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Evaluation of Mariut Lake water quality using Hyperspectral Remote Sensing and laboratory works

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ABSTRACT

It would be an advantage if there were a measurement method, which would provide more detailed spatial information on water contaminations at low cost. Hyperspectral Remote Sensing has a possibility for gathering detailed: contamination information rapidly and inexpensively. This study includes the possibility of assessing heavy metal contamination of water in Mariut Lake and predicting models describe their concentration using spectrum data taken by portable FieldSpec_3 ASD Spectroradiometer.

The main objectives of this research are assessing water contamination by heavy metal in Mariut Lake using laboratory analysis and developing a predictive model for water pollution based on the spectral characteristics and lab data obtained. It is resulted that Pb, Ni and Cr concentrations exceed permissible limit of USEPA. Also, the spectral reflectance of (6–13, 16, 19 and 20) at wavelength 582–653 nm is related to the spectral behavior of the high chlorophyll concentration. Also there are 7 samples (1, 3, 6, 10, 11, 19 and 21) showed high and low values of turbidity. As the suspended sediment concentration increased, reflectance also increased at all wavelengths between 400 and 850 nm. It is concluded that most of models predicting heavy metals concentration using reflectance spectroscopy have high significant correlation ranged from 0.27 to 0.97.

1. Introduction

Reflectance spectroscopy is a rapidly growing science it can be used to derive significant information about surface materials with limited in situ measurement. It is the study of light as a function of wavelength that has been reflected or scattered from a solid, liquid or gas. It may be used in applications when other methods would be too much time consuming and more expensive. Otherwise, hyperspectral images allow for improved detection of chlorophyll and hence algae, due to the narrow spectral bands which are acquired between 450 and 600 nm. Estimation and mapping of water quality constituents such as concentrations of dissolved organic matter, chlorophyll or total suspended matter from optical remote sensing (RS) technologies have proved to be useful and successful and are being investigated for operational use (Hakvoort et al., 2002; Radhi Al-Jabery and Al-Obeidi, 2015; Gholizadeh et al., 2016; Fichot et al., 2016). Detection of water quality parameters is one of the major advantages of hyperspectral remote sensing technologies. Hyperspectral reflectance has been widely used to assess water quality conditions of many open water aquatic ecosystems (Koponen et al., 2002; Thiemann and Kaufmann, 2002).

Suspended sediments increase the radiance emergent from surface water in the visible and near infrared (NIR) proportion of the electromagnetic spectrum so it is promising and feasible to detect water pollutants using spectral signatures in the visible and NIR band (Xing-Ping and Xiao-Feng, 2011). Chlorophyll absorbs strongly in the blue (450 nm) and red (670 nm) regions, also known as the chlorophyll absorption bands. Chlorophyll is the primary photosynthetic pigment in green plants. This is the reason for the human eye perceiving healthy vegetation as green, due to the strong absorption of the red and blue wavelengths and the reflection of the green wavelengths. When the plant is subjected to stress that hinders normal growth and chlorophyll production, there is less adsorption in the red and blue regions and the amount of reflection in the red wave band increases (Abou El-Magd and El-Zeiny, 2014).

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In this research, linear regression analysis was used to develop models describing heavy metals concentration in the studied area of Mariut Lake.

2. Study area

Mariut Lake is a 90–150 cm deep brackish water lake located at north of Egypt, southeast to the Alexandria city, belonging to the Nile River Delta, and one of the most heavily populated urban areas in Egypt (Mateo, 2009).

Nowadays the lake occupies around 250 km^2 due to intense land reclamation for urban and agricultural purposes.

The main sources of pollution are represented by (El-Sharkawi and Fahmy, 1999)

- El-Ommum drain, which discharges about 200,000–300,000 m^3/day of settled sewage into the lake.
- El-Kallaa drain, which discharges about 400,000 m^3/day of agricultural waste water and sewage into the lake after primary treatment. In general, El-Kallaa drain is considered the major source of pollution in the lake.
- Noubaria canal which discharges industrial wastewaters at the western side of the basin.

These sources of pollution in the study area and land use and cover map are shown in Fig. 1.

3. Materials and methods

3.1. Sampling and in situ analysis of water quality parameters

Water samples were collected from twenty-two water stations in Mariut Lake in February 2014. The stations were selected on the basis of variation including all water bodies as shown in Fig. 2. There are traditional analytical methods for determining water quality parameter in the laboratory using very high cost chemical reagents or apparatus and these methods also are time consuming. So, in this study another system of in situ measurements was carried out, which include measuring the physico-chemical parameters of water using the AQUA meter water quality device. The AQUA meter device measures nearly 8 parameters including water temperature, pH, oxidation reduction potentials, specific conductivity, turbidity, chlorophyll, dissolved oxygen as well as, crude oil.

3.2. Laboratory analyses for heavy metals

Water samples were collected, routinely acid-treated with a solution (0.5 N HNO_3) and stored in bottles to prevent contamination. All samples collected for chemical analysis were kept at a temperature of about 4 °C by using cool boxes and cooling agents. The collected water samples were taken to laboratory in the National Research Centre (NRC) for determining heavy metals concentration (Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd and Pb), according to standard method (APHA, 1992).

A quantity of 200 mL of water sample were taken, pH was adjusted from 2 to 3 by adding drops of 1 M HNO_3. The solution was put in 500 mL separating funnel, 1 mL of ammonium pyrolidine dithiocarbamate (APDC) was added, shaking the solution to mix and then, adding 10 or 5 mL of methyl isobutyl ketone. The mixture is shaken manually for 2 min. If an emulsion is formed at the interface of the 2 layers, centrifuged for 2 min, the extraction is repeated with another 5 mL methyl isobutyl ketone. If a precipitate is formed in the solvent phase during the extraction 5 mL of methyl isobutyl ketone is added, and the extraction is repeated with the second 10 mL of the extraction solvent. The organic layers were separated, then acidified with HNO_3 (back extraction). The aqueous acidified solution was treated with the suitable chemical modifier and aspirated directly into flame atomic absorption spectrometer (FAAS) to record the absorbance and then converted to concentration expressed in mg/L.

3.3. Spectral reflectance pattern determination

FieldSpec® 3 ASD Spectroradiometer device is an optical device that uses detectors other than photographic film to measure the distribution of radiation in a particular wavelength region; which measures the radiant energy (radiance and irradiance). It measures the spectral behavior in the visible, near-infrared (VNIR) and shortwave infrared (SWIR) spectra between 350 and 2500 nm in a precision of 1 nm. In the current study, it was used to represent the spectral reflectance patterns of lake water corresponding with water contents.

Hyperspectral data acquired from the FieldSpec needed filtration to exclude the effect of atmospheric gases which might change the obtained spectral reflectance pattern. These filtered regions were defined by FieldSpec operators and included the following wavelength regions: 1350–1450 nm, 1800–1980 nm and 2360–2500 nm. This is followed by performing graphical relationships between wavelengths and reflectance at different parts of the spectrum.

Here, the physico-chemical parameters of Mariut Lake were measured based on the spectral characteristics of the water.

Only the wavelengths from 350 to 1050 nm portion of the spectrum were collected due to the observed low noise-to-signal ratio at both ultraviolet and near-infrared wavelengths (Jupp et al., 1994). All measurements above 1050 nm were neglected due to relatively higher noise-to-signal ratio.

3.4. Modeling of water characteristics

Laboratory analysis and hyperspectral data were statistically analyzed using SPSS software (V, 19). This part of study aims are to determine the relationships between water quality parameters and spectral data from ASD Spectroradiometer device using statistical regression model to predict a model describing each heavy metal concentration by an equation (Fig. 3).

4. Results and discussion

4.1. In situ water analysis

Aqua meter water quality measurements to examine the potential characterization of water properties from optical remote sensing; in situ measurements of water quality parameters were obtained. Indeed, there is a clear spatial variability in the water quality at the sampling locations, which is mainly subjected to changes in water constituents. This is also attributed to the influence of man-made activities including changes of the land use and land cover within the study area as well as the drainage system. The accuracy of measurements of the AQUA meter for each parameter was illustrated in Table 1.

4.1.1. Temperature

The present study revealed that temperature values ranged from 17.3 to 20.9 °C with a mean value of 19.2 °C as shown in Table 2. For Tilapia species, it was suggested that the optimum water temperature ranges between 26 and 30 °C (Adi Santoso and Rachman, 2005).

The too low or too high temperatures pose a serious stress to fish and adversely affect their growth (Lazur, 2000). In addition