2) require permanent control, environmental impact and risk assessment.

Table 2

Principal quality indicators of untreated and treated zoo-technical effluent

Quality indicator		Untreated effl.	I (C/S)	II (C/S, Ox.)	III (C/S, Adv.Ox.)	IV (C/S, chlorin.)	V (C/S, UV)	C.M.A.* (II quality category)	C.M.A.** (discharge in natural receptor)
Colour, HU		2442	1302	580	437	534	124	200	500
Suspended solids, mg/L		1385	476	108	73	92	86	150	60
Turbidity, FTU		1315	415	191	142	156	125	-	-
COD_{Cr}, mg O_2/L		549.2	133.5	81.14	65.3	85.6	25.2	25	125
BOD_5, mg O_2/L		102.3	82.2	75.4	29.6	78.9	23.4	5	25
Phenol index, mg/L		2.9	2.3	1.4	0.9	0.4	0.2	0.001	0.3
Total phosphorus, mg P/L		12.5	10.5	11.20	9.2	4.8	7.3	0.2	2.0
Fixed residues, mg/L		4736	3845	3452	2124	1732	1690	500	2000
Ammonia, mg/L		332	134	65.2	32.2	20.3	18.2	0.3	3.0
Total coliforms, no./L	Min	150	120	90	10	0	0	10000	5000
	Average	4500	2900	2600	300	60	10	10000	5000
	Max	12000	11000	9500	640	130	20	10000	5000
Total fecal coliforms, no./L	Min	80	70	60	10	0	0	500	50
	Average	3600	2200	2000	220	50	6	500	50
	Max	10500	8800	8200	4500	60	10	500	50

* Ministerial Order (MMDD) No.161/2006 (quality categories for water bodies); **Government Directive No. 352/2005 (NTPA 001) (Zaharia, 2008)

The quality indexes and evaluation scores of final treated effluent vary function of disinfection type, selected operational parameters, efficiency of each

treatment type and, also, working regime (continuous or discontinuous) (table 3). The maximum admisible limits of discharges in natural aquatic receptor are locally imposed, respecting Government Directive No.352/2005 approving the technical norms for discharges in natural aquatic receptors (NTPA001) (Zaharia, 2008).

Table 3

Quality indexes (EQ_i) and evaluation scores (ES_i) for different disinfection treatments of untreated and/or treated zoo-technical effluent

Quality indicator	Untreated efluent		I (C/S)		II (C/S, Oxidation)		III (C/S, Adv.Ox.)		IV (C/S, Chlorinaton)		V (C/S, UV)	
	EQ_i	ES_i	EQ_i	ES_i	EQ_i	ES_i	EQ_i	ES_i	EQ_i	ES_i	EQ_i	ES_i
Colour, HU	4.9	4	2.6	5	1.2	6	0.9	7	1.1	6	0.25	8
Suspended solids, mg/L	23.1	1	7.9	4	1.8	6	1.2	6	1.5	6	1.43	6
COD_{Cr}, mg O_2/L	4.7	4	1.1	6	0.5	8	0.5	8	0.07	9	0.2	9
BOD_5, mg O_2/L	4.1	4	3.3	5	3.0	5	1.2	6	3.2	5	0.94	7
Phenol Index, mg/L	9.7	3	7.7	4	4.7	4	3	5	1.3	6	0.67	8
Total phosphorus, mg P/L	6.3	4	5.3	4	5.6	4	4.6	4	2.4	5	3.65	5
Fixed residues, mg/L	2.3	5	1.9	6	1.7	6	1.1	6	0.9	7	0.85	7
Total coliforms, no./L	0.9	7	0.6	8	0.5	8	0.06	9	0.012	9	0.002	9
Average value:	**7.00**	**4.0**	**3.80**	**5.25**	**3.60**	**5.875**	**1.57**	**6.375**	**1.31**	**6.625**	**0.999**	**7.375**

Analyzing the values of quality indexes (EQ_i) and evaluation scores (ES_i) is evident that the natural aquatic environment is affected, but in admissible limits - level 2, with potential effects (treatment V), or over the maximum admissible limits – level 1, with pronounced effects (treatments – III, IV), or level 2, with dangerous effects (treatments – I, II) or can be considered degraded - level 2, with lethal effects at short times of exposure (untreated effluent).

The discharges of final zoo-technical effluents from the studied disinfection area must be periodically controlled for some quality indicators such as: total suspended solids, COD_{Cr}, BOD_5, ammonia, total N and total P, phenol index, fixed residues, but also for microbiological indicators (TC, TFC), among others.

The quality indexes vary between 0.99-7.00, and the evaluation scores are of 4.00-7.375. The final results of impact evaluation by the global pollution index are presented in table 5 for all five disinfection treatments and compared with the untreated effluent (pH 7.50) discharged directly in the local watercourse.

The values of global pollution index (I^*_{GP}) are of 1.782 - 3.419 (table 4) and correspond to some real situations of different local pollution as: a '*natural aquatic environment modified by the disinfection treatment of zoo-technical effluent*' in admissible limits (treatment V), or over these limits with generation of discomfort effects (treatments II-IV) or stress against organisms (treatment I).

These results sustain the necessity of zoo-technical effluent disinfection treatments in terms of good quality and environmental protection, with respecting the imposed quality of final effluent discharging, but also the application of preventive protection strategy and periodic control of discharges in natural receptors.

Table 5

Values of evaluation scores (ES_{water}), global pollution indexes (I^*_{GP}) and estimation of the real pollution state of natural aquatic environment (watercourse)

Effluent disinfection treatment	$\overline{ES}_i^2$	ES_{water}	I^*_{GP}	**Real status of local pollution of the natural aquatic environment**
Untreated effluent / No disinfection treatment	18.50	4.301	5.405	'Aquatic environment modified by the treatment, dangerous for organisms'
I (C/S)	29.25	5.408	3.419	'Aquatic environment modified by the effluent disinfection treatment, with generation of stress against organisms'
II (C/S, Ox, Ads))	36.625	6.052	2.730	'Aquatic environment modified by the effluent disinfection treatment, with generation of discomfort effects'
III (C/S, Adv.Ox,Ads)	42.875	6.548	2.332	
IV (C/S, Chlorination)	46.125	6.792	2.168	
V (C/S, UV)	56.125	7.492	1.782	'Aquatic environment modified by the treatment in admissible limits'

CONCLUSIONS

1. The results of cumulative impact evaluation due to some different disinfections of a final zoo-technical effluent by the global pollution index (I^*_{GP}) indicate a local pollution of natural aquatic environment in comparison with the natural state (ES_{water}=10) (*i.e.* real evaluation scores of 4.301-7.492 (ES_{water}) for aquatic environment of discharging zone).

2. The values of I^*_{GP} (1.782-3.419) correspond to a 'natural aquatic environment modified by the effluent disinfecting treatment' in different ways such as: 'in admissible limits' (treatment V) or 'over the admissi-ble limits', with potential of generation discomfort effects (treatments II-IV) or stress against organisms (treatment I).

3. The direct discharging of untreated zoo-technical effluent in the watercourse is estimated to be generating an 'aquatic environment modified, dangerous for organisms'.

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