APPLICATION OF REMOTE SENSING & GEOGRAPHIC INFORMATION SYSTEM FOR WATER QUALITY MONI- TORING, EVALUATION AND ANALYSIS-A REVIEW

Madipally Vamshi Krishna[1], Ballu Harish[2]
[1] Student, Department Of Centre For Spatial Information Technology, Jntuh-Ist. E-mail: Vamshi.M.94@Gmail.Com
[2] Assistant Professor Of Centre For Spatial Information Technology, Jntuh-Ist . E-mail: Harishballu111@Gmail.Com

Abstract

Water resources are counted as one of the major natural resource. Various anthropogenic activities are responsible for depletion of quality of surface water and ground water. In the present review paper, various water quality parameters are discussed and application of remote sensing & GIS tech- nology for monitoring, evaluation and analysis of water quality. Water quality may be described based on pH, TDS, concentration of Fluoride, iron, sulphur etc. remote sensing and GIS may prove to be an important technique for analysis using various modeling methods like IDW, Krigging and other interpolation methods. Water quality analysis may be used for suitability analysis and to find sources of water for drinking, irrigation, commercial and industrial purpose.

Introduction

There are two types of water resources available on earth for human being, one is ground water and other is surface water. Groundwater can be extract through wells, borewell, hand-pump etc while surface water is available in the form of riv- ers, pond, lakes etc. Quality of these water resources are continuingly depleting because of rapid use of chemicals and disposal of industrial waste in nature. As ground water moves through soil, sediment and rocks, many impurities such as disease-causing micro- organisms are filtered out. Many water resources in developing countries are unhealthy because they contain harmful physical, chemical and biolog- ical agents (Pawari M.J. et al, 2015). The quality of ground water in a given area is determined by the presence f the contaminants and the degree of their concentration. The presence of the contaminants and the degree of their concen- tration can be attributed to the in-situ origin and / or due to dispersion. The in-situ-origin of the contaminants can be either geo-genic and / or anthropogenic. Similarly, the dis- persion of the contaminants can be through a point source and / or a non-point source. Remote sensing technique is an economical way to monitor water quality, because it can monitor large areas in a short time on a repetitive basis it is also easy to update water quality parameters using remote sensing data, which allows continuous monitoring of water quality (Somvanshi S., et al, 2012). GIS can be a powerful tool for developing solutions for water resources problems for assessing water quality, determining water availability, preventing flooding, understanding the natural environment, and managing water resources on a local or regional scale (Tjandra F.L. et al, 2003). remote sensing can be used to temporally monitor any water body using image time series collected, if possible from the same satellite sensor, and de- tect the changes in the water quality. However, the accuracy of this method depends on the availability of the proper sat- ellite sensor, image time series and its calibration and the generated model as well (Ibrahim Saad El-Din M. et al, 2013). One major advantage of remote sensing observations over traditional measurements for water quality monitoring provides both spatial and temporal information of surface water characteristics (Lindell T. *et al*., 1999).

Parameters considered for surface water quality determination

The most commonly measured qualitative parameters of Surface water by means of remote sensing (Gholizadeh M.H. et al, 2016).

Water Quality Parameter	**Units**	**References**
chlorophyll-a	mg/L	[10,36–38]
Secchi Disk Depth	m	[39–42]
Temperature	C	[43–46]
Colored Dissolved Organic Matters	mg/L	[10,47–49]
Total Organic Carbon	mg/L	[50–52]
Dissolved Organic Carbon	mg/L	[53–55]
Total Suspended Matters	mg/L	[56–59]
Turbidity	NTU	[60–62]
Sea Surface Salinity	PSU	[63–66]
Total Phosphorus	mg/L	[29,36,67–69]
Ortho-Phosphate	mg/L	[70]
Chemical Oxygen Demand	mg/L	[71–74]
Biochemical Oxygen Demand	mg/L	[62,75–77]
Electrical Conductivity	s/cm	[78–80]
Ammonia Nitrogen	mg/L	[73,81,82]

Chlorophyll a

Chl-a while mainly reflecting green, absorbs most energy from wavelengths of violet-blue and orange-red light, whose reflectance causes chlorophyll to appear green. Obviously,the addition of chl-b besides chl-a extends the spectrum absorption. Low light conditions tends to favor the production, a rather greater ratio, of chl-b to chl-a molecules, thus in- creasing photosynthetic yield (Schlichter D. et al, 1997).

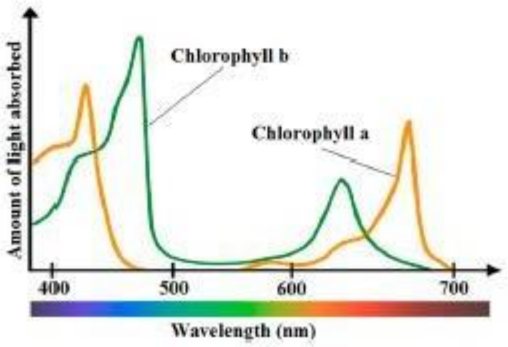

Figure 1: The absorption spectrum of chl-a and chl-b pigments.

Several satellite and airborne imageries can be used for chl-a estimation. Nonetheless, it revealed that the Landsat TM seems to be more appropriate and widely used for chl-a as- sessment. Temporal coverage and spatial resolution of TM and its easy accessibility can be the main reasons for the selection of this (Gholizadeh M.H. et al, 2016).

Colored Dissolved Organic Matters (CDOM)

Colored Dissolved Organic Matters, also called gelbstoff and gilvin, consists of naturally occurring; water-soluble, biogenic, heterogeneous organic substances that are yellow to brown in color (Aiken, G.R et al, 1985). Review of litera- ture revealed that hyperspectral remote sensing can be used for estimation and monitoring of CDOM.

Secchi Disk Depth (SDD)

Secchi disk depth is an optical property of water which show that how much total suspended solid are present in water. Many researchrs applied remote sensing data for estimation of secchi disk depth and found it a useful technique. Braga et al,1993 found that SDD was closely correlated with TM data, especially during high tide. Furthermore, highly suita- ble models were developed for SDD that rangedfrom 4 to 15 m from TM1 and TM3 satellite radiance (Pattiaratchi C. et al, 1994).

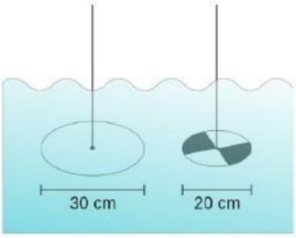

Figure 2: Two different kind of Secchi Disk Depth

Turbidity and Total Suspended Sediments

Water turbidity is an optical property of water, which scatters and absorbs the light rather than transmit it in straight lines. Suspended sediments are responsible for most of the scattering, whereas the absorption is controlled by chl-a and colored dissolved or particulate matter (Myint S., 2002). Landsat images are used by several researchers for finding correlation of remote sensimg and suspended sediments. Lim J. and Choi M., 2002, found that suspended solids was correlated with Bands 2–5 of Landsat-8/OLI, and constructed 3 multiple regression models through single bands of OLI.

Total Phosphorus (TP)

Fertilizer-rich agricultural runoffs and effluents from wastewater treatment plants are the main sources of high phosphorus and nitrogen concentrations in surface waters that threaten many worldwide ecosystems (ReedA. T. et al, 2000). Song K. et al., 2011 studied the correlation between TP and TM1, TM2, TM3, and TM4 from the Landsat 5, and found that each band had a correlation with TP of 0.62, 0.59, 0.55, and 0.51, respectively.

Water Temperature

Thermal remote sensing can be used for measuring water temperature. Remote sensing of water temperature in rivers is more complex than in other waterbodies because of their much smaller dimensions and difficulties of determination at the resolution (pixel size) of the thermal-infrared (TIR) data (Handcock R. et al,2006).

Remote Sensing Sensors used for water Quality

Lavery *et al*. 1993, developed regression models for predicting surface water quality parameters from TM data.Following are the major sensors which are used by researchers for estimation of surface water quality.
Landsat 5-TM,
MSS WorldView-2
IRS-LISS-
III MODIS
MERIS
AVHRR
SeaWiFS
SPOT

Parameters considered for Ground water quality determination

Major parameters considered for ground water quality assessment are as follows:

Table 1: Element-Wise Concentration Limits of Water Quality Classes (Based on Indian Drinking Water Standards as per BIS Guideline-IS: 10500: 2012)

Element	**Potable**		**Non-Potable**
	Desirable limit	**Permissible limit**	
pH	6.5 to 8.5	-	<6.5 or >8.5
Total Hardness (as Ca-Co3) mg/l	<200	200-600	>600
Iron (as Fe) mg/l	<0.3	-	>0.3
Chlorides (as Cl) mg/l	<250	250-1000	>1000
Total Dissolved solids mg/l	<500	500-2000	>2000
Bicarbonate (as MG) mg/l	<500	-	>500
Calcium (as Ca) mg/l	<75	75-200	>200
Magnesium (as Mg) mg/l	<30	30-100	>100
Nitrate (as NO3) mg/l	<45	-	>45
Sulphate (as SO4) mg/l	<200	200-400	>400
Fluoride (as F) mg/l	<1.0	1.0-1.5	>1.5
Manganese (as Mn) mg/l	<0.1	0.1-0.3	>0.3
Sodium (as Na) mg/l	-	-	-
Potassium (as K) mg/l	-	-	-
Arsenic (as As) mg/l	<0.01	0.01-0.05	>0.05
Phenolic Compounds (as C 6H5OH) mg/l	<0.001	0.001-0.002	>0.002
Mercury (as Hg) mg/l	<0.001	-	>0.001
Cadmium (as Cd) mg/l	<0.003	-	>0.003
Selenium (as Se) mg/l	<0.01	-	0.01
Copper (as Cu) mg/l	<0.05	0.05-1.5	>1.5
Cyanide (as CN) mg/l	<0.05	-	>0.05
Lead (as Pb) mg/l	<0.01	-	>0.01
Zinc (as Zn) mg/l	<5	5-15	>15
Anionic detergents (as MBAS) mg/l	<0.2	0.2-1.0	>1.0
Chromium (as Cr6+) mg/l	<4.0	-	>4.0
Polynuclear aromatic hydro carbons (as PAH) mg/l	< 0.2		> 0.2
Mineral Oil mg/l	<0.5	-	>0.5
Pesticides mg/l	-	0-0.001	> 0.001
Radioactive Materials α emitters pci/l	<0.1	-	>0.1
Radioactive Materials β emitters pci/l	<1.0	-	>1.0
Alkalinity mg/l	<200	200-600	>600
Aluminium (as Al) mg/l	<0.03	0.03-0.2	>0.2

pH

pH value of an aqueous solution provides information that whether it is acidic or basic. In general water with pH less than 7 is considered as acidic and pH greater than 7 is con- sidered as basic. Exposure to extreme pH values results in irritation to the eyes, skin, and mucous membranes. Eye irri- tation and exacerbation of skin disorders have been associat- ed with pH values greater than 11. Exposure to low pH val- ues can also result in similar effects. Below pH 4, redness and irritation of the eyes have been reported. (pH in Drink- ing-water Background document for development of WHO Guidelines for Drinking-water Quality, World Health Organ- ization, WHO/SDE/WHO/03.04/12).

Total Hardness (as CaCo3)

Water hardness is the traditional measure of the capacity of water to react with soap, hard water requiring considera- bly more soap to produce a lather Hardness is most com- monly expressed as milligrams of calcium carbonate and magnesium equivalent per litre. Both calcium and magnesi- um are essential minerals and beneficial to human health in several respects. Inadequate intake of either nutrient can result in adverse health consequences. (Hardness in Drink- ing-water Background document for development of WHO Guidelines for Drinking-water Quality, World Health Organ- ization, WHO/HSE/WSH/10.01/10/Rev/1).

Iron (as Fe)

Iron (as Fe2+) concentrations of 40 µg/litre can be detect- ed by taste in distilled water. In a mineralized spring water with a total dissolved solids content of 500 mg/litre, the taste threshold value was 0.12 mg/litre. In well-water, iron con- centrations below 0.3 mg/litre were characterized as unno- ticeable, whereas levels of 0.3–3 mg/litre were found ac- ceptable. (Iron in Drinking-water Background document for development of WHO Guidelines for Drinking-water Quali- ty, World Health Organization, WHO/SDE/WSH/03.04/08).

Chlorides (as Cl)

Chlorides are widely distributed in nature as salts of sodi- um (NaCl), potassium (KCl), and calcium (CaCl2). Chloride concentrations in excess of about 250 mg/litre can give rise to detectable taste in water, but the threshold depends upon the associated cations. Consumers can, however, become accustomed to concentrations in excess of 250 mg/litre. (Chloride in Drinking-water Background document for development WHO Guidelines for Drinking-water Quality, World Health Organization, WHO/SDE/WSH/03.04/03).

Total Dissolved solids (TDS)

Total dissolved solids (TDS) is the term used to describe the inorganic salts and small amounts of organic matter pre- sent in solution in water. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulphate, and nitrate anions. The presence of dissolved solids in water may affect its taste. (Total dissolved solids in Drinking-water, Background document for development of WHO Guidelines for Drinking-water Quality, World Health Organization, WHO/SDE/WSH/03.04/16).

Nitrate (as NO3)

Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. Nitrate is used mainly in inorganic fertilizers.

It is also used as an oxidizing agent and in the production of explosives, and purified potassium nitrate is used for glass making. The toxicity of nitrate to humans is mainly attributable to its reduction to nitrite. The major biological effect of nitrite in humans is its involvement in the oxidation of normal Hb to metHb, which is unable to transport oxygen to the tissues. (Nitrate and nitrite in drinking-water Background document for development of WHO Guidelines for Drinking-water Quality, World Health Organization, WHO/SDE/WSH/07.01/16/Rev/1).

Sulphate (as SO4)

Sulfates are discharged into water from mines and smelters and from kraft pulp and paper mills, textile mills and tanneries. Sodium, potassium and magnesium sulfates are all highly soluble in water, whereas calcium and barium sulfates and many heavy metal sulfates are less soluble. Cathartic effects are commonly reported to be experienced by people consuming drinking-water containing sulfate in concentrations exceeding 600 mg/litre (US DHEW, 1962)

Fluoride (as F)

Fluorine is a common element that does not occur in the elemental state in nature because of its high reactivity. It accounts for about 0.3 g/kg of the Earth’s crust and exists in the form of fluorides in a number of minerals, of which fluorspar, cryolite and fluorapatite are the most common. Many epidemiological studies of possible adverse effects of the long-term ingestion of fluoride via drinking-water have been carried out. These studies clearly establish that fluoride primarily produces effects on skeletal tissues (bones and teeth). (Fluoride in Drinking-water Background document for development of WHO Guidelines for Drinking-water Quality, World Health Organization, WHO/SDE/WSH/03.04/96).

Alkalinity

Alkalinity is a chemical measurement of water’s ability to neutralize acids. Large amount of alkalinity imparts bitter taste in water.

Approaches for water quality Assessment

Spatial Modelling and Surface Interpolation through IDW

GIS can be a powerful tool for developing solutions for water resources problems for assessing water quality, determining water availability, preventing flooding, understanding the natural environment, and managing water resources on a local or regional scale (Collet C., 1996). S.S. Asadi et al, 2007 used spatial interpolation technique through Inverse Distance Weighted (IDW) method for delineation of locational distribution of pollutants. Monitoring of water quality may be estimated using satellite images of pre monsoon and post monsoon seasons. The interpolated data of pre and post monsoon is union to develop a comprehensive water quality map.

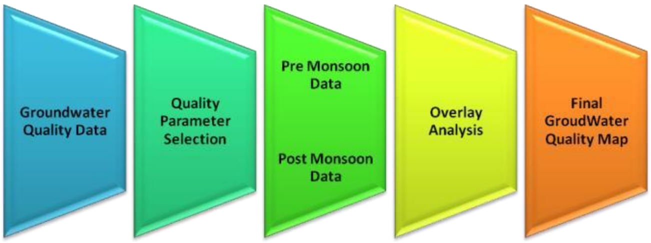

Figure 3: Methodology for groundwater quality mapping.

Regression models for estimation water quality parameters from satellite data

Whitlock C.H. *et al*., 1982 and Wilkinson L., 1997 were established regression models using statistical significance of multiple correlation coefficients (R2), the standard error of the mean Y estimate (SE (Y)), F-ratio values, and probability (P) at 95 percent confidence level. Somvanshi S. et al, 2012 used Multiple Linear regressions to explore the relationship between the water quality parameters (dependent variables) and LISS III radiance data (independent variables) they estimated multiple correlation coefficients (R2) in each combination of independent variables with dependent variables, the maximum value of R2 was considered in the regression equation. The independent variables selection was based on commission and omission technique to eliminate the insignificant independent variables; only those independent variables combination having highest R2 value with dependent variables were selected for the equation and model to estimate water quality parameters. Lavery P. *et al*. 1993 developed regression models for predicting surface water quality parameters from TM data.

Normalized Difference Vegetation and Water Indices (NDVI and NDWI):

Ibrahim Saad El-Din M. et al, 2013 used normalized difference vegetation index (NDVI) to identify various classes of vegetation and determine their health in Lake Timsah, Moreover, the normalized difference water index (NDWI) was used to identify areas of standing water with a surface area greater than 4 m_2 within Lake Timsah.

$$NDVI = \sum \frac{(Red - NIR2)}{(Red + NIR2)}$$

Ibrahim Saad El-Din M. et al, 2013 also found that in NDVI, the red band is used to represent the low level of reflectance from vegetation and a broad NIR to represent the higher reflectance values. In WV-2 images, the NIR2 band has a higher reflectance value than traditional broad NIR bands, and hence should produce a higher NDVI value. It follows that if the coastal blue band of WV-2 is used instead of the red, the vegetation cover will be suppressed and the open water features will be enhanced. The equation for the NDWI is:

$$NDWI = \sum \frac{(Costal\ blue - NIR2)}{(Costal\ blue + NIR2)}$$

Conclusion

Remote sensing and GIS proved to be an important technique for mapping and monitoring water quality. Quality of surface water can be directly monitored using high resolu- tion as well as low resolution images. Landsat TM, ETM, LISS III, LISS IV etc can be used for mapping of waterbod- ies of large area as well as world view and quickbird images can be used for small waterbodies mapping. Various tech- niques like IDW interpolation and regression models were used by researchers along with remote sensing data proves that integration of these techniques give better result. NDVI and NDWI using NIR bands of remote sensing satellite im- ages are also used for water quality mapping.

References

[1] Aiken G.R., McKnight D.M., Wershaw R.L., MacCarthy P., 1985, *Humic Substances in Soil, Sediment, and Water: Geochemistry, Isolation and Characterization*; John Wiley & Sons: New York, NY, USA.

[2] Asadi S. S., Vuppala P., Reddy M. A., 2007, *Remote Sens- ing and GIS Techniques for Evaluation of Groundwater Quality in Municipal Corporation of Hyderabad (Zone-V), India*, International Journal of Environmental Research and Public Health, ISSN 1661-7827, Int. J. Environ. Res. Public Health,Volume 4 issue 1, pp 45-52.

[3] Braga, C.Z.F., Setzer, A.W., de Lacerda L.D., *1993, Water quality assessment with simultaneous Landsat-5 TM data at guanabara bay, Rio de Janeiro, Brazil*. Remote Sens. Envi- ron. pp 95–106.

[4] Collet C., 1996, *Geographic Information System Needs and Software*. Kluwer Academic Publishers, Boston, USA.

[5] Gholizadeh M. H., Melesse A. M., Reddi L.1, 2016, *A Comprehensive Review on Water Quality Parameters Estimation Using Remote Sensing Techniques*. Journal: Sensors 2016, 16, 1298; doi:10.3390/s16081298.

[6] Handcock R., Gillespie A., Cherkauer K., Kay J., Burges S., Kampf S., 2006, Accuracy and uncertainty of thermal infra- red remote sensing of stream temperatures at multiple spatial scales. Remote Sensing of Environment. pp 427–440.

[7] https://www.researchgate.net/publication/259752435.

[8] Ibrahim Saad El-Din M., Ahmed G., Magaly K., Ahmed R.S., 2013, *Remote Sensing Application for Water Quality Assessment in Lake Timsah, Suez Canal, Egypt*. Journal of Remote Sensing Technology, Vol. 1 Issue. 3, PP. 61-74.

[9] Indian Standard, drinking water — specification, bureau of indian standards, IS 10500 : 2012

[10] Lavery P., Pattiaratchi C.,1993, *Water quality monitoring in estuarine waters using the Landsat Thematic Mapper*. Re- mote sensing of environment, 46(33), pp 268-280.

[11] Lim J., Choi M., 2015, *Assessment of water quality based on Landsat 8 operational land imager associated with hu- man activities in Korea*. Environ. Monit. Assess, pp 1–17.

[12] Lindell T., Pierson D., Premazzi G., and Zilioli F. 1999, *Manual for monitoring European lakes using remote sensing techniques*, EUR 18665 EN, Official Publications of the European Communities, Luxembourg. l6lp.

[13] Myint S., Walker N., 2002, *Quantification of surface sus- pended sediments along a river dominated coast with NOAA AVHRR and SeaWiFS measurements:* Louisiana, USA. In- ternational Journal of Remote Sensing, pp 3229–3249.

[14] Pattiaratchi C., Lavery P., Wyllie A., Hick P.,1994, *Esti- mates of water quality in coastal waters using multi-date Landsat Thematic Mapper data*. International Journal of Remote Sensing, pp 1571–1584.

[15] Pawari M.J., Gavande S.M. 2015. *Assessment of Water Quality Parameters: A Review,* International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Volume 4 Issue 7.

[16] Schlichter D., Kampmann H., Conrady S.,1997, *Trophic potential and photoecology of endolithic algae living within coral skeletons*. Mar. Ecol. pp 299–317.

[17] Secchi Disk. Available online: https://en.wikipedia.org/w/index.php?title=Secchi_disk&oldid=710966414.

[18] Somvanshi S. Kunwar P, Singh N.B, Shukla S.P, Pathak V. 2012. *Integrated remote sensing and GIS approach for wa- ter quality analysis of Gomti river, Uttar Pradesh,* interna- tional journal of environmental sciences, ISSN 0976 – 4402 Volume 3, No 1.

[19] Song K., Wang Z., Blackwell J., Zhang B., Li F., Zhang Y., Jiang G., 2011, *Water quality monitoring using Landsat Themate Mapper data with empirical algorithms in Chagan Lake, China*. Journal of Applied Remote Sensing.

[20] *Spatial Database Creation on Ground Water Quality using Legacy Data, Technical Manual/guidelines for preparation of Ground Water Quality layer under RGNDWM project*, NRSC. ISRO, 2012.

[21] Reed A. T., Carpenter S.R., Lathrop R.C.,2003, *Phospho- rus flow in a watershed-lake ecosystem*. Ecosystems. pp 561–573.

[22] Tjandra F. L., Kondhoh A., Mohammed Aslam M.A. 2003, *A Conceptual Database Design For Hydrology Using GIS. Proceedings of Asia Pacific Association of Hydrology and Water Resources.* March 2003,13-15, Kyoto, Japan.

[23] US DHEW, 1962, *Drinking water standards. Washington, DC,* US Department of Health, Education and Welfare, Pub- lic Health Service; US Government Printing Office (Publica- tion No. 956).

[24] Whitlock C.H., Kuo C.Y., LeCroy S.R., 1982, *Criteria for the use of regression analysis for remote sensing of sedi- ment and pollutants*. Remote sensing of environment, pp 151-168.

[25] Wilkinson L., 1997, *SYSTAT: The system analysis for statistics.* SYSTAT, Evanston, III