INTERCRITERIA ANALYSIS OF WASTEWATER TREATMENT QUALITY

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Abstract

Recently developed InterCriteria Analysis (ICrA) is here applied to assess the quality of the processes of water purification in a typical wastewater treatment plant (WTP). Various parameters dependences characterizing the quality of WTP processes such as water quantity, pH, COD, petrol, different mechanical admixtures, PO_4P, NH_4N, etc., are going to be analyzed based on real experimental data. Degrees of "agreement" and degrees of "disagreement" between preliminary determined criteria have been established implementing ICrA. This is expected to result in an additional knowledge acquisition about the WTP process itself and in establishment of some relations between ICrA criteria, especially in terms of time (seasonal) dependences.

Key words: *wastewater, treatment, intercriteria, analysis*

1. INTRODUCTION

The desire for a higher standard of living leads to the increase of requirements towards the quality of water both for its everyday usage by human beings, as well as for its application to domestic settings. When used in industrial application, different admixtures, varied in character and dispersion, which occur into the water, thus turning it into so called "wastewater". Logically, the treatment of large quantities of wastewater before their return to the environment has become an indispensable necessity for the contemporary industry and manner of life. This fact determines the continuous development of the technologies for wastewater treatment plant (WTP) processes. As such, there is a necessity of WTP processes analysis aiming at optimization of the apparatuses exploitation and facilities, included in the technological schemes. On the other hand, rendering all methods and factors that influent the quality of wastewater treatment makes modeling process of WTP technological scheme a real challenge to the researchers.

In this paper the InterCriteria Analysis (ICrA) is applied to establish the relations between process parameters, which reflect the wastewater treatment quality, such as water quantity, pH, COD, petrol, different mechanical admixtures, PO_4P, NH_4N. The existing relations are identified based on real experimental data from a typical WTP during a year.

ICrA is an approach aiming to go beyond the nature of the criteria involved in a process of evaluation of multiple objects against multiple criteria, and, on this basis, to discover any existing correlations between the criteria themselves [Atanassov et al., 2014]. ICrA has been further applied in different areas of science and practice [Atanassova et al., 2014; Krawczak et al., 2016; Pencheva et al., 2016]. ICrA approach has been also implemented to the Mesta river pollution modelling [Ilkova and Petrov, 2015]. Results obtained from this application prove that in the case of some ecological problems ICrA approach could be very useful. Additional knowledge for existing process parameters correlations derived after the application of ICrA might be useful in further analysis and optimization of WTP processes.

2. INTERCRITERIA ANALYSIS

Following [Atanassov, 2012; Atanassov et al., 2014], an Intuitionistic Fuzzy Pair (IFP) ([Atanassov et al., 2013]) as an estimation of the degrees of "agreement" and "disagreement" between two criteria applied to different objects, is obtained. Recall that an IFP is an ordered pair of real non-negative numbers $\langle a,b\rangle$ such that: $a+b\leq 1$.

Consider an Index Matrix (IM) ([Atanassov, 1987; Atanassov, 2010a; Atanassov, 2010b]) whose index sets consist of the criteria (for rows) and objects (for columns). The elements of this IM are further assumed to be real numbers. An IM with index sets consisting of the criteria (for rows and for columns) with elements IFPs corresponding to the degrees of "agreement" and "disagreement" between the respective criteria is then constructed.

Let O denotes the set of all objects $O_1,O_2,\ldots,O_n$ being evaluated, and $C(O)$ be the set of values assigned by a given criteria C to the objects, i.e.

$$O \overset{\text{def}}{=} \{O_1,O_2,\ldots,O_n\}; C(O) \overset{\text{def}}{=} \{C(O_1),C(O_2),\ldots,C(O_n)\}.$$

Then, let:

$$C^*(O) \overset{\text{def}}{=} \{\langle x,y\rangle \mid x\neq y \;\&\; \langle x,y\rangle \in C(O)\times C(O)\}.$$

In order to find the "agreement" between two criteria, the vector of all internal comparisons of each criteria, which fulfill exactly one of three relations R, $\overline{R}$ and $\tilde{R}$, is constructed. In other words, it is required that for a fixed criterion C and any ordered pair $\langle x,y\rangle \in C^*(O)$ it is true:

$$\langle x,y\rangle \in R \Leftrightarrow \langle y,x\rangle \in \overline{R}, \tag{1}$$

$$\langle x,y\rangle \in \tilde{R} \Leftrightarrow \langle x,y\rangle \notin (R\cup \overline{R}), \tag{2}$$

$$R\cup \overline{R}\cup \tilde{R} = C^*(O). \tag{3}$$

From the above it is seen that only a subset of $C(O)\times C(O)$ needs to be considered for the effective calculation of the vector of internal comparisons (further denoted by $V(C)$) since from Eqs. (1)-(3) it follows that if the relation between x and y is known, then so is the relation between *y* and *x*. Thus of interest are only the lexicographically ordered pairs $\langle x,y\rangle$. Denote for brevity:

$$C_{i,j} = \langle C(O_i),C(O_j)\rangle.$$

Then for a fixed criterion C, the vector with $\frac{n(n-1)}{2}$ elements is obtained:

$$V(C) = \{C_{1,2},C_{1,3},\ldots,C_{1,n},C_{2,3},C_{2,4},\ldots,C_{2,n},C_{3,4},\ldots,C_{3,n},\ldots,C_{n-1,n}\}.$$

Let $V(C)$ be replaced by $\hat{V}(C)$, where for the *k*-th component ($1\leq k\leq \frac{n(n-1)}{2}$):

$$\hat{V}_k(C) = \begin{cases} 1, \text{ iff } V_k(C)\in R \\ -1, \text{ iff } V_k(C)\in \overline{R} \\ 0, \text{ otherwise} \end{cases}.$$

When comparing two criteria the degree of "agreement" is determined as the number of matching components of the respective vectors, divided by the length of the vector for normalization purposes. This can be done in several ways, e.g. by counting the matches or by taking the complement of the Hamming distance. The degree of "disagreement" is the number of components of opposing signs in

the two vectors, again normalized by the length. An example pseudocode for two criteria C and C' is presented in the Fig. 1.

Algorithm 1

Require: Vectors $\hat{V}(C)$ and $\hat{V}(C')$

function DEGREES OF AGREEMENT AND DISAGREEMENT($\hat{V}(C), \hat{V}(C')$)
  $V \leftarrow \hat{V}(C) - \hat{V}(C')$
  $\mu \leftarrow 0$
  $\nu \leftarrow 0$
  for $i \leftarrow 1$ to $\frac{n(n-1)}{2}$ **do**
    if $V_i = 0$ **then**
      $\mu \leftarrow \mu + 1$
    else if abs$(V_i) = 2$ **then** ▷ abs(V_i): the absolute value of V_i
      $\nu \leftarrow \nu + 1$
    end if
  end for
  $\mu \leftarrow \frac{2}{n(n-1)}\mu$
  $\nu \leftarrow \frac{2}{n(n-1)}\nu$
  return μ, ν
end function

Fig. 1 A pseudocode of the ICrA algorithm

If the respective degrees of "agreement" and "disagreement" are denoted by $\mu_{C,C'}$ and $\nu_{C,C'}$, it is obvious (from the way of computation) that $\mu_{C,C'} = \mu_{C',C}$ and $\nu_{C,C'} = \nu_{C',C}$. Also, it is true that $\langle \mu_{C,C'}, \nu_{C,C'} \rangle$ is an IFP. In the most of the obtained pairs $\langle \mu_{C,C'}, \nu_{C,C'} \rangle$, the sum $\mu_{C,C'} + \nu_{C,C'}$ is equal to 1. However, there may be some pairs, for which this sum is less than 1. The difference

$$\pi_{C,C'} = 1 - \mu_{C,C'} - \nu_{C,C'} \tag{4}$$

is considered as a degree of "uncertainty".

3. PROBLEM FORMULATION – WASTEWATER TREATMENT PROCESSES IN A TYPICAL WTP

The processes in a WTP can be generally grouped in the following main technological stages: mechanical, physics-chemical, biological treatment.

The mechanical treatment is the first stage of the WTP process. The water undergoes discharged of the roughest materials, which are separated with the help of screens, sieves, sand filters, and so on. The removal of petrol products is executed through precipitation (floatation) and the process is carried out in the so called petrol collectors. The separation of petrol products happens because of the difference of relative densities of the wastewater and the petrol products. For the removal of roughly dispersed admixtures various kinds of construction precipitators (horizontal, radial, etc.) are utilized, thus the heavier particles precipitate because of the gravitational forces, while the lighter once float.

While for the chemically contaminated water this preliminary preparation ensures the enough water purification for entering the biological stage, for the industrial-rain water the water flow enters in the physics-chemical step. The processes of coagulation and floatation are there executed. The main purpose of the coagulation treatment is the removal of the finely dispersed, colloid and emulsified

admixtures in the wastewater. This action is carried out via the coagulants introduction, which triggers destabilization of the colloid systems and glues the pollutant particles in larger aggregates that could be more easily separated from the water. To accelerate and enhance the process (improvement of the density and adhesion properties of the aggregates) different types of flocculants are used – they most often consist of high molecular water dissolvable polymers. During floatation wastewater is saturated with air bubbles, which adhere to the surface of the admixtures, and formed floatation particles-gas bubbles complexes dissociate at the water surface as a foam layer.

Passing through the mechanical and physics-chemical steps, the treated water moves on to the stage of biological treatment. The carbon assimilation processes are there executed, i.e. the assimilation of the organic pollutants found in the water. Carbon dioxide (CO_2), water and ammonia (NH_4) are derived as the end products of the oxidation. The removal of ammonia is ensured through the nitrification process, and as a result ammonia turns into nitrates or nitrites. Then, a denitrification process occurs, in which the oxygen connected in the nitrates or nitrites might be used in a case of a deficit of molecular oxygen for breathing of heterotrophic organisms. The released nitrogen in the form of gas, as well as the CO_2, is removed in a deaerator. The purified wastewater is separated from the active precipitates in the so called secondary radial precipitator. The crucial indices, which are monitored before water discharging, are chemical oxygen demand (COD), biological oxygen demand (BOD), undissolved admixtures, phosphates, general P, general N, N in NO_3, N in NO_2, N in NH_4, etc.

Fig. 2 presents described above main technological stages of the wastewater treatment processes carried out in a typical WTP.

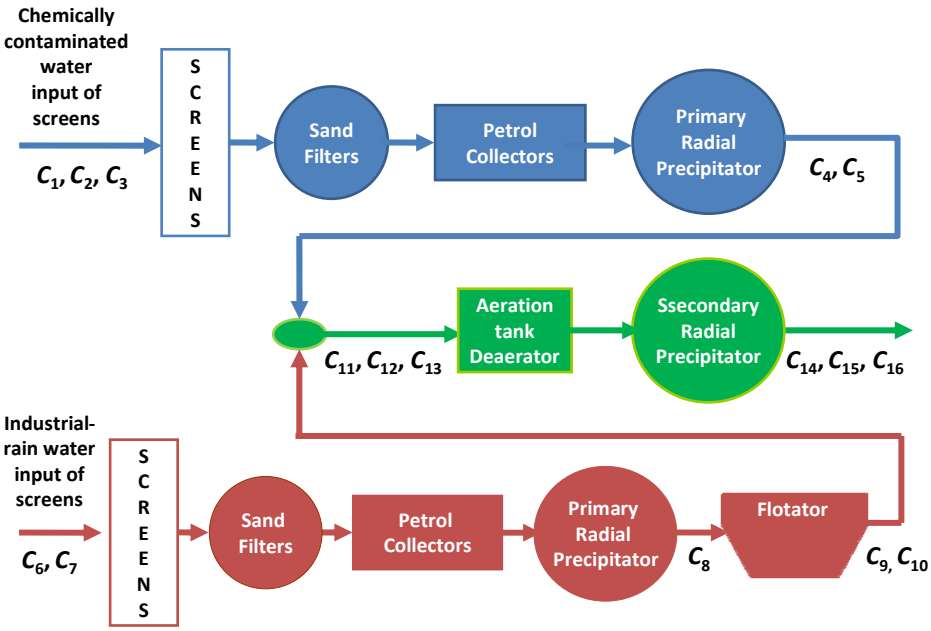


Fig. 2 Technological scheme of a typical WTP

The following criteria for the quality of wastewater purification, presented also in Fig. 2, have been chosen for ICrA based on available real experimental data from a typical WTP:

- C_1 – pH of the chemically contaminated water in the input of the screens,
- C_2 – petrol in the chemically contaminated water in the input of the screens,
- C_3 – mechanical admixtures in the chemically contaminated water in the input of the screens,
- C_4 – petrol in the primary precipitator output,

- C_5 – mechanical admixtures in the primary precipitator output,
- C_6 – pH of the industrial-rain water in the input of the screens,
- C_7 – mechanical admixtures of the industrial-rain water in the input of the screens,
- C_8 – petrol in the flotator input,
- C_9 – petrol in the flotator output,
- C_{10} – mechanical admixtures in the flotator output,
- C_{11} – pH of the mixed water flow in the input of biological treatment stage,
- C_{12} – petrol in the mixed water flow in the input of biological treatment stage,
- C_{13} – NH_4-N in the mixed water flow in the input of biological treatment stage,
- C_{14} – pH of the mixed water flow in the output of biological treatment stage,
- C_{15} – petrol in the mixed water flow in the output of biological treatment stage,
- C_{16} – NH_4-N in the mixed water flow in the output of biological treatment stage.

Input data extracted from the experimental data set from a typical WTP is presented respectively in Table 1 for the winter season and Table 2 for the summer season. As representative for the winter season are chosen the months October, November, December, January and February, while for the summer season – the months May, June, July, August and September.

Table 1. Input data – winter season

	Oct	Nov	Dec	Jan	Feb
C_1	8.276	8.579	8.523	8.755	9.132
C_2	244.245	226.681	208.611	973.945	568.733
C_3	72.148	113.404	116.699	56.656	55.225
C_4	42.732	53.238	52.615	77.916	30.565
C_5	51.601	52.454	54.196	21.352	22.571
C_6	7.284	7.561	7.538	7.740	7.705
C_7	107.930	33.409	33.483	47.710	201.093
C_8	40.805	35.420	34.289	47.469	42.428
C_9	33.361	29.481	28.031	42.297	35.090
C_{10}	12.161	7.702	7.192	5.688	19.552
C_{11}	8.151	8.168	8.042	8.131	8.139
C_{12}	39.896	38.903	32.653	64.105	30.046
C_{13}	25.943	26.491	25.311	29.808	17.158
C_{14}	7.134	7.111	7.084	7.340	7.341
C_{15}	1.140	1.029	1.004	2.956	1.118
C_{16}	6.629	3.130	1.650	18.708	7.061

4. RESULTS AND DISCUSSION

Using presented above input IMs (Table 1 and Table 2) ICrA is performed. Introduced algorithm (Fig. 1) calculates the IFP $\langle \mu_{C,C'}, \nu_{C,C'} \rangle$ for every two pairs of considered sixteen criteria ($C_1, C_2, \ldots, C_{16}$). The results are summarized in Tables 3-4 (winter season) and Tables 5-6 (summer season). Obtained results are analyzed and discussed according to the proposed in [Atanassov et al., 2015] scale for a definition of consonance and dissonance between each pair of criteria (Table 7).

Table 2. Input data – summer season

	May	June	July	Aug	Sept
C_1	8.514	8.862	8.240	8.415	8.579
C_2	245.182	270.039	428.171	224.233	226.681
C_3	80.210	64.294	70.854	60.317	113.404
C_4	24.037	34.920	57.756	38.394	52.615
C_5	21.960	30.043	125.258	46.084	54.502
C_6	7.484	7.758	7.706	7.732	7.740
C_7	113.462	251.763	103.752	109.629	33.483
C_8	38.804	32.535	39.855	36.311	34.289
C_9	31.783	25.490	34.077	29.082	28.031
C_{10}	10.803	10.431	13.042	7.125	12.810
C_{11}	8.256	8.621	8.212	8.245	8.382
C_{12}	26.146	30.275	38.046	31.359	32.653
C_{13}	23.329	27.005	21.967	25.378	35.310
C_{14}	6.902	6.936	7.153	7.182	7.084
C_{15}	0.828	1.106	1.157	0.874	1.004
C_{16}	3.166	3.830	0.534	1.139	3.620

Table 3. Results from ICrA application (degrees of "agreement") – winter season

$\mu_{C,C'}$	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
C_1	1.0	0.5	0.6	0.3	0.3	0.8	0.7	0.1	0.1	0.4	1.0	0.3	0.8	0.3	0.5	1.0
C_2	0.5	1.0	0.5	0.6	0.6	0.5	0.6	0.6	0.6	0.7	0.5	0.6	0.3	0.4	0.8	0.5
C_3	0.6	0.5	1.0	0.5	0.5	0.4	0.3	0.5	0.5	0.8	0.6	0.5	0.6	0.3	0.5	0.6
C_4	0.3	0.6	0.5	1.0	1.0	0.5	0.2	0.6	0.6	0.7	0.3	1.0	0.5	0.8	0.8	0.3
C_5	0.3	0.6	0.5	1.0	1.0	0.5	0.2	0.6	0.6	0.7	0.3	1.0	0.5	0.8	0.8	0.3
C_6	0.8	0.5	0.4	0.5	0.5	1.0	0.5	0.1	0.1	0.4	0.8	0.5	0.8	0.5	0.7	0.8
C_7	0.7	0.6	0.3	0.2	0.2	0.5	1.0	0.4	0.4	0.3	0.7	0.2	0.5	0.4	0.4	0.7
C_8	0.1	0.6	0.5	0.6	0.6	0.1	0.4	1.0	1.0	0.7	0.1	0.6	0.1	0.6	0.4	0.1
C_9	0.1	0.6	0.5	0.6	0.6	0.1	0.4	1.0	1.0	0.7	0.1	0.6	0.1	0.6	0.4	0.1
C_{10}	0.4	0.7	0.8	0.7	0.7	0.4	0.3	0.7	0.7	1.0	0.4	0.7	0.4	0.5	0.7	0.4
C_{11}	1.0	0.5	0.6	0.3	0.3	0.8	0.7	0.1	0.1	0.4	1.0	0.3	0.8	0.3	0.5	1.0
C_{12}	0.3	0.6	0.5	1.0	1.0	0.5	0.2	0.6	0.6	0.7	0.3	1.0	0.5	0.8	0.8	0.3
C_{13}	0.8	0.3	0.6	0.5	0.5	0.8	0.5	0.1	0.1	0.4	0.8	0.5	1.0	0.5	0.5	0.8
C_{14}	0.3	0.4	0.3	0.8	0.8	0.5	0.4	0.6	0.6	0.5	0.3	0.8	0.5	1.0	0.6	0.3
C_{15}	0.5	0.8	0.5	0.8	0.8	0.7	0.4	0.4	0.4	0.7	0.5	0.8	0.5	0.6	1.0	0.5
C_{16}	1.0	0.5	0.6	0.3	0.3	0.8	0.7	0.1	0.1	0.4	1.0	0.3	0.8	0.3	0.5	1.0

pH
petrol
mech. adm.
NH4-N

Table 4. Results from ICrA application (degrees of "disagreement") – winter season

$\nu_{C,C'}$	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
C_1	0.0	0.5	0.4	0.7	0.7	0.2	0.3	0.9	0.9	0.6	0.0	0.7	0.2	0.7	0.5	0.0
C_2	0.5	0.0	0.5	0.4	0.4	0.5	0.4	0.4	0.4	0.3	0.5	0.4	0.7	0.6	0.2	0.5
C_3	0.4	0.5	0.0	0.5	0.5	0.6	0.7	0.5	0.5	0.2	0.4	0.5	0.4	0.7	0.5	0.4
C_4	0.7	0.4	0.5	0.0	0.0	0.5	0.8	0.4	0.4	0.3	0.7	0.0	0.5	0.2	0.2	0.7
C_5	0.7	0.4	0.5	0.0	0.0	0.5	0.8	0.4	0.4	0.3	0.7	0.0	0.5	0.2	0.2	0.7
C_6	0.2	0.5	0.6	0.5	0.5	0.0	0.5	0.9	0.9	0.6	0.2	0.5	0.2	0.5	0.3	0.2
C_7	0.3	0.4	0.7	0.8	0.8	0.5	0.0	0.6	0.6	0.7	0.3	0.8	0.5	0.6	0.6	0.3
C_8	0.9	0.4	0.5	0.4	0.4	0.9	0.6	0.0	0.0	0.3	0.9	0.4	0.9	0.4	0.6	0.9
C_9	0.9	0.4	0.5	0.4	0.4	0.9	0.6	0.0	0.0	0.3	0.9	0.4	0.9	0.4	0.6	0.9
C_{10}	0.6	0.3	0.2	0.3	0.3	0.6	0.7	0.3	0.3	0.0	0.6	0.3	0.6	0.5	0.3	0.6
C_{11}	0.0	0.5	0.4	0.7	0.7	0.2	0.3	0.9	0.9	0.6	0.0	0.7	0.2	0.7	0.5	0.0
C_{12}	0.7	0.4	0.5	0.0	0.0	0.5	0.8	0.4	0.4	0.3	0.7	0.0	0.5	0.2	0.2	0.7
C_{13}	0.2	0.7	0.4	0.5	0.5	0.2	0.5	0.9	0.9	0.6	0.2	0.5	0.0	0.5	0.5	0.2
C_{14}	0.7	0.6	0.7	0.2	0.2	0.5	0.6	0.4	0.4	0.5	0.7	0.2	0.5	0.0	0.4	0.7
C_{15}	0.5	0.2	0.5	0.2	0.2	0.3	0.6	0.6	0.6	0.3	0.5	0.2	0.5	0.4	0.0	0.5
C_{16}	0.0	0.5	0.4	0.7	0.7	0.2	0.3	0.9	0.9	0.6	0.0	0.7	0.2	0.7	0.5	0.0

pH
petrol
mech. adm.
NH4-N

Table 5. Results from ICrA application (degrees of "agreement") – summer season

$\mu_{C,C'}$	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
C_1	1.0	0.5	0.6	0.3	0.3	0.8	0.7	0.1	0.1	0.4	1.0	0.3	0.8	0.3	0.5	1.0
C_2	0.5	1.0	0.5	0.6	0.6	0.5	0.6	0.6	0.6	0.7	0.5	0.6	0.3	0.4	0.8	0.5
C_3	0.6	0.5	1.0	0.5	0.5	0.4	0.3	0.5	0.5	0.8	0.6	0.5	0.6	0.3	0.5	0.6
C_4	0.3	0.6	0.5	1.0	1.0	0.5	0.2	0.6	0.6	0.7	0.3	1.0	0.5	0.8	0.8	0.3
C_5	0.3	0.6	0.5	1.0	1.0	0.5	0.2	0.6	0.6	0.7	0.3	1.0	0.5	0.8	0.8	0.3
C_6	0.8	0.5	0.4	0.5	0.5	1.0	0.5	0.1	0.1	0.4	0.8	0.5	0.8	0.5	0.7	0.8
C_7	0.7	0.6	0.3	0.2	0.2	0.5	1.0	0.4	0.4	0.3	0.7	0.2	0.5	0.4	0.4	0.7
C_8	0.1	0.6	0.5	0.6	0.6	0.1	0.4	1.0	1.0	0.7	0.1	0.6	0.1	0.6	0.4	0.1
C_9	0.1	0.6	0.5	0.6	0.6	0.1	0.4	1.0	1.0	0.7	0.1	0.6	0.1	0.6	0.4	0.1
C_{10}	0.4	0.7	0.8	0.7	0.7	0.4	0.3	0.7	0.7	1.0	0.4	0.7	0.4	0.5	0.7	0.4
C_{11}	1.0	0.5	0.6	0.3	0.3	0.8	0.7	0.1	0.1	0.4	1.0	0.3	0.8	0.3	0.5	1.0
C_{12}	0.3	0.6	0.5	1.0	1.0	0.5	0.2	0.6	0.6	0.7	0.3	1.0	0.5	0.8	0.8	0.3
C_{13}	0.8	0.3	0.6	0.5	0.5	0.8	0.5	0.1	0.1	0.4	0.8	0.5	1.0	0.5	0.5	0.8
C_{14}	0.3	0.4	0.3	0.8	0.8	0.5	0.4	0.6	0.6	0.5	0.3	0.8	0.5	1.0	0.6	0.3
C_{15}	0.5	0.8	0.5	0.8	0.8	0.7	0.4	0.4	0.4	0.7	0.5	0.8	0.5	0.6	1.0	0.5
C_{16}	1.0	0.5	0.6	0.3	0.3	0.8	0.7	0.1	0.1	0.4	1.0	0.3	0.8	0.3	0.5	1.0

pH
petrol
mech. adm.
NH4-N

Table 6. Results from ICrA application (degrees of "disagreement") – summer season

$\nu_{C,C'}$	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
C_1	0.0	0.5	0.4	0.7	0.7	0.2	0.3	0.9	0.9	0.6	0.0	0.7	0.2	0.7	0.5	0.0
C_2	0.5	0.0	0.5	0.4	0.4	0.5	0.4	0.4	0.4	0.3	0.5	0.4	0.7	0.6	0.2	0.5
C_3	0.4	0.5	0.0	0.5	0.5	0.6	0.7	0.5	0.5	0.2	0.4	0.5	0.4	0.7	0.5	0.4
C_4	0.7	0.4	0.5	0.0	0.0	0.5	0.8	0.4	0.4	0.3	0.7	0.0	0.5	0.2	0.2	0.7
C_5	0.7	0.4	0.5	0.0	0.0	0.5	0.8	0.4	0.4	0.3	0.7	0.0	0.5	0.2	0.2	0.7
C_6	0.2	0.5	0.6	0.5	0.5	0.0	0.5	0.9	0.9	0.6	0.2	0.5	0.2	0.5	0.3	0.2
C_7	0.3	0.4	0.7	0.8	0.8	0.5	0.0	0.6	0.6	0.7	0.3	0.8	0.5	0.6	0.6	0.3
C_8	0.9	0.4	0.5	0.4	0.4	0.9	0.6	0.0	0.0	0.3	0.9	0.4	0.9	0.4	0.6	0.9
C_9	0.9	0.4	0.5	0.4	0.4	0.9	0.6	0.0	0.0	0.3	0.9	0.4	0.9	0.4	0.6	0.9
C_{10}	0.6	0.3	0.2	0.3	0.3	0.6	0.7	0.3	0.3	0.0	0.6	0.3	0.6	0.5	0.3	0.6
C_{11}	0.0	0.5	0.4	0.7	0.7	0.2	0.3	0.9	0.9	0.6	0.0	0.7	0.2	0.7	0.5	0.0
C_{12}	0.7	0.4	0.5	0.0	0.0	0.5	0.8	0.4	0.4	0.3	0.7	0.0	0.5	0.2	0.2	0.7
C_{13}	0.2	0.7	0.4	0.5	0.5	0.2	0.5	0.9	0.9	0.6	0.2	0.5	0.0	0.5	0.5	0.2
C_{14}	0.7	0.6	0.7	0.2	0.2	0.5	0.6	0.4	0.4	0.5	0.7	0.2	0.5	0.0	0.4	0.7
C_{15}	0.5	0.2	0.5	0.2	0.2	0.3	0.6	0.6	0.6	0.3	0.5	0.2	0.5	0.4	0.0	0.5

pH
petrol
mech. adm.
NH4-N

Table 7. Definition of consonance and dissonance between each pair of criteria

$\mu_{C,C'}$	Meaning
[0.00-0.05]	strong negative consonance
(0.05-0.15]	negative consonance
(0.15-0.25]	weak negative consonance
(0.25-0.33]	weak dissonance
(0.33-0.43]	dissonance
(0.43-0.57]	strong dissonance
(0.57-0.67]	dissonance
(0.67-0.75]	weak dissonance
(0.75-0.85]	weak positive consonance
(0.85-0.95]	positive consonance
(0.95-1.00]	strong positive consonance

During the summer season (months from May to September), the following dependences have been observed considering pH of the wastewater:

- The relation between pH of the chemically contaminated water flowing to the screens (C_1) and pH of the mixed water flow in the input of biological treatment stage (C_{11}) ($C_1 \leftrightarrow C_{11}$) shows the maximum value of the degree of "agreement", namely $\mu = 1.00$ and as such this criteria pair falls in the range of strong positive consonance. This fact demonstrates that there are no any significant variations in the values of pH of the wastewater flowing in the WTP during the summer season. This conclusion is confirmed also by the observed relations for another two criteria pairs: 1) between pH of the chemically contaminated water flowing to the screens (C_1) and pH of the industrial-rain water flowing to the screens (C_6) ($C_1 \leftrightarrow C_6$), and 2) between pH of the industrial-rain water flowing to the screens (C_6) and pH of the mixed water flow in the input of biological treatment stage (C_{11}) ($C_6 \leftrightarrow C_{11}$). These two criteria pairs fall in the range of weak positive consonance with $\mu = 0.8$.
- The rest of the criteria pairs considering dependences of pH of the wastewater do not show any strong relations and as such they fall in the ranges of dissonance. This fact does not mean at all that the water in the output of the biological treatment stage is not enough purified. The values of pH of the purified water are in the interval of 6.9 to 7.2. ICrA shows μ-values in the range of dissonance because, i.e., in May $C_1 = 8.5$ (higher than August) and $C_{14} = 6.9$ (lower than August), while in August $C_1 = 8.4$ (lower than May) and $C_{14} = 7.2$ (higher than May).

During the summer season the following dependences have been observed considering petrol of the wastewater:

- There is a trend of average tending to high values ($\mu = 0.6$) of the relations between the following: petrol in the chemically contaminated water flowing to the screens (C_2) and petrol in the primary precipitator output (C_4) ($C_2 \leftrightarrow C_4$), and the petrol in the flotator input (C_8) / output (C_9) throughout ($C_2 \leftrightarrow C_8$) / ($C_2 \leftrightarrow C_9$) and petrol in the mixed water flow in the input of biological treatment stage (C_{12}) ($C_2 \leftrightarrow C_{12}$). The trend in the relations between those values demonstrates a relatively strong (albeit not prominent enough) dependency throughout the winter period. Such dependencies are also present between ($C_4 \leftrightarrow C_8$), ($C_4 \leftrightarrow C_9$) and

($C_4 \leftrightarrow C_{12}$). Throughout the summer period the relations between ($C_2 \leftrightarrow C_8$) and ($C_2 \leftrightarrow C_9$) exhibit a factor $\mu = 1.0$, which illustrates a high dependency.

- The following key points can be inferred from the analysis:

1. Throughout the winter period the mechanical and physically-chemical removal of petrol derivatives depends on the tendencies in the temperature of the precipitation processes (floatation). Under lower temperatures (respectively lower water viscosity), the treatment`s effectiveness worsens.
2. Throughout the winter period there are seasonally dependent fluctuations in the petrol concentration. On the other hand, the relation between the petrol in the mixed water flow in the biological treatment stage`s output (C_{15}) ($C_2 \leftrightarrow C_{15}$) and ($C_2 \leftrightarrow C_{15}$) exhibits high degree of consonance ($\mu = 0.8$ winter / $\mu = 0.9$ summer) regardless of season. Those values indicate the permanently good working of the biological step, slightly better consonance during the winter.
3. During the summer period the higher temperature values have a negative influence on the solubility of O_2 in water. The biochemical processes, however, speed up with higher temperatures i.e. temperatures do not have a uniform influence.
4. During the summer period seasonal dependence of wastewater pollution and probably seasonal difference in concentration due to at times incidentally bigger quantity of atmospheric water content is observed. This leads to variety in influence of the basic component "Industrial rain water", dilution and "shift" of the relations between the different steps in the wastewater plant.

During the summer season the following dependences have been observed considering different mechanical admixtures of the wastewater:

- There exists an average value of the degree of "agreement" ($\mu = 0.5$) between the indices „mechanical admixtures in the chemically contaminated water in the input of the screens" (C_3) and "mechanical admixtures in the primary precipitator output" (C_5) ($C_3 \leftrightarrow C_5$). This dependence is high in ($C_3 \leftrightarrow C_{10}$) ($C_{10}$ – mechanical admixtures in the flotator output) and falls down to $\mu = 0.8$ only during the winter period. During the summer period the value is $\mu = 0.3$, i.e. negative consonance. The high dependence during the winter period is supposed to be inferred from the character of the wastewater flows. The quantity of industrial wastewater is bigger throughout the whole period, and therefore has bigger drift of pollutants from the area containing the water on the facilities' territory.

During the winter season (months of October to February), the following dependences have been observed considering pH of the wastewater:

- In this case the maximum value of the degree of "agreement", namely $\mu = 0.9$ is obtained for the criteria pair $C_1 \leftrightarrow C_6$ and as such it falls in the range of positive consonance. This observation is caused by the fact that during the winter season there are no any significant month variations in the values of pH of the two wastewater flows – chemically contaminated and industrial-rain water. In comparison, in the summer season this correlation is a bit weaker ($\mu = 0.8$).
- For this year season, a weak positive consonance is observed for the criteria pair the $C_1 \leftrightarrow C_{14}$ ($\mu = 0.8$). The same relation is expected for the criteria pair $C_6 \leftrightarrow C_{14}$, although the results show weak dissonance ($\mu = 0.7$). Having in mind that for this analysis real experimental data are used, such a small discrepancy might be caused by the measurement errors.
- In contrast to summer season, the criteria pairs $C_1 \leftrightarrow C_{11}$ and $C_6 \leftrightarrow C_{11}$ fall into the ranges of dissonance, which means that no strong relations have been observed.

- Considering NH_4-N of the wastewater in the input (C_{13}) and in the output (C_{16}) of biological treatment stage it is observed weak positive consonance during the summer season and dissonance in the winter period.

5. CONCLUSIONS

In this investigation ICrA approach is applied, employing the apparatuses of index matrices and intuitionistic fuzzy sets. ICrA works based on an existing index matrix with multiobject multicriteria evaluations aiming to produce a new index matrix that contains intuitionistic fuzzy pairs with the correlations revealed to exist in between the set of evaluation criteria. Here, ICrA is implemented for such an important problem as wastewater treatment processes assessment. ICrA is applied to assess the quality of wastewater treatment processes in a typical WTP and to determine possible dependencies between some criteria preliminary defined as of significant importance.

Real data for pH, petrol, mechanical admixtures, NH_4N, observed at different stages of WTP process, are defined as sixteen ICrA criteria. ICrA approach has been implemented and obtained results have been thoroughly analysed. Degrees of "agreement" and "disagreement" between preliminary determined criteria have been established. This results in an additional knowledge of the WTP process itself and in the establishment of some relations between ICrA criteria, especially in terms of time (seasonal) dependences.

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