Advances in Pure and Applied Chemistry (APAC)
Vol. 1, No. 1, 2012, ISSN 2167-0854

www.worldsciencepublisher.org

Physicochemical assessment of water quality with respect to Remote sensing and GIS techniques

Rajnee Naithani,

Banasthali Vidyapeeth, Rajasthan, India

Email: rajneepranavnaithani@gmail.com

and

Dr. I.P. Pande

Oil Extraction, Environmental & Disaster Management Lab
D.A.V. (PG) College, Dehra Dun, Uttrakhand, India
Email: ippande@gmail.com

Abstract: The water bodies in India have been polluted due to escalating population, urbanization and economic activities resulting in severe deterioration of the water quality. In view of the continuously degrading quality of our water resources and its impact on human health, aquatic life and the environment, effective water quality assessment has become critical. The predominant techniques used in India for water quality assessment involve *in situ* measurements and/or the collection of water samples followed by laboratory analyses. These popular techniques however, are limited on temporal and spatial scales of the water quality trends. This paper highlights the limitations associated with the conventional water quality assessment method and discusses the recent advanced RS and GIS techniques as a promising perspective for effective water quality assessment. The paper concludes with suggestions on applications of RS and GIS in effective water quality assessment and in taking prompt and consistent water management decisions for the conservation of water resources in India.

Keywords: Water quality, remote sensing, GIS, water assessment.

1. Introduction

Water is the most important natural resource which supports all life forms on earth and has no known alternative (Kumar, Singh and Sharma, 2005). Earth has abundant water due to the presence of the water cycle on it but even then most of it is unfit for human use and consumption. Out of approximately 71% of water present on the surface of the earth, less than 3% is potable and easily accessible to human beings. According to Kumar et al. (2005), in India the surface and ground water resources are put to multiple uses in cultivation, manufacturing units, hydro-power, forestry, navigation, domestic uses, aquaculture, recreational-activities. Thus, considering its various attributes, water is indispensable and a unique asset for us. In view of the importance of this precious natural resource, the National Water Policy of the Government of India (2002) stipulates water allocation priorities broadly in the following order: (1) Drinking Water, (2) Irrigation, (3) Hydro-power, (4) Navigation, (5) Industrial and other uses (National Water Policy, 2002). The fresh water of the rivers has always been the chief source of drinking water for human beings and animals because of which all the pre-historic human settlements have prospered alongside the rivers (Khaiwal, Ameena, Meenakshi, Monica, Rani and Kauhik, 1999). Even now river basins are highly populated areas due to the availability of productive land and water for drinking, irrigation, manufacturing and navigation purposes (Vega, Pardo, Barrado and Debaan, 1998). Water plays a vital role in maintaining ecological balance, sustaining soil fertility, development of forest resources and conservation of wildlife (Suthar, Nema, Chabukdhara and Gupta, 2009). It also plays a pivotal role in all the human developmental activities which has resulted in its pollution and once polluted this unique resource cannot be easily and cost effectively restored to pristine purity (Kumar et al. 2005).

2. Factors contributing to the degradation of water quality

Both natural processes as well as anthropogenic activities adversely affect the quality of water (Maheshwari, Sharma and Sharma , 2011). The major natural sources are the salts introduced from contact of the surface water with various rocks and soil minerals, vegetation, erosion in various stages of bio degradation, dissolved gases native to the environment and volcanic activities. The major anthropogenic sources include activities related to land use in agricultural areas, seepage from sewage system and industrial activities. Yoo and Park (2000) mentioned that water is confronted by both point and non point source pollutants which contribute to the degradation of its quality. Point sources are organized sources of pollution with measurable pollution load (CPCB 2008). Such sources include surface drains transporting waste waters of industries and sewage system, where as non-point sources are non-measurable sources of pollution. Such sources are numerous and influenced by the land-use patterns in the overall watershed. These include both, the natural processes and the human activities (Ritchie, Zimba and Everitt, 2003).

The addition of organic matter to water supplies from domestic, industrial and agricultural wastes causes Eutrophication. The organic matter after bio-degradation release nutrients in the water. High nutrient concentration leads to Eutrophication, a condition characterized by significant diurnal variation in dissolved oxygen concentration and excessive algal growth (CPCB 2009). Eutrophication caused by the enrichment of nitrogen and phosphorus in the water bodies is adversely affecting the quality of surface water water all over the world (Cherry, Shephered, Withers and Mooney, 2008; Ouyang, Wang, Hao and Srinivasan, 2009). Shafique, Fulk, Autrey and Flotemerch (2003) stated that this phenomenon degrades the water quality by affecting its taste and odour due to excessive growth of algae and also that the microbes booming in eutrophicated water are a potential danger to human health.

According to Weiqi, Chen, Xuehua and Chen, (2008) factors such as the rapidly increasing human population, industrialization coupled with urbanization and ever increasing cultivation activities have deteriorated the quality of surface and ground water globally. Due to these factors river water is also subjected to increased pressure resulting in degradation of the water quality (Suthar, Nema, Chabukdhara and Gupta, 2009). In their studies Khaiwal et al., (1999) stated that river water quality has been adversely affected since ancient times, because the rivers have additionally severed the purpose of cleaning and dumping of various kinds of effluents. Rivers are the main medium for transportation and assimilation of municipal as well as industrial effluents, animal droppings, agricultural runoffs, resulting in large scale deterioration of the water quality (Vega et al., 1998; Ward and Elliot, 1995). Urban runoffs and sewage disposal in the catchment area of rivers also contribute to their poor water quality (CPCB 2008).

3. Impact of Water Pollution

Water is a universal solvent with a unique characteristic of dissolving a variety of substances. Due to this, large volumes of available surface and ground water resources are able to dissolve a variety of organic, inorganic and toxic wastes generated by the natural processes and anthropogenic activities. This not only deteriorates the water quality but also has an adverse impact on human health impacts of poor water quality is transformed into increased mortality rates, reduced life expectancy, malnutrition, followed by high medical expenditures. Excessive salinity of ground water is undesirable for drinking due to its objectionable taste. Public health is adversely affected when it exceeds the permissible limits. Saline water is also undesirable for agriculture as it impairs the plant growth (Srinivasn and Reddy, 2009) . Furthermore, the use of partly treated wastewater from the industries containing toxic contaminants like cadmium and lead get accumulated in soil and finds its way into the food chain via the uptake by crops (Mitra & Gupta 1999; Srinivsan and Reddy, 2009). The exploitation of ground water resources also increases the concentration of elements like fluoride and arsenic consequently posing a potential health risk to the consumer. The hazardous effects of some of the major water quality parameters on ecosystem, human health and aquatic life have been described below (CPCB 2009) .

3.1. Core parameters

Water Temperature: Temperature affects the aquatic life. Warm water also makes some substances, such as cyanides, phenol, xylene and zinc that are more toxic for aquatic animals, also the toxicity is increased by high water temperatures and low dissolved oxygen. Affects fish migration.

pH: It guides the corrosion/scaling tendency of water. The high pH waters are usually scale forming while the low pH waters are corrosive in nature. It also affects the aquatic life.

Nitrate: It causes 'Blue baby disease' (methemoglobineamia). Nitrates can be reduced to toxic nitrites in the human intestine, and many babies have been fatally poisoned by well water containing high levels of nitrate nitrogen.

Nitrite: Forms nitrosamines which are carcinogenic.

3.2. General parameters

Total dissolved solids - High dissolved solid in water is undesirable. It causes undesirable taste and gastrointestinal irritation.

Turbidity: It may provide lodging and breeding place for some harmful microorganisms.

Ammonia: Indicates pollution, growth of algae. It is toxic to fish and aquatic organisms, even in very low concentrations.

3.3. Major cations and anions

Phosphate: Phosphate promotes algal growth and in very high concentrations causes eutrophication in water bodies and affects human digestion.

Fluoride: its concentration below 1.5mg/l is desired in potable water for the protection of the teeth. However, its higher concentration is undesirable and may cause mottled enamel in teeth. It also causes dental & skeletal fluorosis and non-skeletal manifestations.

3.4. Trace metals

Arsenic: Toxic, bio-accumulation, affects the central nervous system, carcinogenic.

Mercury: Highly toxic, causes 'minimata' disease-neurological impairment and renal disturbances, mutagenic, affects the food chain.

Cadmium: Highly toxic, causes 'itai-itai' disease-a painful rheumatic condition, affects the cardiovascular system, gastrointestinal upsets and hypertension.

Lead: Causes plumbism-tiredness, lassitudes, abdominal discomfort, irritability, anaemia, bio-accumulation, impaired neurological and motor development and damage to kidneys.

Copper: Liver damage, mucosal irritation, renal damage and depression, restricts the growth of aquatic plants.

3.5. Pesticides

Pesticides: Affects the central nervous system, have found their way into the food chain.

4. Emerging water problems

The per capita availability of water is declining day by day due to rapidly escalating human population. The pollution of the existing water resources due to domestic, industrial and agricultural effluents across the globe is further restraining the availability of utilizable water resources. The situation in India is alarming. It accounts for approximate 25 of the world's geographical area and 4% of its fresh water but bit has to support 17% of the world's population and 15% of its livestock, indicating a total disparity between our water resources and the population to be supported (Roy and Rao, 2007).

According to the international norms the per capita availability of water less than 1700m^3 puts a country in the water stressed category and if it is less than 1000m^3 per capita then the country is categorized as water scarce (Kumar et al., 2005). In India the per capita availability of fresh water, which was 5,177m^3 in 1951 and 1,869m^3 in 2001 is likely to reduce to 1,341m^3 and 1,140m^3 by the year 2025 and 2050 respectively, thus forecasting a water emergency in the country (Roy and Rao, 2007).
Water scarcity is possible to pose the greatest challenge in the country. Moreover, the water quality report of (CPCB, 2009) clearly indicates the continuous deterioration of water quality of various water bodies in the country. Hence, considering the importance of water for our survival, it's continuously degrading quality and its scarcity in the years to come, there is an urgent need to develop comprehensive strategies for effective assessment, management and conservation of water resources in India.

5. Water Quality Assessment- The conventional Method Approach

It goes beyond doubt that the conservation and management of our water resources are the major challenge for the developing world, especially for a country like India which traditionally has an agriculture based economy and its water resources from the backbone of that economy. It is therefore, essential to conduct comprehensive water quality monitoring programs to get an integrated assessment of physical, chemical and biological characteristics of the water bodies in order to safeguard human health, environment and above all to preserve our valuable water resources.

The water quality management in India is accomplished under the provision of water (Prevention and Control of Pollution Act, 1974). The basic objectives of this Act are to maintain and restore the wholesomeness of national aquatic resources by India is conducted by the Central Pollution Control Board supervised by the Ministry of Environment and Forests at 1700 stations, under three-tier programmes namely, Global Environment Monitoring System, Monitoring of Indian National Aquatic Resources and Yamuna Action Plan (CPCB 2008). Due to limited financial resources, the government water quality monitoring agencies in India agencies in India are unable to monitor all the water bodies in the water bodies in the country throughout the year (CPCB, 2009). Monitoring of water quality in the inland water quality monitoring programme of the CPCB, involves measurements of the basic parameters only (such as pH, bio-chemical oxygen demand (BOD), dissolved oxygen (DO), temperature, chemical oxygen demand (COD), nitrite, nitrate, ammonium nitrogen, total and faecal coli form). According to (CPCB, 2008), limited numbers of organic pollution related parameters are monitored monthly or quarterly whereas major cation, anions, other inorganic ions and micro pollutants (Toxic Metals & POP's) are analyzed once in a year to keep a track of water quality over a large period of time.

In India the water quality of inland water bodies like the river, lakes and ponds is assessed to establish their water quality status and pollution level (CPCB, 2009). For this, predominantly the convectional water quality assessment methods have been commonly used. The current techniques usually used in the country for monitoring and assessing the quality of water bodies involves in situ measurement and/or the collection of water, samples for subsequent laboratory analysis so as to retrieve the chemical, physical and biological characteristics of water that help in assessing its quality. The use of recent advanced technical tools like the remote sensing and geographical information system is however limited. While the conventional methods give accurate information about the quality of water at the geographically specific station in the water bodies, yet these results are not very helpful in providing a complete picture of the quality of water, of the whole water body. Numerous researches done on the assessment of the quality of water using the recent advanced techniques like the remote sensing in integration with Geographical Information System bring to light the limitations associated with conventional methods.

Conventional water quality assessment method is costly and time consuming as it involves travelling, sampling and laboratory analysis. It does not give a complete i.e., (Spatial and Temporal) overview of water quality trends of the water bodies (Sugumaran, Clayton, Ecker, Stigliani, Gimond and Green, 2005; Weiqui et al., 2008). Additionally, the conventional water sampling method does not provide water quality data for every location in the water body (Sugumaran et al., 2005).

Monitoring of water bodies using the conventional method requires time and other resources. Therefore it is difficult to monitor the water bodies constantly throughout the year. Ritchie and Copper (2001) state that apart from being costly, a major limitation of this method is that it does not provide spatial as well as temporal representation of water quality trends required for the assessment and management of water quality of the various water bodies across the landscape. Besides this the usefulness of the data generated by the conventional method may be in question due to insufficient quality control and quality assurance protocols like the extended holding times prior the analysis and use of non-standardized methods for analysis of the water samples (Glasgow, Burkholdera, Reeda, Lewitusb and Kleinmana, 2004).

Due to these limitations, the conventional water quality monitoring method fails in monitoring and assessing water quality of the entire water body thus becomes a barrier in monitoring water bodies and water quality forecasting. Resultantly, the absence of accurate and relevant information on water bodies further affects the water resource management decisions and mitigation strategies.

5.1 Water Quality Assessment- The Remote Sensing and GIS perspective

Taking the Indian Scenario into consideration, managing our water resources is a major challenge for the country. According to Gupta and Deshpande (2004) in view of the invasive and extensive effects of water management decision on our economy, society and the overall environment; relevant, accurate and timely information is a pre-requisite for its strategic management. Kumar et al. (2005) mention that for the complete assessment of river water, management and restoration of our water resources, temporal and spatial data of the whole water body and more importantly a computer database to store, analyze and manipulate the collected data is required. Kumar et al. (2005) further state that the recent advanced techniques such as the Remote Sensing (RS) and Geographical Information System (GIS) in judicious combination with the conventional in situ measurements are crucial for monitoring and managing the water resources of our country.

Over the last 30 years satellite remote sensing and Geographical Information System techniques have been internationally exploited to gather information needed to monitor various water bodies across the world. The RS tool allows continuous surveillance of the water bodies helpful in fast detection of changes and trends in the key indicators of water quality (Glasgow et al., 2004). Remote sensing has already proven its capability to provide information on natural resources such crop pattern, land use, land cover, forests, rivers, on a regular basis. In our country this technology has been successfully used in varied disciplines such as flood mapping and management, water treatment, drought monitoring, irrigation performance evaluation etc. (Roy and Rao, 2007).

According to Glasgowa et al., (2004) in addition to satellite technology, the contributions of advancement in computer technologies have had a profound impact on the science of water quality monitoring. Computers are able to store, process and analyses the large sets of data generated by most of the Remote Sensing (RS) projects. The use of decision support system like the Geographical Information System (GIS) provides as efficient tool for storing, manipulating and analysis data (Huang and Xia, 2001). This allows for unmatched monitoring capability to strengthen insights in designing mitigation mitigation and management strategies for water quality and water quantity. Thus a GIS helps in enhancing the contributions of water quality modelling to practical water quality forecasting (Yang, Merry and Sykes, 1996), which is essential for sustainable water resources management. Due to the advanced functionality and interoperability of the available RS and GIS techniques, not only their use in water quality monitoring and management will grow but also most of the future water quality models will be the ones with the integration of RS and GIS techniques (Han, 2009).

Many researchers have used RS and GIS tools for water quality assessment and have shown many positive results. Glasgow et al., (2004) reported that with the improvement and advancements in sensor technologies real time remote monitoring will prove to be an important tool in assessing water quality. Sugumaran et al., (2005) while working on the use of hyper spectral RS and GIS tools to assess the water quality in coastal areas and shallow inland lakes of Iowa, U.S.A., reported that the tools showed many positive results and that remote sensing was useful in monitoring water quality. Sugumaran et al., (2005) also reported that the integration of RS and GIS along with in situ water sampling and analysis can simplify and accelerate the procedure for water quality assessment with an acceptable degree of accuracy.

Realising the importance of RS and GIS , in being effective tools for monitoring water quality and also that GIS could be a powerful tool in developing solutions for water related problems like assessment of water quality, determining availability of water , managing water resources regionally. Asadil, Padmaja, Vuppala and Reddy (2007) used RS and GIS along with field studies for the estimation of land use changes on the quality of groundwater in zone-V under the Municipal Corporation of Hyderabad (Andhra Pradesh, India) and reported that the integrated use of RS and GIS was very useful in evaluating and presenting various water quality parameters and also in evaluating and quantifying the impacts of land use changes in the quality of groundwater.

Hadjimitsis, Toulios and Clayton (2010) studied the potential of using satellite remote sensing for the qualitative evaluation of water quality in inland water bodies in Cyprus and concluded that satellite remote sensing was an effective tool for monitoring and quantitatively assessing the water quality in inland water bodies including spatial, temporal water quality variations and to assess the trophic state of the water bodies.

As evident from the above examples numerous national and international studies have suggested that the integrated use of RS and GIS for the assessment of water quality is a superior method as compared with the convectional water quality assessment method. Integrated RS and GIS also provide a suitable alternative to the convectional approach. It is evident from the literature that the RS and GIS techniques are playing a rapidly increasing role in the field of water resource management.

6. Conclusion and Recommendations

It has long been established that the use of RS and GIS is a resource saving (cost effective), time saving (quick) and more accurate method for water quality monitoring. The integrated use of these techniques could also help in addressing many of the limitations associated with the conventional method. Thus it can be concluded that the use of RS and GIS for water quality assessment especially for a geographically large country like India with vast water resources and limited financial assets, could open new and unmatched dimensions in monitoring capabilities of our water resources. It would enable the concerned water regulatory agencies in effective and efficient water quality predictions and in taking prompt and consistent water management decisions for the conservation of the available water resources in the country.

A better co-ordinated approach is recommended between water quality monitoring agencies (e.g. CPCB and Water Quality Assessment Authority) and Indian RS and GIS institutes. This will help in executing advanced water quality assessment efforts using latest technology. It is hoped that the integration will further enhance and speed up the various aspects of water resource management such as:

- Water quality assessment,
- Faster and accurate identification of pollution source,
- Location of hot spots of poor water quality on a geographic basis,
- Formulation of mitigation policies and implementation and,
- Feedback on the outcome of the water resource projects.

In the future, with continuous improvements in Indian space technologies, the new series of satellites with improved spatial, spectral and temporal resolution will provide more and better data services . This will help the water resource manager in better understanding of water quality monitoring and subsequently developing management programs and action plans to ensure that water quality is protected.

References:

Asadi , S.S ., Vuppala , P. ,Reddy, M.A., (2007) . Remote Sensing and GIS techniques for evaluation of ground water Quality in Municipal corporation of Hyderabad (zone-V), India. International Journal of Environment Research and Public Health. 4(1), 45-52.

Cherry, K.A., Shepherd, M., Withers, P.J.A., & Mooney, S.J., (2008). Assessing the effectiveness of action to mitigate nutrient loss from agriculture: a review of methods. Science of the Total Environment. 406, 1-23.

CPCB (2008). Status of water quality in India. Central Pollution Control Board, New Delhi, India.

Glasgow, H.B., Burkholdera, J.M., Reed, R.E., Lewitus & A.J., Kleinman , J.E., (2004). Real time remote monitoring of water quality: A review of current applications, and advancements in sensor, telemetry and computing technologies. Journal of Experimental Marine biology and Ecology. 300, 409-448.

Gupta, S.K., Deshpande, R.D. (2004). Water for India in 2050: First order assessment of available options. Current Science. 86 (9), 1216-1224.

Hadjimitisis, D.G., Hadjimitisis, M.G., Toulios. L., and Clayton, C. (2010). Use of space technology for assisting water quality assessment and monitoring of inland water bodies. Physics and Chemistry of the Earth. 35, 115-120.

Han, L. (2009). Applying Geographic Information techniques to study water resources for the next 20 years, Universities Council on Water Resources. Journal of Contemporary Water Research and Education. 142, 25-27.

Huang, G.H. and Xia, J,. (2001). Barriers to sustainable water quality management. Journal of Environmental Management. 61, 1-23.

Khaiwal, R., Ammena Meenakshi, Monica, Rani, Kaushik, A., (1999). Seasonal variations in Physico-chemical characteristics of River Yamuna in Haryana and its ecological best designated use (online) (23rd Sept, 2010). https://uhra.herts,ac.uk/dspace/bitstream/2299/2044/1/902171.pdf

Kumar, R., Singh, R.D., Sharma, D., (2005). Water recourses of India. Current Science 89 (5). 794-811.

Maheshwari, A., Sharma, M., Sharma, D., (2011). Hydro Chemical Analysis of Surface and Ground Water Quality of Yamuna River at Agra, India, Journal of Materials and Environment Science. 2 (4), 373-378.

Mitra, A., Gupta, S.K., (1999). Effect of sewage water irrigation on essential plant nutrient and pollutant element status in a vegetable growing area around Calcutta. Indian Journal of Society and Soil Science. 2 (4), 373-378.

National Water Policy (2002) National Water Policy, Ministry of Water Resources, Government of India. (23rd Sept, 2010) http://wrmin.nic.in/writereaddata/linkimages/nwp20025617515534.pdf

Ouyang., W., Wang, X., Hao, F., and Srinivasan, R., (2009). Temporal-Spatial dynamics of variation on non-point source nutrient pollution. Ecological Modeling. 220, 2702-2713.

Ritchie, J.C., and Cooper, C.M., (2001). Remote sensing techniques for determining water quality: applications to TMLDs. In TMDL Science Issues Conference, Water Environment Federation, Alexandria. VA, 367-374.

Roy, P.S., and Rao, V.V., (2007). Remote Sensing and GIS- Water Management. Indo-US Workshop on Innovative E-technologies for Distance Education and Extension and Extension/Outreach for Efficient water Management, March 5-9, 2007, ICRISAT, Hydrabad, Andhra Pradesh, India.

Shafique, N.A., Fulk, F.A., Autrrey, B.C., Flotemersch, J.E., (2003). Hyper spectral Remote sensing of water quality parameters for large rivers in the Ohio River Basin. First Interagency Conference on Research in the Watersheds, BENSON, AZ, October 27-30, 2003, USDA Agricultural Research Service, Washington, DC.

Srinivsan, J.T., and Reddy, V.R., (2009). Impact of irrigation water quality on human health: A case study in India. Ecological Economics. 68, 2800-2807.

Suthar, S., Nema, A.K., Chadukdhara, M., Gupta, S.K., (2009). Assessment of metals in water and sediments of Hindon River, India: Impact of industrial and urban discharges, Journal of Hazardous Materials 171, 1088-1095.

Sugumaran, R., Clayton, M., Ecker, M., Stigliani, B., Gimond, M., Green, N., (2005). Hyper spectral Remote Sensing and Geographical Information Systems Tools to Assess Water Quality Areas and Shallow Inland Lake, University of Northern Iowa and NASA Kennedy Space Center. Iowa Space Grant (Cooperative) Final Technical Report. 1-35.

Vega, M., Pardo, R., Barrado, E., and Debaan, L., (1998). Assessment of seasonal and polluting effects on the quality of river water by exploratory data analysis, Wat. Res. 32 (12), 3581-3592.

Weiqi, H.E., Chen, S., Xuehua, L., Chen, J., (2008). Water quality monitoring in a slightly polluted inland water body through remote sensing-case study of Guanting Reservoir in Beijing, China, Frontiers of Environmental Science and Engineering China 2 (2), 163-171.

Ward A.D.. and Elliot W.J., (1995). In Environmental Hydrology. ed. A.D. Ward and W.J. Elliot, pp. 1. CRC Press, Boca Raton.

Yang, M.D., Merry, C.J., Sykes, R.M., (1996). Adaptive short-term water quality forecasts using remote sensing and GIS, Proceedings of the AWRA Annual Symposium on GIS and Water Resources [Eds.: C.A. Hallam, J.M. Salisbury, K.J. Lanfear, and W.A. Battaglin], 22-26 September, Ft. Lauderdale, Florida, 109-118.

Yoo, K.H., Park, H., (2000). A Development of the Integrated Water Quality Management System using GIS for a Small Watershed. The 4th International Conferences on Hydro-Science and Engineering, Korea Advanced Institute of Science and Technology (KAIST), Seoul, Korea, September, 2000.