OBJECTIVIZATION OF RESIDUAL CHLORINE ESTIMATION IN DRINKING WATER
OBJEKTIVIZACIJA ODREĐIVANJA REZIDUALNOG HLORA U VODI ZA PIĆE

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ABSTRACT

Residual chlorine in drinking water is of crucial importance for water consumers because its existence out of range means that water must not be used for human consumption. The exact determination of residual chlorine in drinking water could be only provided in laboratories but that process could not be provided fast and in an efficient way. For fast and efficient checking of residual chlorine content in drinking water, the auxiliary test with comparator. This test is based on the subjective estimation of the person who takes the sample. In this research, we investigate the possibility of objectification of that process to minimize the subjective perception of residual chlorine levels in drinking water. The approach in this research is based on the analysis of the colors in RGB (red, green, blue) and HSL (hue, saturation, lightness) color models. The equality of colors is tested by utilizing students' statistics, and L1 and L2 norms.

KRATAK SADRŽAJ

Rezidualni hlor u pijaćoj vodi je od kritičnog značaja za potrošače jer njegovo prisusvo izvan granica označava da voda ne sme biti korišćena za piće. Tačno određivanje rezidualnog hlora u vodi za piće može se vršiti jedino u odgovarajućim laboratotijama ali je ovaj proces spor i nije efikasan. Za brzo i efikasno određivanje sadržaja hlora u pijaćoj vodi koristi se priručni test koji se realizuje primenom komparatora. Ovaj test bazira se na subjektivnoj proceni osobe koja uzima uzorak vode. U ovom istraživanju bavimo se mogućnošću objektivizacije tog procesa uz težnju da se minimizira subjektivna percepcija nivoa rezidualnog hlora u pijaćoj vodi. Pristup u ovom istraživanju zasnovan je na analizi boja u RGB (crveno, zeleno, plavo) i HSL (nijansa, zasićenje, osvetljenost) modelima. Jednakost boja se testira uz prmenu studentove statistike, L1 i L2 normi.

INTRODUCTION

The residual chlorine in the drinking water is an important indicator of its quality and usability. A detailed guide for residual chlorine testing is given by WHO (World Health Organization) [1]. »The quickest and simplest method for testing chlorine residual is the dpd (diethyl para phenylene diamine) indicator test, using a comparator. « [1] The chlorine concentration is determined by comparing the strength of color obtained by the comparator and predetermined colors. The most similar colors indicate the chlorine concentration. This method is based on the subjective impression (i.e. of certain characteristics of the eye) of a person who tests the residual chlorine.

The scientific base for this research is the Young-Helmholtz theory of color vision [2, 3]. This theory is related to physiological optics and it is also called trichromatic theory as a “conceptual framework by which human vision matches the color of any test light to that of an additive mixture of the spectra of three primary lights in appropriate proportions.” [4] The three primary lights are considered to be: red, green, and blue i.e. every color could be obtained by an appropriate mixture of those three basic colors.

Even though the person who tests the residual chlorine should be experienced it is certainly limited by the characteristics of its eyes. Starting from the assumption that human eyes are different in color perception and bearing in mind the significance of residual chlorine levels in drinking water the authors conducted this research to objectivize the process of this test.

The objectification of the residual chlorine test provided by the device named comparator is based on the further algorithm:

Providing residual chlorine test following the instructions;

- Estimating the residual chlorine content in water according to a subjective approach;
- Make a photo of the comparator;
- Opening the photo of the comparator by the default program and
- Taking values from the picture of the comparator by the “color picker” tool.

The taken values by the “color picker” toll were the RGB and HSL values. The acronym HSL represents the color system based on the values of hue, saturation, and lightness of the pixels.

MATERIALS AND METHODS

The materials for this research were a set of color RGB and HSL data taken from the picture of the comparator obtained on August 23rd in the year 2024 at 13 o’clock. The picture is given in the figure 1.

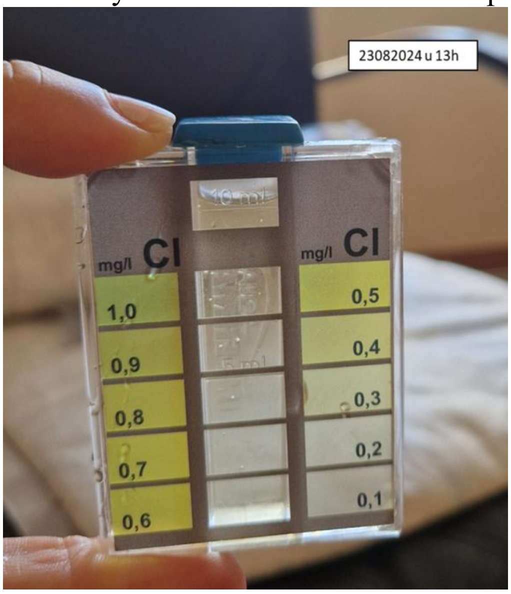

Figure 1. the picture of comparator

The middle column in Figure 1 represents the color of water which contains residual chlorine, while the left and right columns represent the colours which shows the reference values. The person should compare the color of the middle column with the nearest color of reference columns and should make a decision (according to their subjective opinion) about which amount of residual chlorine is contained in the drinking water.

Objectification of this decision, according to the proposed method, should be provided on the base of reading RGB and HSL values by the “Color Picker” tool (a part of “Power Toys” package), and after the provided analysis a more objective estimation should be obtained.

The method is based on the reading RGB and HSL values in nine points for each “window” in the middle column and some values in appropriate reference windows. The values obtained from the picture were put in a table for further analysis. Figure 2 shows the positions on the pictures where the RGB and HSL values were read.

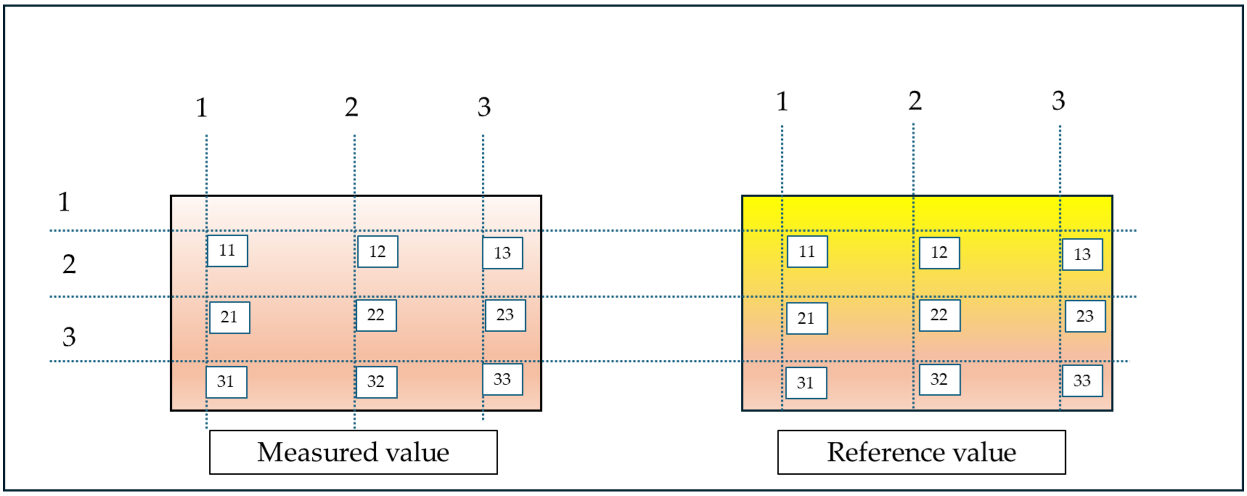

Figure 2. The positions of read RGB and HSL values

The model of research was provided by calculation of each value of color in the RGB and HSL model. Obtained results for the residual chlorine in the drinking water (middle column of the comparator) are given in Table 1.

Table 1. Color RGB and HSL model’s values of residual chlorine in the drinking water.

The middle column (measured)							
Window	Point	R	G	B	H	S [%]	L [%]
1	11	127	119	99	43	12	44
	21	135	125	105	40	13	47
	31	141	129	105	40	15	48
	12	150	137	115	38	14	52
	22	149	142	120	46	12	53
	32	153	146	127	44	11	55
	13	152	135	111	35	17	52
	23	149	132	107	36	17	50
	33	149	135	110	38	16	51

Table 1. Color RGB and HSL model's values of residual chlorine in the drinking water (continued).

The middle column (measured)							
Window	Point	R	G	B	H	S [%]	L [%]
2	11	158	147	123	41	15	55
	21	158	150	128	44	13	56
	31	158	150	129	43	13	56
	12	151	142	121	42	13	53
	22	155	148	130	43	11	56
	32	158	151	133	43	11	57
	13	160	152	131	43	13	57
	23	165	156	139	39	13	60
	33	169	163	151	40	9	63
3	11	164	161	146	50	9	61
	21	168	168	154	60	7	63
	31	168	166	154	51	7	63
	12	169	166	151	50	9	63
	22	162	162	150	60	6	61
	32	167	168	159	67	5	64
	13	168	166	154	51	7	63
	23	165	163	151	51	7	62
	33	167	167	158	60	5	64
4	11	166	167	153	64	7	63
	21	168	167	154	56	7	63
	31	165	166	153	65	7	63
	12	167	167	157	60	5	64
	22	164	163	151	55	7	62
	32	168	168	156	60	6	64
	13	174	171	159	48	8	65
	23	170	170	158	60	7	64
	33	167	165	153	51	7	63
5	11	169	165	153	45	9	63
	21	166	163	151	48	8	62
	31	159	160	146	64	7	60
	12	170	167	156	47	8	64
	22	160	158	145	52	7	60
	32	161	159	146	52	7	60
	13	171	167	155	45	9	64
	23	159	153	137	44	10	58
	33	162	159	142	51	10	60

For the purpose of comparison, the similar color between the reference and value obtained in the middle column of the RGB and HSL values were obtained for the reference values in Windows 0.1, 0.2, 0.3, and 0.4. The values of RGB and HSL values obtained for reference windows are given in Table 2.

Table 1. Color RGB and HSL model's values of reference values (right column)

The right column (reference)							
Window	Point	R	G	B	H	S	L
0.4	11	165	166	109	61	24	54
	21	172	173	115	61	26	56
	31	172	175	118	63	26	57
	12	167	166	109	59	25	54
	22	173	172	115	59	26	56
	32	170	171	113	61	26	56
	13	173	173	113	60	27	56
	23	170	170	109	60	26	55
	33	173	174	116	61	26	57
0.3	11	174	177	148	66	16	64
	21	173	174	142	62	16	62
	31	177	177	144	60	17	63
	12	178	179	148	62	17	64
	22	169	174	141	69	17	62
	32	176	177	145	62	17	63
	13	181	183	152	64	18	66
	23	175	177	144	64	17	63
	33	174	175	145	62	16	63
0.2	11	175	177	164	69	8	67
	21	176	178	165	69	8	67
	31	171	169	155	52	9	64
	12	174	175	161	64	8	66
	22	171	172	158	64	8	65
	32	166	164	149	53	9	62
	13	174	175	161	64	8	66
	23	172	174	160	69	8	65
	33	173	174	160	64	8	65
0.1	11	167	165	153	51	7	63
	21	163	160	147	49	8	61
	31	161	159	147	51	7	60
	12	161	157	146	44	7	60
	22	165	162	150	48	8	62
	32	157	153	141	45	8	58
	13	162	158	143	47	9	60
	23	157	150	134	42	1	57
	33	158	152	140	40	8	58

The comparison method is based on the following approach:

- Calculating the average values and standard deviation of each RGB and HSL value for each window of measured residual chlorine in drinking water (middle column);
- Calculating the average values and standard deviation of each RGB and HSL value for each reference window (right column);
- Testing statistical hypotheses about equality of parameters (values RGB and HSL) for windows of residual chlorine content in drinking water (measured);
- Forming the differences between referenced windows (right column) and average values for all five windows with residual chlorine in drinking water (middle column);
- Calculating the L1 and L2 norms from the differences and
- Finding the minimal L1 and L2 norms.

The minimal value of L1 and L2 norms obtained from the differences should define the nearest value between measured and reference windows i.e. the residual chlorine content in the drinking water sample. The L1 and L2 (Euclidian distance) norms are given by the following formulas:

$$\mathrm{L}_1 = \sum_{i=1}^{n} |d_i| \quad (1)$$

$$\mathrm{L}_2 = \sqrt{\sum_{i=1}^{n} d_i^2} \quad (2)$$

where d_i is calculated as follows:

$$d_i = c_i^m - c_i^r \quad (3)$$

where:

- c_i^m – is the average color characteristics for all windows for residual chlorine estimation (RGB and HSL) and
- c_i^r – is the average color characteristics for reference windows (RGB and HSL).

RESULTS AND DISCUSSION

The obtained results of average values and standard deviations for the measured values are given in Table 3, while the obtained results for the reference values are given in Table 4.

Table 3. Average values of RGB and HSL color models for residual chlorine measurement

Window	Value	R	G	B	H	S [%]	L [%]
1	$\bar{c}_{1i}^m$	145.00	133.33	111.00	40.00	14.11	50.22
	$\sigma_{\bar{c}_{1i}^m}$	8.85	8.29	8.56	3.71	2.26	3.38
2	$\bar{c}_{2i}^m$	159.11	151.00	131.67	42.00	12.33	57.00
	$\sigma_{\bar{c}_{2i}^m}$	5.25	5.89	8.96	1.66	1.73	2.92
3	$\bar{c}_{3i}^m$	166.44	165.22	153.00	55.56	6.89	62.67
	$\sigma_{\bar{c}_{3i}^m}$	2.30	2.59	4.03	6.27	1.45	1.12
4	$\bar{c}_{4i}^m$	167.67	167.11	154.89	57.67	6.78	63.44
	$\sigma_{\bar{c}_{4i}^m}$	2.96	2.42	2.71	5.68	0.83	0.88
5	$\bar{c}_{5i}^m$	164.11	161.22	147.89	49.78	8.33	61.22
	$\sigma_{\bar{c}_{5i}^m}$	4.91	4.66	6.33	6.16	1.22	2.11

Table 3. Average values of RGB and HSL color models for residual chlorine measurement (continued)

Window	Value	R	G	B	H	S [%]	L [%]
overall	$\bar{c}_i^m$	160.47	155.58	139.69	49.00	9.69	58.91
	$\sigma_{\bar{c}_i^m}$	9.25	13.91	18.46	7.88	3.34	5.46

The statistical hypotheses about equality between different windows within the measured values of residual chlorine showed that there were significant differences between some windows in the middle column. The source of these differences should be investigated in further research.

Table 4. the value of reference windows

Window	Value	R	G	B	H	S [%]	L [%]
0.4	$\bar{c}_{0.4}^r$	170.56	171.11	113.00	60.56	25.78	55.67
	$\sigma_{\bar{c}_{0.4}^r}$	2.88	3.26	3.35	1.24	0.83	1.12
0.3	$\bar{c}_{0.3}^r$	175.22	177.00	145.44	63.44	16.78	63.33
	$\sigma_{\bar{c}_{0.3}^r}$	3.38	2.78	3.40	2.70	0.67	1.22
0.2	$\bar{c}_{0.2}^r$	172.44	173.11	159.22	63.11	8.22	65.22
	$\sigma_{\bar{c}_{0.2}^r}$	2.96	4.31	4.84	6.45	0.44	1.56
0.1	$\bar{c}_{0.1}^r$	161.22	157.33	144.56	46.33	7.00	59.89
	$\sigma_{\bar{c}_{0.1}^r}$	3.49	4.90	5.73	3.87	2.35	1.96

After differences calculation and utilizing the formulas (1) and (2) we finally have obtained the values of L1 and L2 norms. Those results are given in the table 5.

Table 5. The values of differences and norms

							L1		L2	
Difference	R	G	B	H	S	L	RGB	HSL	RGB	HSL
0.4-meas	10.09	15.53	26.69	11.56	16.09	3.24	52.31	30.89	32.49	20.07
0.3-meas	14.76	21.42	5.76	14.44	7.09	4.42	41.93	25.96	26.64	16.69
0.2-meas	11.98	17.53	19.53	14.11	1.47	6.31	49.04	21.89	28.85	15.53
0.1-meas	0.76	1.76	4.87	2.67	2.69	0.98	7.38	6.33	5.23	3.91

The final conclusion about the content of residual chlorine in the sample of drinking water, based on the proposed method, is that it was near a value of 0.1. Three persons, who determined the residual chlorine in the drinking water agreed that the value is 0.2. This difference could lead to the conclusion that the objectification method makes sense to be introduced as a control method.

The weakness of the proposed model is the lack of experience and that it was not validated by the other objective and independent models. But, according to some findings, authors agree that this method deserves further investigation.

In this research the implicit assumption was introduced that quality of photographs, resolution and source of light have the same influence on the results of researched values. Those assumptions shall be investigated in the future experiments.

CONCLUSION

The proposed model of residual chlorine in drinking water objectification is meaningful and could contribute to the more accurate determination of residual chlorine content in drinking water. Bearing in mind the importance of accurate determination of residual chlorine in drinking water, especially in borderline cases, this method should be researched in detail. Bearing in mind that this research was provided based on only one sample, one program for identifying colors, and two color models further research must be based on the utilization of more color models and more samples. The further research should be focused on the influence of light sources and resolution on the results of proposed model.

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LITERATURE

[1] https://cdn.who.int/media/docs/default-source/wash-documents/who-tn-11-measuring-chlorine-levels-in-water-supplies.pdf?sfvrsn=616c5e2a_4 (accessed 15.08.2024)

[2] Millington, E. C. (1942). *History of the Young-Helmholtz theory of colour vision*. Annals of Science, 5(2), 167-176.

[3] Heesen, R. (2015). *The Young-(Helmholtz)-Maxwell theory of color vision*. https://philsci-archive.pitt.edu/11279/ (accessed 01.08.2024)

[4] Brill, M. H. (2021). *Trichromatic theory. In Computer Vision: A Reference Guide (pp. 1288-1291). Cham: Springer International Publishing*.

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