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Monitoring the Tannery Effluent Characteristics Using Remote Sensing Technique

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In the conventional method, industrial discharges are monitored by conducting water quality analysis at selected locations. This process is expensive, time consuming and involves lot of man power. Remote sensing is an ideal tool for monitoring wastewater quality, as the satellite data gathers data easily, cost effectively and repeatedly over the earth. The present contribution examines the prediction of tannery effluent characteristics from their spectral radiance measurements. A common effluent treatment plant near Chennai, which treats the effluent from a group of tanneries, was chosen for the study. With a spectro-radiometer, the spectral reflectance of tannery effluent in the wavelengths between 450 and 1000 nm were measured. Regression equations were developed between the spectral radiance and the effluent characteristics. The equations can be used to estimate the characteristics of tannery effluent form satellite data with limited field checks. The approach paves way for a cost effective alternate means of monitoring not only tannery effluent other wastewaters.

Key Words: Tannery effluent, Reflectance, Spectroradiometer.

INTRODUCTION

In remote sensing, data collected from space may be analyzed to obtain information about the objects, areas or phenomenon to be investigated. The sensors acquire data about various earth features from the emitted/reflected electromagnetic energy. With the aid of reference data, the information about the conditions of various earth features are derived. Remote sensing images are computer enhanced and they provide spectral information on lithology, alteration types, vegetation and suspended sediment concentration. Utilization of satellite data for assessing suspended sediment concentrations have been reported by many researchers[1-8].

The estimation of wastewater characteristics over large areas using *in situ* sampling is time consuming, expensive and involves lot of manpower. The remotely sensed spectral radiance measured by satellite sensors could provide an alternative, synoptic, rapid and economic method of assessing the wastewater quality. In the present study, tannery effluent was chosen since it is a highly polluting industry. From the spectral reflectance of tannery effluent measured at ground level, the study can be extended to data collected by satellites in orbit. The approach paves way for a cost effective monitoring of the wastewater discharges from space.

Spectral reflectance measurement: To establish the spectral signature for the tannery wastewater, the common effluent treatment plant (CETP) at Pammal near Chennai, India was chosen as the test site. This plant treats about 3000 m^3 of effluent per day, generated from nearly 132 tanneries at Pammal. All tanneries adopt similar processing techniques and have pretreatment units to remove coarser and inorganic particles as well as oils and greases. The pretreated effluent from the individual tanneries reaches a receiving sump (dimension 1.9 m × 1.9 m × 2.5 m) at the entrance of CETP through underground pipelines, from where it flows to the main treatment plant through a coarse screen. In practice, many industries are disposing off their effluent into the nearby water bodies or sea without any treatment. Hence the inlet point (untreated effluent) at CETP was selected for the investigation rather than the outlet where the treated effluent meets the imposed standards.

Spectral response of earth objects can be obtained through laboratory or field experiments using spectroradiometer. This device measures the energy coming from an object as a function of wavelength. HINDHIVAC Spectroradiometer, a ground survey radiometer working in the visible to near Infrared range (450-1000 nm) was used in the present investigation. Spectroradiometer was set on a tripod in a near vertical position at the edge of the receiving sump. The location of the instrument was selected in such a way, that it was kept opposite to the direction of sun and also for avoiding any shadows falling on the instrument as well as on the effluent in the receiving sump. The wavelength was set at 450 nm and zero adjustment was done. First the barium plate was kept over the wire mesh on the top of the receiving sump and incoming radiation was quantified. Then the barium plate and the wire mesh were removed and the effluent was focused. The presence of foam on the surface of the effluent will considerably alter the reflectance values hence it was removed before noting the reflectance of the tannery wastewater. The same procedure was repeated for the other wavelengths-500, 520, 550, 590, 600, 650, 690, 700, 750, 800, 850, 900, 950 and 1000 nm. As the behaviour of tannery effluent in different wavelengths is not yet established, the wavelengths for observation were selected closely to cover all the spectral regions without any omission as well as based on the bands available in various sensors currently in orbit. Finally the spectral reflectance (in %) was computed by ratioing the reflected energy of the effluent to the reflected energy of the barium plate at different wavelengths. After completing the reflectance measurements, a sample was collected from the receiving sump. In total, 50 sets of samples with concurrent reflectances were collected on bright sunny days between 9 am to 11 am. The samples were analysed for temperature, pH, total solids, total suspended solids, total dissolved solids, chemical oxygen demand, biochemical oxygen demand, chloride, nitrogen and chromium, following standard methods[9].

Spectral signature of tannery effluent: The spectral signature for tannery effluent is plotted (Fig. 1) based on the mean reflectance in each band of the 50 samples whose composition is given in Table-1. From the figure, it is observed that below 520 nm and beyond 750 nm, energy incident upon the wastewater is essentially absorbed. Reflectance gradually increases from 520-750 nm. Thus, in green and red spectral regions, the energy reflected from tannery effluent is high and attaining a maximum in the near Infrared. It is noted that reflectance values remain the same in 690 and 700 nm wavelengths.

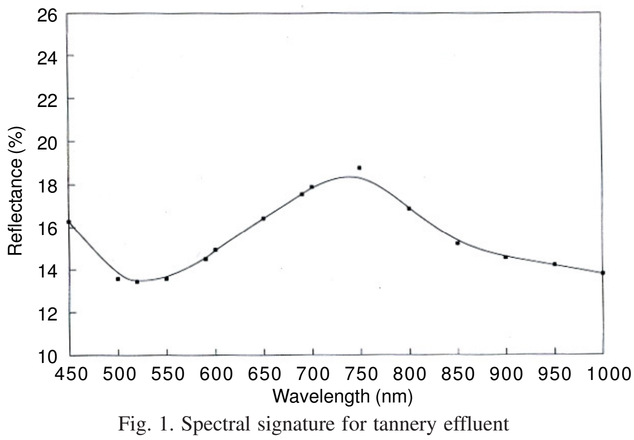

Fig. 1. Spectral signature for tannery effluent

TABLE-1
PHYSIOCHEMICAL CHARACTERISTICS OF TANNERY EFFLUENT

Parameter	Range
Temperature (ºC)	25-30
pH	6.1-8.1
Total solids (mg/L)	5500-7700
Total suspended solids (mg/L)	290-700
Total dissolved solids (mg/L)	5200-7400
Chemical oxygen demand (mg/L)	2100-2900
Biochemical oxygen demand (mg/L)	1200-2000
Chloride (mg/L)	1000-3000
Nitrogen (mg/L)	20-120
Chromium (mg/L)	10-75

In comparison with the spectral signature for clear water[14], the spectral reflectance curve for the wastewater shows a peak at 750 nm and a trough at 520 nm whilst the maximum reflectance for clear water occurs around 580 nm and with total energy absorption in near Infrared wavelengths. The percentage of energy reflected from the wastewater is high compared with the clear water, which could be attributed to the physiochemical parameters of the wastewater.

The physiochemical parameters were correlated with the spectral reflectance in each band. Bivariate correlation coefficients were computed (Table-2). In general, the parameters show a positive correlation with reflectance values except for total suspended solids and chemical oxygen demand. Other than pH, the parameters are poorly correlated with the reflectance in individual bands. This indicates that, to determine the wastewater characteristics, individual wavelengths are unsuitable. Green and red wavelengths exhibit a good relationship with pH. Linear combinations of wavelengths were used to assess any possible improvement in the relationships with the parameters. Regression equations were developed for each parameter, using the reflectance values in four different wavelengths in the following empirical form:

$$\text{Parameter} = aR_1 + bR_2 + cR_3 + dR_4 + e$$

where, a, b, c, d: regression coefficients, e: constant, R: reflectance values, 1, 2, 3, 4: wavelengths.

To develop a statistical model, the four spectral bands with the highest correlation coefficients in Table-2 were chosen for each parameter. Thus, the wavelength combinations differ for the various physiochemical parameters of the effluent.

The four band regression equations for each parameter with the corresponding multiple correlation coefficients are given in Table-3. It appears that a functional relationship exists between the water quality parameters and the reflectance in the 550-850 nm spectral region. *In situ* optical study detected only a weak water signal from the blue end of the spectrum producing an insignificant and unreliable response to changes in the wastewater quality. Similarly, beyond 900 nm the spectral response is low. Although the correlation coefficients in Table-3 were insignificant, there is a considerable improvement on the results from the single band regression. This demonstrates that a linear multiple regression model is superior to the bivariate models.

To validate the model, an independent reflectance measurement of the effluent was made and the physiochemical characteristics of a sample were analyzed in the laboratory. The reflectance values were substituted in the corresponding regression equation to predict the characteristics of the sample (Table-4). The deviation between the measured and predicted values of temperature, pH, total solids, TSS, TDS, COD and chloride are within the limits of ± 7 % (Table-4) whereas BOD and nitrogen are predicted very much on the higher side. It is clear that chromium cannot be predicted from the model, which needs more investigation.

The results encourage that remote sensing may be a useful technique for assessing the wastewater characteristics, however studies may be conducted for other industrial effluents and for other physiochemical parameters to confirm their relationship with spectral reflectance. The accuracy of the model can

TABLE-2
CORRELATION BETWEEN SPECTRAL REFLECTANCE AND PHYSIOCHEMICAL PARAMETERS

Wavelength (nm)	Temp. (ºC)	pH	TS	TSS	TDS	COD	BOD	Cl	N	Cr
450	0.25	0.46	0.15	-0.10	0.17	0.04	0.04	0.08	0.18	0.19*
500	0.19	0.62	0.11	-0.08	0.13	-0.04	0.13	0.16	0.23	0.15
520	0.16	0.63	0.10	-0.02	0.10	-0.04	0.20	0.17	0.26	0.12
550	0.21	0.69*	0.15	-0.04	0.16	-0.03	0.20	0.22	0.24	0.10
590	0.28*	0.71*	0.24	-0.02	0.24*	-0.04	0.24*	0.31	0.29	0.15*
600	0.23	0.69*	0.18	0.08	0.17	-0.12	0.22	0.30	0.32*	0.07
650	0.27	0.70*	0.22	0.08	0.21	-0.15	0.26*	0.34*	0.29*	0.04
690	0.23	0.65	0.26*	0.18*	0.22*	-0.19*	0.29*	0.33*	0.30*	0.02
700	0.29*	0.64	0.30*	0.15*	0.27*	-0.16	0.29*	0.37*	0.30*	0.07
750	0.33*	0.50	0.25*	0.13*	0.22	-0.29*	0.21	0.37*	0.25	0.04
800	0.33*	0.43	0.25*	0.12	0.23*	-0.25*	0.09	0.25	0.25	0.15*
850	0.14	0.45	0.09	0.15*	0.06	-0.16	0.04	0.10	0.27	0.13
900	0.07	0.45	0.06	0.09	0.04	-0.10	0.09	0.04	0.18	0.18*
950	0.04	0.49	0.01	0.10	-0.02	-0.10	0.10	0.05	0.22	0.14
1000	0.12	0.51	0.04	0.11	0.01	-0.17	0.07	0.07	0.24	0.11

*Wavelength selected for developing regression model.

TABLE-3
REGRESSION MODEL

Regression equations	Multiple correlation
Temp. = $0.05 R_{590} – 0.16 R_{700} + 0.20 R_{750} – 0.04 R_{800} + 26.15$	0.37
pH = $0.02 R_{550} + 0.02 R_{590} - 0.02 R_{600} + 0.03 R_{650} + 6.05$	0.71
TS = $-166.86 R_{690} + 218.46 R_{700} – 46.65 R_{750} + 9.58 R_{800} + 6205.58$	0.43
TSS = $39.84 R_{690} – 34.84 R_{700} – 4.63 R_{750} + 3.05 R_{850} + 429.92$	0.36
TDS = $-29.08 R_{590} – 240.30 R_{690} + 297.71 R_{700} – 21.39 R_{800} + 5679.84$	0.47
COD = $42.97 R_{690} – 83.57 R_{750} + 40.57 R_{800} – 3.63 R_{1000} + 2703.40$	0.50
BOD = $-10.25 R_{590} – 4.37 R_{650} – 2.13 R_{690} + 25.06 R_{700} + 1332.16$	0.31
Cl = $-50.26 R_{650} – 198.56 R_{690} + 268.67 R_{700} + 2.45 R_{750} + 1505.05$	0.50
N = $4.04 R_{600} – 6.050 R_{650} – 2.36 R_{690} + 5.80 R_{700} + 49.61$	0.36
Cr = $0.30 R_{450} – 0.23 R_{590} - 0.28 R_{800} + 0.66 R_{900} + 17.62$	0.21

TABLE-4
VALIDATION OF THE MODEL

Parameters	Measured	Predicted	Deviation (%)
Temperature (ºC)	28	28.56	-2.0
pH	7.19	7.26	-1.0
TS (mg/L)	6451	6387.66	1.0
TSS (mg/L)	470	501.31	-6.7
TDS (mg/L)	5981	5817.27	2.7
COD (mg/L)	2250	2350.14	-4.5
BOD (mg/L)	1206	1570.59	-30.2
Chloride (mg/L)	2008	2143.89	-6.8
Nitrogen (mg/L)	70	85.83	-22.6
Chromium (mg/L)	10	30.79	-207.9

be further improved by increasing the sample size, adopting higher order equations, selecting more than four bands as well as ratios of band combinations.

Conclusion

From the present study, it is concluded that red wavelengths are suitable for the prediction of tannery wastewater characteristics, more specifically 690 and 700 nm wavelengths. Similarly 590, 750 and 800 nm wavelengths also show good relationship with the physiochemical parameters. Blue band is unsuitable to study the tannery effluent. Reflectances show a close association with pH while Cr exhibits a reverse trend.

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