Quantification of the Degree of Comfort given by Drinking Water Characteristics

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This paper proposes a way to quantify comfort provided by drinking water. There are treated three parameters: quality, flow and pressure of potable water to the consumer. Each of the three parameters is composed of several elements studied. It was quantified the comfort provided by each of these factors, taking as reference the values of the studied limit factors provided by law. It was obtained a final value of comfort provided by water consumption in a certain point of consumption, which corroborates the values obtained for each of the studied elements .

Keywords: Comfort, flow, pressure, quality characteristics

Water is the most important food irreplaceable. Water is a fundamental part of the human body, essential survival, with an overall 60% of body weight, 40% intracellular and 20% extracellular. Any small imbalance created between the proportions may cause serious disorders of the body.

Roles of water in human body are numerous and decisive as following structural role - the main component of human body; the reaction medium in all the metabolic processes; has a great contribution to the maintaining of homeostasis being also a source of minerals and other useful body substances.

Limited water resources in general and of drinking water in particular leads to a rational consumption of drinking water, even limited in certain areas of the world. The current trend and future is the increase the importance of water in general and drinking water in particular, due to the awareness of water quality limits sources. Earth's water reserves are mostly polluted and there are in a large decline if we relate to the growing population. Therefore, in the near future drinking water will be a strong currency for all nations. For this reason it must be a unitary standardization of drinking water characteristics and especially the comfort given by the characteristics of the water. Quantifying of the drinking water characteristics and quantifying the degree of comfort given by the characteristics of drinking water are issues which arise more acutely [1-4].

To make this process we must respect all legislation in force. There is a Primary Legislation: Law 458/2002 on the quality of drinking water with additions and changes in the law 311/2004 and Law 124/2010 approving Government Ordinance 11/2010 for the amendment and completion of Law 458/2002 [12-16,19] and Secondary Legislation: Government Decision 974/2004 for the approval of the supervisory sanitary inspection and drinking water quality monitoring, Ministry of Health Order 299/2010 approving the methodology for granting exemptions for chemical parameters of drinking water and Health Ministry Order 764/2005 for the approval of the registration at the Ministry of Health laboratories performing drinking water quality monitoring [20].

Experimental part

To illustrate the practicality of the research results, we used an approved laboratory for studying the water quality of Deva county.

We sampled water from Deva distribution network in block A2 branching point scale IV. Samples were taken 3 times per day in time intervals: [7^{00}, 8^{00}], [13^{00},14^{00}] and [21^{00}, 22^{00}], on a daily basis for 7 consecutive days within the month of June. To the scale IV block A2, living 38 people, both active and retired persons. Slots that are chosen for sampling intervals where there is maximum hourly consumption flows [11,17,18].

Note that Deva, has a complex water supply as follows: a. It captures water from the lake Santamaria Orlea near Haţeg city at a distance of 45km from Deva. The water comes from the River Râu Mare, which has a number of nine hydropowers along its middle and lower course; b. Captured water is treated in Santamaria Orlea treatment plant where the water is decanted, filtered and disinfected; c. The water is transported by gravity to a distance of about 45 Km to Deva, then is pumped back to the 11 storage tanks serving the distribution network of the municipality, which has seven pressure zones; d. When leaving the storage tank that serves consumers studied there is done a new disinfection with sodium hypochlorite; e. Water is transported by gravity from the tank to consumers. The approximate length of the pipe up to the tank to the connection from which water samples have been taken is 5.65 km.

The drinking water samples were collected in specially designed bottles which ensure tightness. Samples must be delivered to the laboratory in less than 30 min after collection. Laboratory has analyzed following parameters of drinking water: a. physical parameters: the hydrogen ion concentration (*p*H), electrical conductivity, colour and turbidity; b. organoleptic parameters: the smell and taste; c. chemical parameters: aluminum, free residual chlorine, ammonia, nitrites, nitrates and dissolved oxygen; d. bacteriological parameters: total number of colonies at 37° C and the total number of colonies at 22°C [21-26].

The parameters that have not been analyzed, have been considered ideal values, in order not to change the result of the subjective evaluation.

Table 1 presents the values recorded along the measurements:

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Parameter / hour	residual chlorine	taste	odor	color	pH	ammonia	electrical conductivity	aluminium	dissolved oxygen	nitrogen	nitrate	turbidity	col.no. at 37°C	col.no. at 22°C	Hnec / Hd
7^{00}-8^{00}	0.4	0	0	0	7.0	0	87.7	0	1.12	0	0	1.73	0	0	0.98
13^{00}-14^{00}	0.38	0	0	0	7.0	0	86.9	0	0.96	0	0	1.62	0	0	1.012
21^{00} - 22^{00}	0.35	0	0	0	7.0	0	87.3	0	1.12	0	0	1.13	0	0	1.01
7^{00} - 8^{00}	0.4	0	0	0	7.0	0	86.3	0	1.12	0	0	105	0	0	0.99
13^{00} - 14^{00}	0.4	0	0	0	7.0	0	87.3	0	1.09	0	0	1.01	0	0	1.01
21^{00} - 22^{00}	0,3	0	0	0	7.0	0	88.2	0	0.92	0	0	0.98	0	0	1.02
7^{00} - 8^{00}	0.39	0	0	0	7.0	0	87.7	0	0.98	0	0	0.98	0	0	1.00
13^{00} - 14^{00}	0.38	0	0	0	7.0	0	87.9	0	1.10	0	0	0.84	0	0	1.011
21^{00} - 22^{00}	0.36	0	0	0	7.0	0	86.6	0	1.08	0	0	0.72	0	0	1.021
7^{00} - 8^{00}	0.4	0	0	0	7.0	0	88.1	0	0.88	0	0	0.60	0	0	0.98
13^{00} - 14^{00}	0.4	0	0	0	7.0	0	87.4	0	1.04	0	0	0.62	0	0	0.99
21^{00} - 22^{00}	0.25	0	0	0	7.0	0	86.9	0	1.02	0	0	0.64	0	0	1.01
7^{00} - 8^{00}	0.32	0	0	0	7.0	0	88.1	0	0.91	0	0	0.53	0	0	1.011
13^{00} - 14^{00}	0.22	0	0	0	7.0	0	87.6	0	1.01	0	0	0.51	0	0	1.012
21^{00} - 22^{00}	0.18	0	0	0	7.0	0	87.5	0	0.99	0	0	0.56	0	0	1.02
7^{00} - 8^{00}	0.4	0	0	0	7.0	0	87.2	0	0.86	0	0	0.88	0	0	0.99
13^{00} - 14^{00}	0.4	0	0	0	7.0	0	86.9	0	0.95	0	0	0.82	0	0	0.998
21^{00} - 22^{00}	0.36	0	0	0	7.0	0	88.3	0	0.96	0	0	0.78	0	0	1.001
7^{00} - 8^{00}	0.37	0	0	0	7.0	0	88.1	0	1.02	0	0	0.69	0	0	1.00
13^{00} -14^{00}	0.35	0	0	0	7.0	0	87.6	0	1.08	0	0	0.66	0	0	1.001
21^{00} - 22^{00}	0.32	0	0	0	7.0	0	87.9	0	1.12	0	0	0.62	0	0	1.01
media	0.349	0	0	0	7,0	0	87.5	0	1.016	0	0	0.86	0	0	1.004
note	4.06	10	10	10	10	10	9.56	10	8.48	10	10	9.14	10	10	9.36

Table 1
THE VALUES PARAMETERS OF WATER ANALYSIS

Due to the complexity of the water supply system for the city of Deva, the most prevalent parameter of perception of comfort given by the characteristics of drinking water is QUALITY.

Therefore, the final grade is a well - balanced geometric mean of the three parameters evaluation grades:

$$N = \frac{N_C^2 * N_{\%E} * N_H}{10^2} \quad (1)$$

where:

N_C - Grade awarded for quality characteristics; $N_{\%E}$ - Grade awarded for the quantity (flow) of water; N_H - Grade awarded for provided pressure.

$$N_c = \frac{N_F^2 * N_{OL}^2 * N_{CH} * N_{BIO} * N_{BAC} * N_{RAD}}{10^7} \quad (2)$$

Due to the lack of real data in the study, we consider N_{BIO} and N_{RAD} 10.

Grade awarded for physical qualities:

$$N_F = \frac{N_{pH} * N_{ce} * N_{cul}^2 * N_{cut}^2 * N_t^2}{10^7} = 7,99 \quad (3)$$

where:

N_{pH} - Grade awarded for water pH; N_{ce} - Grade awarded for the electrical conductivity of water;

N_{cul} - Grade awarded for water color; N_t - Grade awarded for water turbidity;

In the study, we consider N_t =10 due to the lack of real data.

Grade awarded for organoleptic qualities:

$$N_{OL} = \frac{N_{mir} * N_{gust}}{10} = 10 \quad (4)$$

Grade awarded for chemical qualities:

$$N_{CH} = \frac{N_{al} * N_{cl} * N_{nh4} * N_{no2} * N_{no3} * N_{cco} * N_{o2}}{10^6} = 3,44 \quad (5)$$

where:

N_{al} - Grade awarded for aluminum content; N_{cl} - Grade awarded for free residual chlorine content;

N_{nh4} - Grade awarded for the concentration of ammonia; N_{no2} - Grade awarded for the concentration of nitrogen; N_{no3} - Grade awarded for nitrate concentration; N_{o2} - Grade awarded for the concentration of dissolved oxygen; In the study, we consider N_{CCO} - chemical oxygen consumption - 10 due to the lack of real data.

Grade awarded for bacteriological qualities:

$$N_{BAC} = \frac{N_{nr.37} * N_{nr.col}}{10} = 10 \quad (6)$$

It follows that the mark given for water quality is: N_c = 2.2

The final grade for the comfort given by drinking water from the branch scale IV Deva block A2 is: N = 0.45, which has been introduced based on measurements and calculations, $N_{\%E}$ = 10, N_H = 9.36 [5-10].

Results and discussions

To obtain a final grade which defined precisely the degree of comfort given by drinking water there have to be established three important parameters of investigation:

- water quality – N_C is the mark given to water quality;
- water flow – N_E is the mark given to water flow;
- water pressure – N_H is the mark given for the ensured pressure.

Each of these parameters is composed of several elements whose scores will feed into the final grade for each of the three parameters. The final grade for the comfort given by the characteristics of drinking water will be obtained by a well - balanced average of the grades of the three evaluation parameters (quality, flow and pressure).

The three main parameters of the investigation will have different weights in the final mark awarded to the comfort

given by the characteristics of drinking water due to the subjective perception of overall comfort and the comfort given by drinking water in particular. In this case, the share that each of the three evaluation parameters of comfort given by the drinking water features have in the final evaluation is given by conjectural perceptions of consumer of drinking water even if all three parameters are equally important. This perception may differ from case to case:

I. Water source has exceptional qualities, shall by permanently enshured a falling pressure into the limits, but the water flow is fluctuating. The perception of comfort provided will be mainly oriented by water flow parameter provided. In this case, the final grade for the comfort given by the characteristics of drinking water is a weighted geometric mean of the three parameters evaluation grades were the grade provided for the convenience conferred by the water flow available is at 2th power.

$$N = \frac{N_{\%E}^2 * N_H * N_C}{10^2} \quad (7)$$

2. Water source has exceptional qualities, ensures the required water flow continuously required by consumers but consumer pressure is variable. The perception of comfort provided will be mainly oriented to pressure parameter ensured. In this case, the final grade comfort given by the characteristics of drinking water is a weighted geometric mean of the three parameters evaluation grades, of the mark provided for convenience conferred through the pressure ensured is 2th power.

$$N = \frac{N_H^2 * N_{\%E} * N_C}{10^2} \quad (8)$$

3.Water source has medium quality, ensures permanently the required consumers water flow and pressure falling within the limits set. The perception of comfort provided will be mainly oriented by water quality parameter. In this case, the final grade comfort given by the characteristics of drinking water is a weighted geometric mean of the three parameters evaluation grades, the grade provided for convenience conferred by the water quality is available to the 2th power.

$$N = \frac{N_C^2 * N_{\%E} * N_H}{10^2} \quad (9)$$

The marks given to the degree of comfort provided by water flow falls within the closed interval:

$$N_{\%E} \in [5;10] \quad (10)$$

The marks given to the degree of comfort given by water pressure falls within the closed interval:

$$N_H \in [1;10] \quad (11)$$

The final grade given to the degree of comfort provided by the quality of drinking water is composed of scores given to the comfort given by the following quality categories:

A. Physical Qualities – N_F; B. Organoleptic Qualities – N_{OL};

C. Chemical Qualities – N_{CH}; D. Biological Qualities – N_{BIO}

E. Bacteriological Qualities – N_{BAC}; F. Radiological Qualities – N_{RAD} (fig. 1).

Each of the six categories is composed of several elements. Each of these elements will evaluate and will participate with a grade for the value it presents. To give grades each element taken into account under the laws in force, ranges values intervals that are beneficial human to body health. There will be many ways of calculating the

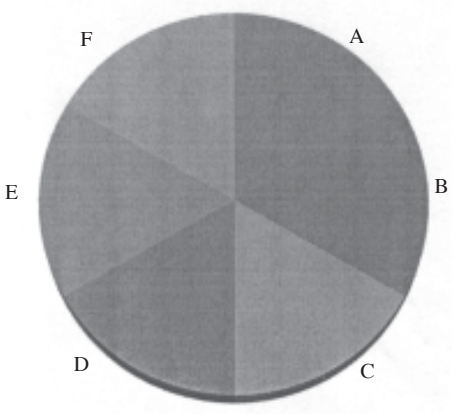

Fig. 1. Drinking water qualities

grade given with the comfort characteristics of drinking water, according to the correlation values within the legal ranges grading system.

We established the following equations for calculating the grade for each type of evolution characteristic studied.

For intervals with increasing values directly proportional with the grade:

$$N = N_{min} + \frac{N_{max} - N_{min}}{V_{max} - V_{min}} (V - V_{min}) \quad (12)$$

For intervals with decreasing values inversely proportional to the grade:

$$N = N_{max} + \frac{N_{min} - N_{max}}{V_{max} - V_{min}} (V - V_{min}) \quad (13)$$

where:

N – grade given to the comfort provided by the characteristic; V – characteristic value.

The final mark awarded for the level of comfort given by the quality of drinking water is a weighted geometric mean of the marks obtained by the comfort provided by each category of grade.

Thus, any of the categories may disqualify drinking water in terms of quality by cannot be used as drinking water a water if does not correspond to intervals stipulated by the legislation in force for the six categories of quality. However, when it comes to level of comfort, the perception of drinking water quality is subjective. Some of the categories that define water quality are more acutely perceived by the consumer, even if all are equally important.

Physical and organoleptic qualities are perceived by human senses, therefore have a higher weight in the comfort perception. For this reason the comfort scores given by physical and organoleptic qualities will be included in the formula to the power of 2:

$$N_c = \frac{N_F^2 * N_{OL}^2 * N_{CH} * N_{BIO} * N_{BAC} * N_{RAD}}{10^7} \quad (14)$$

Note N_C will be within the range (0, 10].

The final mark awarded for the level of comfort given by the chemical qualities of water consists of grades awarded for concentrations of chemicals studied in laboratories that determine the water potability. The chemicals most commonly studied in determining water potability are: aluminum (Al); Residual chlorine in water disinfected by chlorine (Cl); Ammonia (NH_4); Nitrite (NO_2); Nitrate (NO_3); Oxidizable organic substances (CCO-Mn); Dissolved oxygen (O_2).

The final mark awarded for the level of comfort given by the chemical qualities of water is the geometric mean of the marks obtained by the concentration of each substance

N_{al}	N_{cl}	N_{nh4}	N_{no2}	N_{no3}	N_{cco}	N_{o2}	N_{CH}
10	10	10	10	10	10	10	**10,00**
9	10	10	10	10	10	10	**9.00**
10	9	8	7	6	5	4	**0,6048**
8	7	6	5	4	9	9	**0.5443**
1	1	1	1	1	1	1	**10^{-6}**

studied. Any of the marks obtained by the concentrations of the substances studied may disqualify the water in terms of chemical qualities. It cannot be used for drinking water a water that does not correspond to intervals stipulated by the legislation in force.

$$N_{CH} = \frac{N_{al} * N_{cl} * N_{nh4} * N_{no2} * N_{no3} * N_{cco} * N_{o2}}{10^6} \quad (15)$$

Grade N_{CH} will be within the range $[10^{-6}; 10]$.

Table 2 presents five different situations of computation of the comfort provided by the chemical qualities.

We present an example of calculation of grades given to the aluminum concentration. The calculation of the grades for concentrations of other chemicals contained in drinking water is similar.

Grades given to the concentration of aluminum (Al) – Nal

According to STAS 1342 1991 for aluminum concentration, the maximum allowed value is 0.05 mg/dm^3 (0.2 mg/dm^3 exceptional value allowed) by the method of analysis contained in STAS 6326 1990.

0 mg/dm^3 value is considered as ideal for water consumption, will therefore will be marked with 10.

Interval (0, 0.05] mg/dm^3 considered interval of transition from the ideal value 0 for the allowed values in the range (0, 0.05] mg/dm^3. During this interval the grading will be linear, inversely proportional to the aluminum concentration value. Minimum grade in this interval is 5, maximum grade 10.

Interval [0.05, 0.2) mg/dm^3 is accepted exceptionally and make the transition to the allowed concentration range [0, 0.05] mg/dm^3. In this interval the notation will be linear, inversely proportional to the concentration of aluminum. The minimum grade in this interval is 1, maximum grade 5.

The values that are not belonging to interval [0, 2] mg/dm^3 will be denoted by 0.

Calculation model

$$N_{al} = \begin{cases} 10 - \frac{10-5}{0,05-0}(V_{al} - 0) \rightarrow V_{al} \in [0;0,05] \\ 5 - \frac{5-1}{0,2-0,05}(V_{al} - 0,05) \rightarrow V_{al} \in [0,05;0,2] \\ 0 \rightarrow V_{al} \notin [0;0,05] \end{cases} \quad (16)$$

Figure 1 for the interval [0 ; 0.05]:

Figure 2 for the interval [0.05; 0.2]:

For $V_{al} \neq [0 ; 0.2] \rightarrow N_{al} = 0$

In conclusion, grade values given to aluminum concentration are in the range [1, 10] for the admissible values of aluminum content, i.e. [0, 2] mg/dm^3.

For forbidden values of aluminum content by the regulations in force, the note is 0, thus disqualifying evaluated water.

Table 2
FINAL GRADE GIVEN TO THE COMFORT PROVIDED BY CHEMICAL QUALITIES

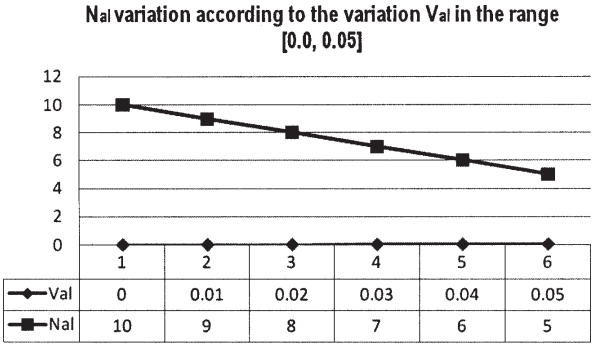

Fig. 2. Grade given for the aluminum content of the water in the interval [0, 0.05]

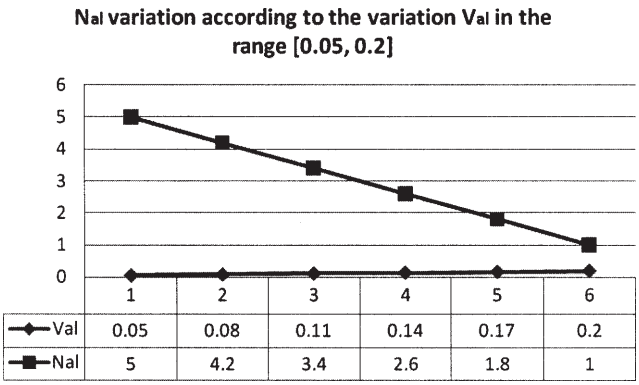

Fig. 3. Grade given for the aluminum content of the water in the interval [0.05; 0.2]

Conclusions

The quantification of comfort given by the drinking water features can provide a clear picture of the entire water supply system, equipment and operation of the inside facilities of water distribution and the quantification of comfort given by the drinking water can make the difference / the comparison between different systems / sources of drinking water resources.

Romanian legislation is one of the most restrictive in the world in terms of value ranges in which the parameters studied are admitted. The considering the exceptional values of the parameters (for short periods of time) corresponds to reality. For accurate quantification of comfort given by the drinking water, after the system return to normal, the values of parameters drawn from measurements and determinations will be respected.

This way of evaluating the degree of comfort given by the characteristics of drinking water is an absolute novelty and is intended as a start up for theorizing and practice of quantifying objective characteristics and subjective perception of an absolutely necessary element who determine the existence of human society - drinking water.

In the future, the final grade provided to the comfort given by the characteristics of drinking water will be a parameter for assessing the market price of drinking water. This price will influence the value of a property or a dwelling, with its positioning, length of construction, energy consumption and other objective parameters and / or subjective being crucial in the final evaluation.

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