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A Study on the Quantitative Measurement Method of Organoleptic Chromaticity for Sandy Water

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ABSTRACT

Water landscape quality is an important part of environmental quality. However, in the environment impact assessment, there is no method at present that can quantitatively assess the colour changes of the water landscape affected by sediments. This paper presents a conception of organoleptic chromaticity according to the engineering requirement. Water organoleptic chromaticity is defined as a water chromaticity which is caused by both soluble substances and insoluble substances and observed directly by naked eyes. Using the spectrophotometry, it was found that the maximum absorption peak of coloured-turbid water occurred at 350nm which is defined as the characteristic wavelength of water organoleptic chromaticity. Based on the standard turbidity and chromaticity solutions, the metric system of organoleptic chromaticity was established. The absorbance of water with different turbidity and chromaticity showed that it is linear with the organoleptic chromaticity. Measuring the organoleptic chromaticity of different sandy waters, the results demonstrated that the metric system of organoleptic chromaticity could apply to the quantitative assessment of landscape quality for engineering sandy water in practical engineering.

INTRODUCTION

Water landscape quality is an important part of environmental quality (Chen et al. 2011). In the environment impact assessment, especially for the environmental sensitive areas, such as scenic spot, nature reserve and religious area that have high requests on the landscape, the assessment of water landscape quality is too important to ignore. Sampei (2002) showed the importance of perception and evaluation of water landscape. In engineering, during the construction period or operation period, various factors can cause the change of water landscape, such as sediment, microorganisms and heavy metals (Liu et al. 2013). Among them, sediment is one of the most common factors. Fig. 1 shows the landscape of Kumano River in Japan flowing into the sea. As shown in Fig. 1, Kumano River, which was with high sediment concentrations, led to a huge colour difference in the estuary and had a bad influence on the landscape of the sea. However, there is no method at present that can quantitatively assess the color changes of water landscape, affected by sediment. So it is difficult to assess the water landscapes of environmental sensitive areas scientifically.

As a vital physical quantity for characterizing the water hue and saturation, chromaticity is an important parameter in monitoring water quality and landscape impact assessment (Hiraoka et al. 1998). In the measurement of chromaticity (1989), the methods for water chromaticity measurement include the platinum-cobalt method and the dilution multiple method, which measures the chromaticity of filtered water (real chromaticity for short in this paper). In order to save the costs, some researchers proposed and proved the feasibilities and rationalities of substituting the chromium-cobalt standard liquid for the platinum-cobalt standard liquid (Yu et al. 2013). Moreover, many researchers also proposed the spectrophotometry for measuring water chromaticity (Dag & Gunvor 1996, Cao et al. 2001, Iain & Paul 1992, Crowther & Evans 1981). The APHA (1998), introduced several methods about measuring water chromaticity by the spectrophotometry. And the measurement method of water real chromaticity (Taiwan Environmental Protection Department 1999) was published according to the American standard. However, in these methods, chromaticity is measured for the transparent water that is filtered, so it mainly applies to the landscape assessment for the water, such as the urban drinking water, scenic water and polluted water, which has little insoluble substances (Kang & So 2013, Grayson et al. 2012, Fergus et al. 2011).

As a matter of fact, for sandy water, especially with high sediment content, part of visual colours come from the soluble substance (real chromaticity) and others come from the

Fig. 1: The picture of Kumano River in Japan flowing into the sea (Asahi News, September 8, 2011).

suspended sediments in water, thus, the results by using the current measurement methods have big difference when observed by eyes. Horowitz & Arthur (2009) and Chen et al. (2014) put forward that the insoluble substances have a significant influence on the water turbidity, and cause vital effects on the urban scenic water, but they did not propose the methods for water chromaticity measurement considering the turbidity effects. Huang et al. (2014) invented the patent about evaluating the apparent quality of landscape water structure based on the relationship between the reflectivity of light in water and the wavelength. Wang et al. (2012) also reported a method for evaluating the apparent quality of scenic water based on reflection spectrum. Both of the above studies researched the influences of chromaticity and turbidity on the apparent quality for water, based on the measurement method of reflection spectrum. However, they did not quantitatively determined the relationships between the apparent quality and the chromaticity as well as turbidity. Meanwhile, due to the complex operations of the reflection spectrum, the above methods were hardly applied in the actual conditions. Up to now, there were only few articles to discuss the effect of sediments (turbidity) on the scenic quality of water, and it has not been reported how to quantitatively measure the water color, observed by naked eyes, which was caused by both soluble substance and insoluble sediments.

Due to the requirement of landscape impact assessment for the water with high sediment concentrations flowing into the sea or the lake, it is important to quantify the effects of sediment concentration on the organoleptic chromaticity of sandy water. Therefore, this paper aims to establish a measuring index and methods that can be used to characterize the changes for water organoleptic chromaticity, which is caused by the combined effects of real chromaticity and turbidity, and discuss the relationship between sediment concentrations and the water organoleptic chromaticity.

THE DEFINITION AND BASIC PRINCIPLE OF ORGANOLEPTIC CHROMATICITY

The definition of organoleptic chromaticity: In reality, the water chromaticity in vision is caused by both the soluble and insoluble substances in water. The effects of the soluble substances are reflected as the real chromaticity, and the insoluble substances, especially the sediments, are mainly reflected as the turbidity. In this paper, the organoleptic chromaticity is defined as the water color that is caused by both soluble substances and insoluble substances (mainly as sediments) and represents the water color observed by naked eyes. So the water organoleptic chromaticity could be regarded as the interaction of real chromaticity and turbidity to naked eyes. The organoleptic chromaticity is based on the observation of naked eyes, including all of the factors that can make the differences in vision, such as the water color, transparency and luminance.

The basic principle of organoleptic chromaticity: Since the spectrophotometry is a precise method for real chromaticity measurement, and it is also an important method in APHA (1998), this paper chose the spectrophotometry to measure the organoleptic chromaticity of coloured sandy water.

The visual perceptions of human for water landscape mainly come from the real chromaticity and turbidity. In the spectrophotometry of water quality measurement, the soluble substances which results for real chromaticity of water will absorb the incident light while the insoluble substances which results for turbidity of water will scatter the incident light. Both the kinds of substances will lead to the change of water absorbency. So the absorbency can reflect the collective effects of real chromaticity and turbidity. In other word, an absorbency value can be corresponding to different combinations of real chromaticity and turbidity. And the absorbency can build a quantitative relationship with real chromaticity as well as turbidity. However, in the quantitative measurement method of spectrophotometry, the absorbency is only an optical intermediate quantity, so it fails to be an assessment index in engineering. Therefore, it is the key to analyse the change of water absorbency collectively affected by real chromaticity and turbidity, and search the organoleptic chromaticity index, which can build a quantitative relationship with absorbency and has the same results with the observation of naked eyes. Then, landscape quality of water can be quantitatively assessed.

For the coloured sandy water, the sample can be used in place of the mixed liquid of real chromaticity standard liquid (chromium-cobalt standard liquid) (Yu et al. 2013) and turbidity standard liquid (forma-hydrazine standard liquid (turbidimeter 1994)). And then explore the relationship of

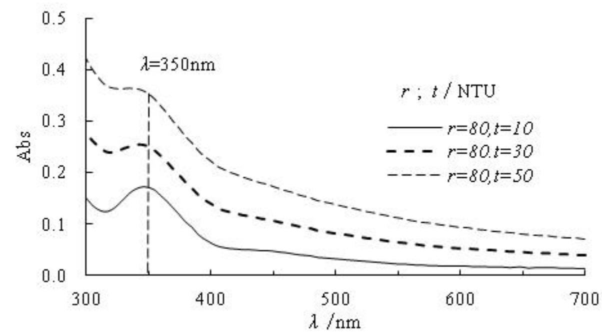

Fig. 2: The whole band scanning results of mixed water of different chromaticity and turbidity.

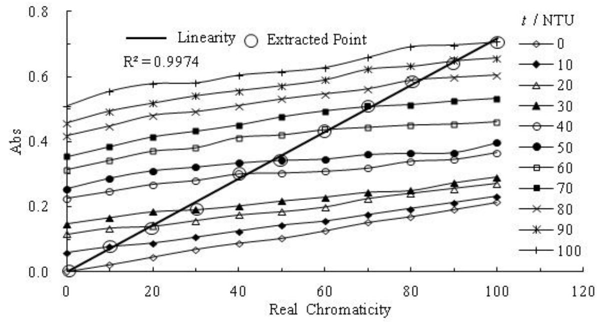

Fig. 3: The measured absorbance of different real chromaticity and turbidity mixed solutions.

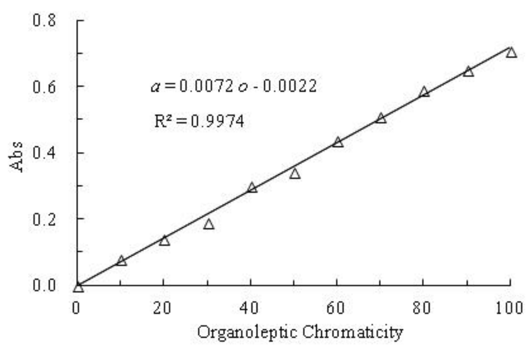

Fig. 4: The relationship between absorbance and water organoleptic chromaticity.

organoleptic chromaticity (o), real chromaticity (r), turbidity (t) and absorbency (a) to determine the metrics system of organoleptic chromaticity. Finally, through measuring the organoleptic chromaticity of different coloured sandy water, the rationality and the application of metrics system of organoleptic chromaticity can be demonstrated.

THE ESTABLISHMENT OF METRICS SYSTEM OF ORGANOLEPTIC CHROMATICITY

The experiment on the characteristic wavelength of coloured sandy water: In the spectrophotometry, the first step was determining the characteristic wavelength of the samples, where the maximum absorption peak occurred, it would have the best sensitivity. So the whole band scanning would be done to determine the characteristic wavelength of the coloured sandy water.

On the basis of the definition for organoleptic chromaticity in the present paper, real chromaticity standard liquid and turbidity standard liquid has been mixed as the sample. Fig. 2 shows the whole band scanning results of the sample. It could be found that the maximum absorption peak of the sample occurred at 350nm, so 350nm could be the characteristic wavelength of the coloured sandy water.

The research on the metrics system of organoleptic chromaticity: To conduct the further study on the metrics system of organoleptic chromaticity for coloured sandy water, and search the rational organoleptic chromaticity standard liquid, the real chromaticity standard liquid (chromium-cobalt standard liquid) with different chromaticity and the turbidity standard liquid (forma-hydrazine standard liquid) with different turbidity were mixed, and the absorbance of mixed solutions was measured at the 350nm. Fig. 3 shows the measured absorbance of the mixed solutions. The chromaticity and turbidity in Fig. 3 were both the ones in the mixed samples. From Fig. 3, it was found that the absorbance of mixed solutions presents the positive relationship with chromaticity and turbidity.

From Fig. 3, it was found that, if defined the mixed liquid, when the value of real chromaticity and turbidity were same (extracted point in the Fig. 3), as the standard liquids of organoleptic chromaticity, and the metric of organoleptic chromaticity is defined as “x Chr” when the real chromaticity of the mixed solution was “x Chr” and the turbidity was “x NTU”, the absorbance of mixed solutions would show a good linear relationship with its organoleptic chromaticity, as shown in Fig. 4. Therefore, the water organoleptic chromaticity defined in this paper has a good linear relationship with the absorbance measured at 350nm, and it can be quantified exactly.

We transferred the standard liquids of organoleptic chromaticity into 50mL colorimetric tubes, which were set in the white background, and looked down and observed the water color. The water color observed by naked eyes was determined with the color card (GSB 16-1517-2002 China Building Color Card), and Fig. 4 shows the results. The color label of the color card is denoted by H(Hue) V(Value)/ C(Chroma), white is the neutral color, that is denoted by N V (Value). Fig. 5 shows that the hue changed from white (N) to the yellowish-green (GY) to the yellow (Y) and to the red (R) with organoleptic chromaticity values increasing. In a word, the integral colours of the standard liquids became more and more yellow and deeper with the increase of organoleptic chromaticity of solution, which indicated that

Organoleptic Chromaticity	0	10	20	30	40	50	60	70	80	90	100
Color Label	N9	9.4GY 9/1	8.8GY 9/1	7.5GY 9/1	3.8Y 9/1	2.5Y 9/1.2	9.4Y 9/1.6	9.4Y 9/1.6	8.8Y 9/2	7.5Y 9/3.6	1.3R 9/1

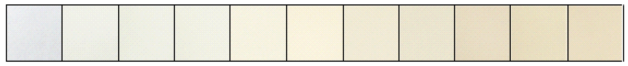

Fig. 5: The results of the standard liquids of organoleptic chromaticity compared with the color cards.

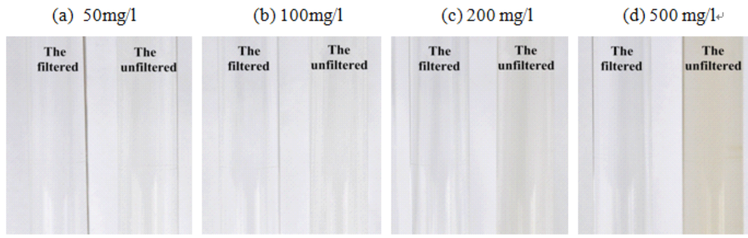

Fig. 6: The pictures of different sandy water (without background chromaticity) filtered and unfiltered.

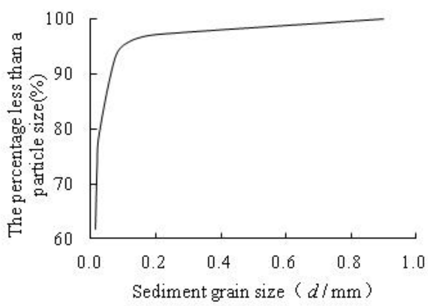

Fig. 7: The gradation of the sample sediment.

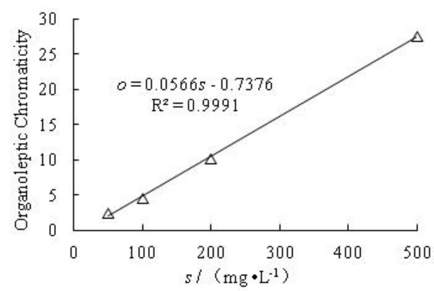

Fig. 8: The relationship between organoleptic chromaticity and sediment concentration.

the metrics of the organoleptic chromaticity defined in this paper kept consistent with the observation of naked eyes. Therefore, the metrics system of organoleptic chromaticity in this paper could be used to assess the effect of sediment on the scenic quality of water, and meet the requirement of landscape assessment in the engineering projects.

APPLICATION OF ORGANOLEPTIC CHROMATICITY FOR SANDY WATER

Application of organoleptic chromaticity to high sediment concentrations water: For the water with high sediment concentrations, its turbidity may exceed the maximum of the previous standard liquids (100NTU). A further experiment was conducted to examine whether the measurement method of organoleptic chromaticity could be used for the water with high sediment concentration water when the dilution multiple method was used.

Based on the metrics system of organoleptic chromaticity, samples with different yellow sediments concentrations (d=0.018mm) were prepared and diluted according to the given multiples. The organoleptic chromaticity of these samples was measured at 350nm and Table 1 shows the results.

From Table 1, it was found that the ratios of organoleptic chromaticity for the samples before diluted and after diluted were close to the dilution multiples, and their relative errors were all less than 10%. Obviously, the organoleptic chromaticity of sandy water was inversely proportional to the dilution multiple while directly proportional to the sediment concentration. Therefore, the organoleptic chromaticity of water with high sediment concentrations can be measured after diluted, which indicates that the present measurement method has a good application to the water with different sediment concentration.

Application of organoleptic chromaticity to water with uniform sediments: To study the application of organoleptic chromaticity to water with uniform sediments, the sediments used in the samples were yellow and with a diameter of 0.018mm. The real chromaticity of samples was used as the chromium-cobalt standard liquid to prepare. And to study the difference between the real chromaticity and the organoleptic chromaticity, both the methods for real chromaticity and for organoleptic chromaticity in this paper were used respectively to measure the chromaticity for samples with different real chromaticity and sediment concentrations.

Table 1: The organoleptic chromaticity of samples before dilution and after dilution.

Sediment concentration (mg/L)	Organoleptic chromaticity before dilution	Dilution multiples	Organoleptic chromaticity after dilution	The before diluted/ The after diluted	Relative error (%)
500	47.0	2	22.7	2.1	3.5
		5	9.3	5.1	1.1
1000	94.5	2	45.7	2.1	3.4
		5	17.5	5.4	8.0

Table 2: The comparison results of organoleptic chromaticity under different background chromaticity.

	Real Chromaticity		Organoleptic Chromaticity			
Sediment concentration (mg/L)	Background chromaticity 0	Background chromaticity 10	Background chromaticity 0	Background chromaticity 10	Organoleptic chromaticity difference value	Average value
50	0.3	9.8	4.3	7.0	2.7	3.0
100	0.2	9.6	9.4	12.7	3.3	
200	0.2	9.7	17.5	21.3	3.8	
500	0.2	10.1	47	49.1	2.1	

The real chromaticity of samples was measured at 350 nm after filtering through 0.45μm membrane filters and the results are shown in Table 2. Meanwhile, the organoleptic chromaticity of samples was measured based on the method proposed in this paper (Table 2). From the results in Table 2, when compared the real chromaticity with the organoleptic chromaticity of samples, it was found that the real chromaticity was nearly equal to its background chromaticity, which indicated that only the background chromaticity (namely real chromaticity) was left in the water when it was filtered, and there was no correlation between the real chromaticity and sediment concentration. So the real chromaticity could not reflect the true observation of naked eyes for sandy water. While, there was a positive correlation between the measured organoleptic chromaticity and sediment concentration (Table 2). Therefore, it indicated that organoleptic chromaticity index could reflect the effects of turbidity for coloured sandy water. When compared the organoleptic chromaticity under different background chromaticity, it was found that the organoleptic chromaticity with background chromaticity of 10 Chr was larger than that with blank background, and the difference value was 3 or so (Table 2). It indicated that the organoleptic chromaticity index could reflect the effects of real chromaticity for coloured sandy water. In a word, the above results indicated that the organoleptic chromaticity index could reflect the combined effects of turbidity and real chromaticity.

Fig. 6 shows the pictures of different sandy water (with blank background) filtered and unfiltered. From Fig. 6, it was found that under the same sediment concentrations, the filtered samples presented transparent and with no color. Whereas the unfiltered samples presented light yellow color and became deeper with the increase in the sediment concentrations. Based on the results of Table 2 and Fig. 6, it could be said that, the organoleptic chromaticity of this paper could reflect the observation of naked eyes for coloured sandy water. In other words, the organoleptic chromaticity defined in this paper could be the index to measure the color of sandy water and the metrics system of organoleptic chromaticity could reflect the color changes caused by different sediment concentrations.

Application of organoleptic chromaticity to water with non-uniform sediments: The sediment in the previous experiment was uniform sediment with single particle size. However, to demonstrate the application of the metrics system of organoleptic chromaticity for non-uniform sediment in practical conditions, the sediment in samples was made up according to the sediment gradation in the practical conditions (Fig. 7). From Fig. 7, it was found that the sediment consisted of various particle sizes under the 1.0mm and had the continuous gradation. The organoleptic chromaticity of the samples was measured and it was found that there was a good positive correlation between the organoleptic chromaticity and sediment concentration (Fig. 8). Obviously, the experimental results were same as compared with the previous results, which indicated that the metrics system of organoleptic chromaticity could quantitatively characterize the effects of different sediment concentrations on observed water chromaticity, and it not only applied to the water with uniform sediment but also applied to the water with non-uniform sediment. Using the metrics system of organoleptic chromaticity, it was possible to quantitatively forecast and assess the landscape of mixed areas for sandy water.

CONCLUSION AND FUTURE WORK

This paper proposed a conception of organoleptic chromaticity that was defined as the water color caused by both soluble substances and insoluble substances and observed by naked eyes. The organoleptic chromaticity represents the combined effect of chromaticity and turbidity on the water color in vision. The maximum absorbance of sandy water occurs at 350 nm and this value was chosen as the characteristic wavelength. Based on the standard chromaticity and turbidity solutions, the metrics system of organoleptic chromaticity was established in this paper and the organoleptic chromaticity was defined as "x Chr" when the background chromaticity is "x Chr" and the background turbidity is "x NTU". The absorbance at 350 nm presented a good linear relationship with the metrics of organoleptic chromaticity, which indicated that organoleptic chromaticity can exactly quantify the color of sandy water.

By measuring the chromaticity and organoleptic chromaticity for sandy water which has different sediment concentrations and different particle size, the results showed that real chromaticity, which is the normal index for water color, could not reflect the color for water with high sediment contents, whereas the organoleptic chromaticity was suitable for measuring the color for sandy water, and the results were consistent with the observation of eyes. Therefore, it was demonstrated that the metrics system of organoleptic chromaticity in this paper is rational and could be used to quantify the observation of naked eyes for coloured sandy water directly. The organoleptic chromaticity would benefit in quantitatively assessing the landscape of engineering sandy water truthfully and effectively.

The real chromaticity standard liquid (chromium-cobalt standard liquid) which was yellow used in the experiment, so the metrics system of organoleptic chromaticity only applied to the water with yellow color. Further study should be conducted on the metrics system of organoleptic chromaticity for the water with different colours. In addition, it is the emphasis in the future that combined with results of numerical simulation to quantitatively assess the organoleptic chromaticity effects in different mixed areas for sandy water.

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