# Spectral Analysis for Polychromatic Light Sources and Drinking Water Samples By Using Blind Quality Assessment

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***Abstract---*** *An attempt to quantify the spectral response of the polychromatic light sources and drinking water samples has been presented in this research. This had been executed by an objective methods of image quality assessment, in which the criteria of error visibility (differences) between images had been applied theoretically and practically. The theoretical part had been presented here by image quality assessment which gave results match with that of the practical part resulted by lab investigation. Otherwise and in spite of its differences in physical and chemical properties, samples of drinking water with their existence percentage didn't make any variation in the spectrum of polychromatic light sources and hence the spectrum of the light sources remains unchanged.*

***الملخص ـ*** *يقدم البحث الحالي تجربة لتقييم الاستجابة الطيفية لمصادر ضوئية متعددة الألوان مع نماذج مختارة من مياه الشرب، حيث تم اعتماد النظريات الكمية لمؤشرات تقييم كفاءة الصورة والتي اعتمد فيها مبدأ رؤية الخطأ (الفروق) بين الصور وتطبيقها نظريا" وعمليا". تمثل الجزء النظري بمؤشرات تقييم كفاءة الصورة والتي أعطت نتائج اتفقت مع الفحوص المختبرية في الجانب العملي. من الجانب الأخر وبالرغم من الاختلافات في الخواص الكيميائية والفيزيائية لعينات الماء المستخدمة فأنه لم يلاحظ أي تغيير في طيف مصادر الضوء متعدد الألوان وبقاء الطيف من دون أي تغيير يذكر*

***Keywords--- Blind quality assessment, Polychromatic light source, Normalized Cross-Correlation (NK), Structural Content (SC), Structural Similarity Index Metric (SSIM).***

## 1. INTRODUCTION

The elementary task of digital image processing is to record images; process, improve, and analyze image's data using appropriate algorithms; supply results that derived from them; and then interpret the results [1]. H. L. Fernandez-Canque et al. for an example used image processing in detecting the micro-organism in drinking water in more reliable way than that by using the existing manual methods. They combined Normarski Differential Interface Contras (DIC) and florescence microscopy using FITC and UV filters in such detecting [2]. On the other hand Z. Iqbal et al. have been used a mobile phone to use it as illumination source and image detector for quantitative optical analysis of colored liquid samples and solid samples. They found algorithmic concentration dependence in accordance with Beer-Lambert law that described the data of the colored liquids [3]. Other researchers represented by Q. Wei et al. introduced a smart-phone-based hand-held platform that allows the quantification of mercury ions in water samples with parts per billion (ppb) level of sensitivity [4].

For many image processing applications, an image quality assessment is a crucial need [5]. For example, if a designer wants to examine several medical imaging devices, he decides to measure the quality of their images [6]. Image quality assessment is closely related to image differences assessment in which quality is based on the differences between the unmodified image and degraded image [7].

Image quality can be measured in two ways; subjective and objective methods. Due to some considerations, an objective method is more preferable than the subjective one. These considerations are related to the absence of the original image at some times, be sides, the objective measure is not much expensive like that in the subjective method [6]. Due to this reason, the objective measurement shall be hold.

## 2. OBJECTIVE IMAGE QUALITY ASSESSMENT

These are an automatic algorithms for quality assessment that could analyze images and report their quality without human involvement. Most existing approaches are known here as [7,8]:
(i) Full-Reference algorithm (FR): the reference image in this algorithm is fully accessible when evaluating the distorted image.
(ii) No-Reference (NR) algorithm or "blind"

quality assessment: the reference image here is not available.

(iii) Reduced-Reference (RR) algorithm: In this approach, a partial information about the reference image is available.

The work in this research is based on the design of the blind quality assessment. The objective quality assessment has two general approaches [7-9]:

- Simple correlation based metrics
- Human Visual System (HVS) feature based metrics

There are a lot of metrics of image quality. The adopted measures can be listed as follows:

### 2.1 SIMPLE CORRELATION BASED METRICS

#### 2.1.1 NORMALIZED CROSS-CORRELATION (NK):

The similarity between two digital images can be quantified in terms of correlation function. Normalized Cross-Correlation (*NK*) measures the closeness between two images and is given by [7]:

$$NK=\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(x(i,j).y(i,j))}{\sum_{i=1}^{M}\sum_{j=1}^{N}(x(i,j))^2} \quad ...(1)$$

Where $x(i,j)$ and $y(i,j)$ represents reference and distorted image respectively. Pixel position of the $M$x$N$ image is $i$ and $j$ respectively.

#### 2.1.2 STRUCTURAL CONTENT (SC)

This approach measures the similarity also between images which is given by the next equation [7]:

$$SC=\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(y(i,j))^2}{\sum_{i=1}^{M}\sum_{j=1}^{N}(x(i,j))^2} \quad ...(2)$$

Hence, the best value for *NK* and *SC* is "one" and it is achieved if and only if $x(i,j)=y(i,j)$.

### 2.2 HUMAN VISUAL SYSTEM (HVS) FEATURE BASED METRICS

#### 2.2.1 STRUCTURAL SIMILARITY INDEX METRIC (SSIM)

This measure compares two images using information about luminous, contrast and structure as follow [7,10,11]:

$$l(x,y)=\frac{2\mu_x(x,y)\mu_y(x,y)+C_1}{\mu_x^2(x,y)+\mu_y^2(x,y)+C_1} \quad ...(3)$$

$$c(x,y)=\frac{2\sigma_x(x,y)\sigma_y(x,y)+C_2}{\sigma_x^2(x,y)+\sigma_y^2(x,y)+C_2} \quad ...(4)$$

$$s(x,y)=\frac{\sigma_{xy}(x,y)+C_3}{\sigma_x(x,y)\sigma_y(x,y)+C_3} \quad ...(5)$$

Where $x$ and $y$ are two different blocks in two separate images, $\mu_x$, $\sigma_x$ and $\sigma_{xy}$ are the average of $x$, standard deviation of $x$, and the covariance of $x$ and $y$ respectively where [7,8]:

$$\mu_x(x,y)=\sum_{p=-P}^{P}\sum_{q=-Q}^{Q}w(p,q)x(x+p,y+q)...(6)$$

$$\sigma_x^2(x,y)=\sum_{p=-P}^{P}\sum_{q=-Q}^{Q}w(p,q)[x(x+p,y+q)-\mu_x(x,y)]^2 \quad ...(7)$$

$$\sigma_{xy}(x,y)=\sum_{p=-P}^{P}\sum_{q=-Q}^{Q}w(p,q)[x(x+p,y+q)-\mu_x(x,y)][y(x+p,y+q)-\mu_y(x,y)]..(8)$$

Where $w(p,q)$ is a Gaussian weighting function such that:

$$\sum_{p=-P}^{P}\sum_{q=-Q}^{Q}w(p,q)=1 \quad ...(9)$$

And $C_1$, $C_2$ and $C_3$ are constants given by [8,11]:

$C_1=(K_1L)^2$ …(10)

$C_2=(K_2L)^2$ ...(11) , and

$C_3=C_2/2$ ...(12)

L is the dynamic range for the sample data, i.e. L=255 for 8 bit content and $K_1 \langle\langle 1$ and $K_2 \langle\langle 1$ are two scalar constants. Throughout this research a value of 0.01 and 0.03 are set to parameter $K_1$ and $K_2$ respectively [8,11]. The structure similarity can be written as [10,11]:

$$SSIM(x,y)=[l(x,y)].[c(x,y)].[s(x,y)]...(13)$$

*SSIM* is a decimal value between (-1,1) [9].

#### 2.2.2 *MSSIM*

The mean of *SSIM* is denoted *MSSIM* and is given as [7,9]:

$$MSSIM(x,y)=\frac{1}{M}\sum_{j=1}^{M}SSIM(x_j,y_j) \quad ...(14)$$

where $M$ is the total no. of windows over the image, $x_j$ and $y_j$ are image's content at the j^th local window.

#### 2.2.3 *DSSIM*

This is the structural dissimilarity metric which is derived from *SSIM* as follows [9]:

$$DSSIM(x,y) = \frac{1}{1 - SSIM(x,y)} \quad ...(15)$$

The greater values of *SSIM* and *DSSIM* refer to greater similarity between images [7].

## *3.* WATER QUALITY

The quality of water varies with the source. It may be or not contain dissolved minerals, dissolved gases, organic matter, microorganisms, or combinations of these

Impurities that cause deterioration of metalworking fluid performance [12]. It is not correct to assume that clear water is always healthy. Slightly turbid water for an example can be perfectly healthy, while clear water could contain unseen toxins or unhealthy levels of nutrients [13].

## 4. EXPERIMENTAL RESULTS

### 4.1 LAMORATORY INVESTIGATIONS

### 4.1.1 WATER INVESTIGATION

From different sources, samples of drinking water have been collected and carried out within 24 hours. The source for each sample can be summarized in the next table.

***TABLE 1.*** *Drinking water samples with their description*

| Source of Drinking Water | Description |
|---|---|
| Ozonated Magnetic water | The ozonated water was magnetized by using two different magnet poles which affixed to the exterior surface of the water container. |
| House water tank | Tap water inside an aluminum tank which is located upon house's roof |
| Boiled tap water | Tap water boiled to the boiling point |

The previous samples had been examined at Environment and Water Researches and Technology Directorate/ Ministry of Science & Technology. Table (2) shows the results for this examination.

**TABLE 2.** Laboratory investigations at Environment and Water Researches Technology Directorate/ Ministry of Science & Technology.

| Source of Drinking Water | $No_3$ ppm | PH | TDS mg/L | EC ms/cm | DO mg/L | FCL mg/L | TURB NTU |
|---|---|---|---|---|---|---|---|
| Ozonated Magnetic water | 0.589 | 7.45 | 41 | 82.3 | 4.79 | 0.02 | 1.02 |
| House water tank | 1.055 | 7.6 | 243 | 486 | 5.43 | 0.01 | 3.02 |
| Boiled tap water | 1.006 | 7.9 | 211 | 421 | 4.63 | 0.00 | 2.03 |

### 4.1.2 LIGHT SOURCES INVESTIGATION

The experimental part of this research needs to utilize different light sources. The spectrum for each source has been tested at the Center of Laser and Optoelecronic-Directorate of Material Researches at the Ministry of Science and Technology and can be shown in Fig.(1).

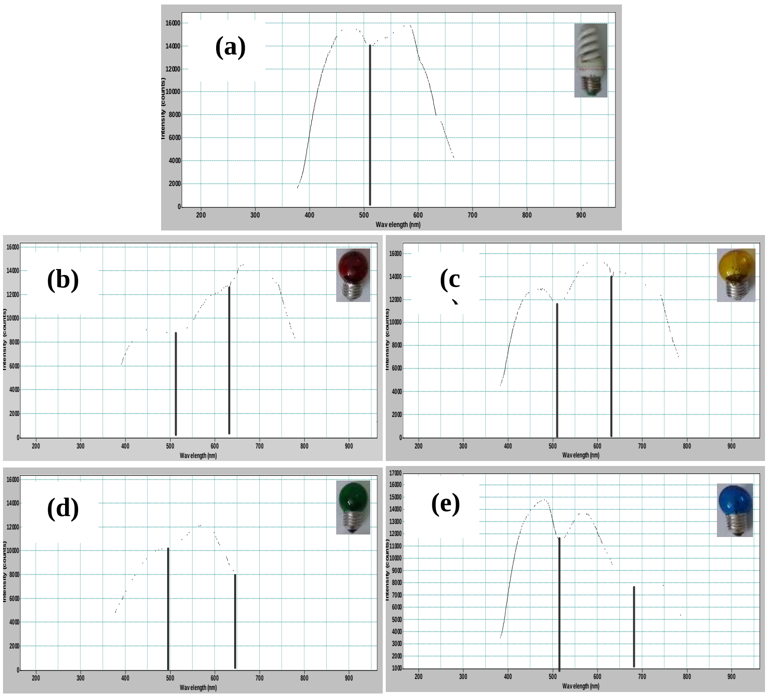


**Fig. (1)** Spectrum for:
(a) White light source (Full spiral saving energy lamp (economic)/ SAVA® NOOR 220V-240V SPIRAL 12W E27)
(b) Red light source (President 220V G40 E27 15W)
(c) Yellow light source (President 220V G40 E27 15W)
(d) Green light source (President 220V G40 E27 15W) and
(e) Blue light source (President 220V G40 E27 15W)

According to [14], the corresponding wavelength for each light source can be derived from these spectrums. In spite of its interior pigment which is gave its general look, the corresponding wavelength for each light source can be extracted and listed in the next table.

**TABLE 3.** Laboratory investigations at Center of Laser and Optoelecronic- Directorate of Material Researches at the Ministry of Science and Technology

| Polychromatic Light Source | Corresponding Wavelength (nm) | Corresponding | |
|---|---|---|---|
| | | Emitted Light | Intensity (counts) |
| White | 515 | Green | 14200 |
| Red | 520<br>630 | Green<br>Red | 8500<br>12400 |
| Yellow | 510<br>630 | Green<br>Red | 11500<br>14000 |
| Green | 490<br>645 | Green<br>Red | 10100<br>8200 |
| Blue | 515<br>680 | Green<br>Red | 11600<br>8300 |

From Table (3), one can conclude that all the light sources emit the red light in addition to the green light except for the white light source which emits the green light only.

## 4.2 IMAGE QUALITY ASSESSMTEN RESULTS

### 4.2.1 ACQUISITION SYSTEM

For the purpose of this experiment, a designing system has been prepared and can be shown in Fig.(2). The system is a cubic box painted with gray spray. This system consists of a polychromatic light source, test tube filled with water and a Sony Cyber-shot DSC-W710 camera of 5x optical zoom and 16.1 Mega pixels. Fig.(3) shows such captured images of the test tube with drinking water samples which has been utilized here by using different light sources.

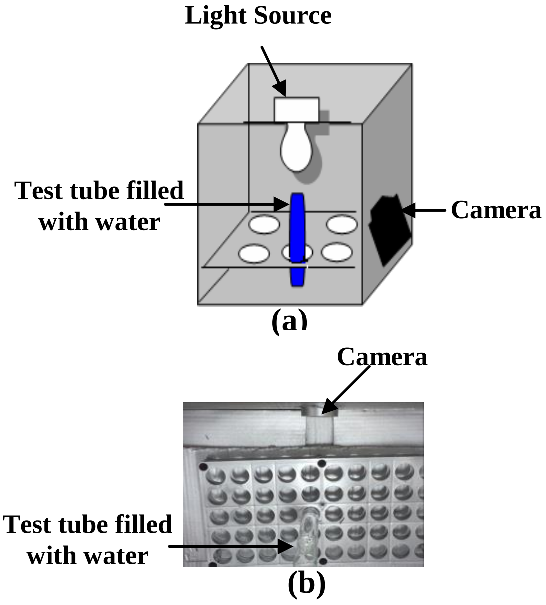


**Fig. (2)** The acquisition designing system
**(a)** General overview **(b)** A close look inside the system

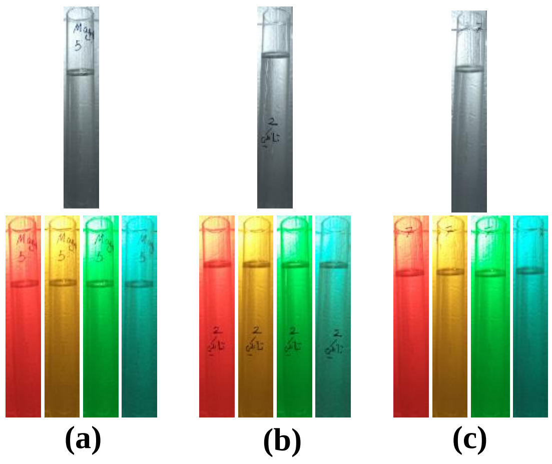


**Fig.(3)** The captured images for the test tube containing
(a) Ozonated magnetic water
(b) House water tank
(c) Boiled tap water
by using white, red, yellow, green and blue light sources respectively.

### 4.2.2 AN OBJECTIVE LMAGE QUALITY RESULTS AND DISCUSSIONS

For each sample of drinking water, the assessment has been executed by adopting two different images of the same drinking water. The original image was proposed to be that captured one by using white light source while the distorted image is that image which captured by using the colored light source (i.e. Red, Yellow, Green and Blue light source respectively). Since the quality in image quality assessment related on the differences between the unmodified and distorted images, one can see that all the polychromatic light sources have been emitted light in the red band of the visible spectrum. Hence, the previous result was obtained with a sequence in intensity begins with the yellow light followed by red, blue lights and ends with the green polychromatic light. This can be proved clearly by noticing the resulted data for all image quality assessment that have been used here and can be best illustrated in Table (4). For all metrics and for all drinking water samples that have been utilized here, the sequence for the used polychromatic light sources from highest to the lowest values for image quality metrics are: Yellow-Red-Blue-Green. According to this result, all the used metrics (i.e. *NK*, *SC*, *SSIM*, *DSSIM* & *MSSIM*) have been introduced a strong evidence ensured by the sequence of the intensity for the corresponding remainder part of the emitted light. On the other side, heating process, magnet effect and other physical and chemical properties with their percentages for samples of drinking water given in

Table(2) didn't make any dispersion upon the spectrum of the whole polychromatic light sources that have been used here.

***TABLE 4*** *Image quality assessment results*

| Source of Drinking Water | Captured Images by using | | Objective Measurements | | | | |
|---|---|---|---|---|---|---|---|
| | 1st Light Source | 2nd Light Source | *NK* | *SC* | *SSIM* | *DSSIM* | *MSSIM* |
| Ozonated Magnetic water | White | Red | 0.752 | 0.568 | 0.911 | 11.278 | 0.925 |
| | | Yellow | 0.784 | 0.617 | 0.946 | 18.542 | 0.944 |
| | | Green | 0.531 | 0.282 | 0.642 | 2.800 | 0.688 |
| | | Blue | 0.637 | 0.408 | 0.795 | 4.895 | 0.824 |
| House water tank | white | Red | 0.722 | 0.524 | 0.917 | 12.091 | 0.904 |
| | | Yellow | 0.756 | 0.574 | 0.939 | 16.415 | 0.927 |
| | | Green | 0.526 | 0.278 | 0.704 | 3.378 | 0.683 |
| | | Blue | 0.690 | 0.479 | 0.890 | 9.112 | 0.877 |
| Boiled tap water | white | Red | 0.684 | 0.470 | 0.895 | 9.600 | 0.872 |
| | | Yellow | 0.756 | 0.575 | 0.951 | 20.695 | 0.927 |
| | | Green | 0.514 | 0.265 | 0.687 | 3.204 | 0.665 |
| | | Blue | 0.601 | 0.362 | 0.787 | 4.703 | 0.781 |

## CONCLUSIONS

This research presented an attempt to achieve one of the elementary tasks of image processing in our daily life. The spectral response for several drinking water samples and polychromatic light sources has been executed by using a system designed for this purpose. Based on the difference criteria between images, an image quality assessment show results with a sequence proved later by adopting the difference criteria to the lab investigation that had been resulted here. On the field of water investigation, the physical and chemical properties with their percentage didn't affect upon the received spectrum and hence, under these considerations, the spectrum for polychromatic light source remains unchanged.

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