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Environmental Science and Remote Sensing Applications in Hydrological Studies

R KUMAR[1,*], P R PUJARI[1], P CHAUHAN[2], S P AGARWAL[2], S K JAIN[3], S JAIN[3], L ELANGO[4], P R MUDULI[5], C PADMAKAR[1], L DESHPANDE[1], A KAPLEY[1], R VIJAY[1], S DHYANI[1] and P VERMA[1]
[1]*CSIR-National Environmental Engineering Research Institute, Nehru Marg, Nagpur, India*
[2]*Indian Institute of Remote Sensing, Dehradun, India*
[3]*National Institute of Hydrology, Roorkee, India*
[4]*Department of Geology, Anna University, Chennai, India*
[5]*Chilika Lake Development Authority, Chilika, India*

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The present review deals with some of the works of Environmental Science and Remote sensing in the Hydrological applications. The results are categorised Institute wise with the Principal workers being identified.

Keywords: Geogenic Contaminants; Water Quality; In-situ Treatment; Satellite Data

Introduction

The water bodies globally are often under stress from geogenic and anthropogenic stresses. The increasing population accompanied by the increasing urbanization has put lot of stress on the quality of water bodies. As the water bodies provide very important eco system services, it is necessary that they are to be protected. There are various quality issues with the water quality, which require solutions which are site specific and people centric. The issues range from geogenic contaminants, namely arsenic and fluoride in groundwater to the poor quality of surface water bodies like streams and lakes in terms of very high BOD and COD in the urban settings. Restoration of the water quality is being attempted by both in-situ and ex-situ approach. The use of Remote Sensing in delineating Environmental Management Plan of water bodies has emerged as a very popular tool. The efforts are made by different Institutes in India to provide sustainable solutions. The Institutes have been working in individual capacity as well as joining hands when multi Institutional and Multi-disciplinary approach is required to address the issues. The present review discusses the work carried out by different R & D Institutes and Academic Departments. The work shared by the lead researchers is shared. If any work in this period is missed, it is inadvertent.

Studies at CSIR-National Environmental Engineering Research Institute

Studies on geogenic contaminants namely Fluoride and Arsenic are being carried out at CSIR-NEERI. The studies are focussed on the assessment of fluoride and arsenic in groundwater quality and adopting suitable mitigation strategies. The high fluoride in the groundwater sources in the Chindwada district has been a cause of concern since it has led to both dental and skeletal fluorosis. High fluoride concentration exceeding the permissible limit (1.5 mg/L) is reported in many villages in the District by Central Ground Water Board (CGWB) in 2013. The presence of high fluoride in the groundwater was attributed to the granitic formations which underlie the top Basalts in the District. Accordingly, the PHED of Madhya Pradesh shifted to sinking of large diameter shallow wells to provide drinking water with fluoride within the permissible limit. CSIR-NEERI and CSIR-NGRI worked jointly in the 12th plan (Year 2012-2017) for

*Author for Correspondence: E-mail: r_kumar@neeri.res.in

mitigation of fluoride in the ShivlalDhana village in Chindwada district which has high fluoride concentration (3.0-5.6 mg/L). Detailed studies were undertaken wherein Conductivity and Thermal logging was carried out in a Mark-II hand pump with high fluoride concentration and it was observed that the fluoride bearing granitic rocks were at a depth of 55 m and were overlain by Basalts. Subsequently, a roof top rainwater harvesting system was installed and the harvested water was injected to the sub-surface by two recharge shafts. The recharge shaft was designed to accommodate the peak rainfall in 15 minutes. A post-project monitoring was carried out on a monthly basis and it was observed that the fluoride concentration reduced to less than 1 mg/L from the level 4.0 mg/L which was observed before the implementation of recharge experiment.

Study on arsenic contamination in ground water of Chowki Block of Rajnandgaon, Chhattissgarh was carried out at CSIR-NEERI by analysing ground water samples from 813 sources. It was observed that 45 ground water samples in 11 villages had arsenic concentration above 50 µg/L. The highest concentration (1890 µg/L) was observed at the Koudikasa village. There were 129 sources which contained arsenic in the range of 10 µg/L to 48 µg/L. There were 122 samples in which arsenic concentrations ranged between 2 µg/L and 9 µg/L. Hence, technological options for providing arsenic free water and recommendations for future course of action were delineated.

A rapid hydride generation – inductively coupled plasma (HG-ICP) spectrometric method has been developed which can estimate arsenic in drinking water samples within 30 seconds. The detection limit for arsenic by this method is 2.0 µg/L.

Coagulation Flocculation studies were conducted for arsenic removal on water samples collected from arsenic affected sources in West Bengal. Extensive treatability studies have shown that a dose of 3.0 mg/L of chlorine (for pre-chlorination) followed by 50 mg/L of ferric solution was able to bring down the arsenic level in treated water below 25 µg/L which is less than the then permissible limit of 50 µg/L prescribed by BIS (IS 10500: 2012).

Adsorption studies carried out for removal of arsenic using bauxite were found to bring down the arsenic level in ground water samples of West Bengal to less than 25 µg/L.

A cost effective clariflocculation process was developed and was designed for removal of arsenic which could suffice the need of a family of six persons.

A sustainable remediation process for mitigation of arsenic was developed based on use of iron for removal of arsenic and filtration through sand bed to produce arsenic safe water at community level. Chemo-dearsenification using Fenton's reagent and iron salts was developed and successfully demonstrated in arsenic affected area of Kaudikasa village in Rajnandgaon district of Chhattisgarh state. This technology is very useful at household level. Both the technologies are capable of removing arsenic to less than 10 µg/L which is the WHO guideline value as well as BIS acceptable limit for arsenic in drinking water.

Keeping in view the need for arsenic detection kit, CSIR-NEERI has developed a prototype kit, t which is capable of detecting arsenic concentration as low as 0.01 mg/L, the WHO guideline value as also BIS acceptable limit for arsenic in drinking water and the Know-how of the kit was transferred to an Entrepreneur.

CSIR-NEERI has developed IN-Situ treatment system and it uses natural attenuation principle with engineered tools to treat sewage drain water as it flows in the nallahs. The treatment systemis called RENEU (REstoration of Nallahs with Ecological Units). This is one of the unique technologies developed by NEERI, which uses mostly natural and nature based processes to treat the water. The process can attract widespread recognition for both the funding and implementation agency after successful demonstration at key locations of discharges near rivers and lakes. The treatment process is installed in such a way that the drain gets transformed into a public space and attracts visibility of people due to its natural appearance. It is found that the system can achieve nallah wastewater treatment without the use of conventional STPs, as the technology employs natural systems and relies on flowing water channel (already present in nallahs), no major civil construction is required. Civil construction is the major cause of delays and cost escalations of any project thus its non-requirement

would make any technology more attractive economically. The nallah cleanup technology does not require any electricity for running the operation. However, pumps will be used to remove sludge build up at regular intervals. The treatment system leads to minimum 40% reduction in COD and reduces BOD to a level of <30 mg/L. The treatment system is demonstrated at the Nallas at Prayagraj during the Mahakumbh.

CSIR-NEERI has been working on building nature-based resistance to hydro-meteorological hazards. In this connection, the ecosystem services of mangroves remain at the center of discussion considering their exceptional ability to survive in the fragile coastal environment, while providing tremendous services such as acting as buffers and reducing salinity ingress, storm surge control, sediment retention, etc. The study on understanding the role of mangroves at Bhitarkanika in Odisha and predicting their plausible alternate scenarios is being carried out in multilateral project funded by Asia Pacific Network on Climate Change. Bhitarkanika is the most diverse mangrove forest of India and it is spread over 35 km. along the coast of Bay of Bengal. The study is focused on assessing the Ecosystem Services provided by these estuary mangrove forests and how drivers of loss will also affect the flow of ecosystem services especially disrupting ecological balance in not so far future 2020.

Remote Sensing Analysis is being used in Hydrological studies at NEERI to delineate Environmental Management Plan (EMP). It has been effectively used in preparing facilitate EMP for the Sambhar lake in Rajasthan. The changes in the Sambhar Lake, one of the major Ramsar sites have been studied by Remote Sensing analysis. The satellite images of 1976, 1981, 1997, 2013 and 2019 have been considered for landuse land cover analysis of the study area. It is observed that encroachment is taking place in waterbody and the area of the waterbody is decreasing drastically. Algal growth, expansion of saltpans are coming under the periphery of the lake. Construction of the check dams, anicuts in the catchment of the lake is responsible for the reduction of the runoff into the lake that is the serious reason for areal reduction of the lake. In this situation conservation of Sambhar lake is necessary to protect the ecological balance and effective management of potential water resources.

Studies at the Chilika Development Authority (CDA), Odisha

The CDA has been working on the environmental status of the Chilikalakeand research works carried out in the last 4 years have been published in reputed peer reviewed international journals. The scientific data are also made public through health report card in local language. The health report card of an ecosystem is an effective tool to communicate the complex volume of scientific data and information into a simple communicable format which is comprehended by a wide audience including the local communities, policy makers, and the stakeholders. The first report card was prepared for 2012 in collaboration with National Centre for sustainable Coastal Management (NCSCM, Chennai, MoEF, Govt of India) and United Nations Environment programme (UNEP/GEF) with partnership of Application Network from the University of Maryland Centre for Environmental Science. Subsequently health report for Chilika were prepared for 2014, 2016 and 2017-18. The health report card is based on ten (10 nos) indicators, which are organized in to three main indices i.e. water quality, fisheries, and biodiversity. For water quality indices (i) water clarity, (ii) DO (iii) total chlorophyll; for biodiversity indices (i) bird (ii) dolphin (iii) benthic faunal diversity (iv) phytoplankton diversity and for fisheries indices (i) total catch (ii) size (iii) diversity are taken in to account.

The environmental parameters such as dissolved oxygen (DO), biochemical oxygen demand (BOD), pH, ammonia (NH3) are measured and the results arecompared with the thresholds prescribed by Central pollution control board (CPCB), New Delhi for propagation of wild life and fisheries. Besides, physicochemical parameters such as temperature of air, water, salinity, depth , transparency, Oxidation Reduction Potential (ORP), Chlorophyll-a, nutrients such as nitrate, nitrite, phosphate, silicate, ammonia, total nitrogen, total phosphorous, organic nitrogen and phosphorous, sediment quality parameters are also studied on monthly basis from 33 fixed locations covering the entire Chilika lagoon. As part of the monitoring program, several biological parameters are also studied such as; biomass and species diversity of phytoplankton, zooplankton, benthos; fish species and

stock assessment etc.

In order to keep a record on the nutrient flux from the river, monitoring (every 10 days interval) is carried out on 13 major rivers which serve as inlet to the lake. It is observed that the load of nitrogen (N) and phosphorous (P) significantly alters the nutrient biogeochemistry of the Chilika Lake influencing the productivity and biodiversity of the Chilika. Apart from nutrient from rivers and sea, nutrient uptake rate has been studied by the CDA in collaboration with the Physical Research Laboratory (PRL). To quantify the same, the rates of dissolved inorganic N (DIN) uptake and N2 fixation along with N isotopic composition of particulate organic matter (15N-POM) were derived for Chilikanlake.

The CDA has also studied the level of petroleum hydrocarbon (PHC) in the surface water and in the sediment of the lagoon to examine the impact of the motorised boats in the lagoon. The results showed the level of PHC were in the safe limit. However, the accumulation of the same for a longer period could be harmful which warranted a survey for accumulation level in fish. CDA has been studying the same for some selected commercially important fishes and shell fishes found in the lagoon.

It need to be mentioned that there are 52 rivers and rivulets which drain into the Chilika and can be potential sources of transporting contaminants to the lake. Hence, metal accumulation and assessment of pesticide level isbeing carried out by CDA for some selected commercially important fishes and shell fishes of Chilika.

The fresh, brackish and saline water in Chilika in different sectors and seasons is the ideal environment which supports large variety of fishes and shellfishes in the lagoon and supports approximately 2 lakh people CDA has initiated the study of nutrient Profiling of Chilika fishes and shell fishes of Chilika through which the protein, fat, mineral, fatty acid, amino acid and vitamins content are examined. Information on the food value would help moving market value chain and would provide better income for fishery sector.

Remote Sensing is being used by the CDA to study the dynamics in the coastal ecosystems. The CDA in collaboration with NRSA used the Landsat data for 30 years for the period 1988 to 2017 and observed greening trend in the northern sector of the ChilikaLake. The robust trend of the multi spectral indices (NDVI and EVI) indicate the positive trend.

Studies at the Indian Institute of Remote Sensing (IIRS): IIRS Contribution

The IIRS is contributing significantly in the field of water resources assessment and monitoring in North West Himalayan (NWH) river basins, water quality assessment, irrigation water requirement and drought estimation, flood early warning system for entire NWH, flood prone area assessment, polar remote sensing in parts of Antarctica and Svalbard, Arctic, experiential rainfall simulator based study for understanding of hill slope hydrology processes, urban flood and potable water distribution network modelling, urban micro-climate modelling and extensive field hydro-meteorological instrumentation mainly in NWH and other parts of India and Antarctica.

These themes have used remote sensing data from Indian and other freely available optical, microwave and thermal sensors to map and monitor various hydrological and land surface parameters such as rainfall, evapotranspiration (ET), water level, runoff, discharge, top surface soil moisture (SM), snow cover, glacier radar zones, glacier surface velocity, snow density, snow depth, snow wetness, snow water equivalent (SWE), water turbidity, and terrestrial water storage. The water level for major reservoirs, lakes and wide rivers was estimated using SARAL-Altika, Jason-3 and Sentinel-3A/3B altimeters with high accuracy. The SAR based glacier facies and glacier lakes were mapped for major glaciers of NWH and Sikkim. Glacier surface velocity is estimated using optical image based feature tracking and SAR based DInSAR methods for all major glaciers of Himalaya, with velocity ranging from 5 to 130 m/year. The SAR based glacier facies and velocity map of Svalbard and Antarctica were generated. The polarimetry SAR based snow depth and SWE is estimated using TANDEM-x data for parts of Beas basin. The long term snow cover of entire High Mountain Asia region, traditionally know as Hindu Kush Himalayan region is operationally mapped using Indian and other satellite data and data products. The change in snow water equivalent (ΔSWE) in NWH region is estimated using Indian scatterometer,

Scatsat-1 data.

The week crop water requirement and irrigation water requirement of entire country has been estimated using remote sensing data from Indian Geostationary satellites (INSAT). Along with this, high-resolution ET maps are also generated for selected command areas in the country using freely available remote sensing data of Landsat series. Assessment of meteorological droughts in Bundelkhand region, Marathwada region has been done using geo-spatial approach. The impact of meteorological droughts on agricultural systems and their inter-relationship has been evaluated using remote sensing data/products. The performances of these irrigation projects is evaluated using the remote sensing derived irrigation water requirements.

The water quality of ChilikaLake has been mapped using multispectral and hyper spectral remote sensing datasets. High-resolution Hyperspectral data from AVIRIS-NG mission was acquired over this water body and parts of Ganag River for assessment of water quality parameters from remote sensing, encouraging results are achieved in this exercise. To calibrate and validate these RS based hydrological products and to provide point based hydro-meteorological data, IIRS installed 27 AWS, 10 snow depth sensors, two snow pack analysers, one SWE gauge, 4 snow precipitation gauge, three water level recorders in NWH and other parts of India and Antarctica.

The spatial coverage in RS data is excellent, but temporal coverage is not as high as the variations in some of the hydrological variables such as rainfall, snow, ET, SM and SWE, which can have diurnal variations. Therefore, process based meteorological, hydrological and hydrodynamic models have been carried out to better understand and model the hydrological cycle and estimate the water balance. In one of such studies, the water balance of all Indian River basin was estimated from 1979 to 2015 at 0.25 km grid scale and impact of land use land cover change from 1985, 1995 and 2005 on hydrology was quantified. The surface water potential assessed using this approach aggress closely with CWC's estimates. The impact of future climatic scenarios in terms of hydrological extremes (dry/wet) are evaluated using modeling approach. Similarly, in case of flood early warning in NWH, a high resolution Weather Research and Forecasting (WRF) model at 3-km resolution is being used to forecast 72 hour precipitation and other surface metrological variable, and these variable are using in hydrological modelling system (HMS) to simulate flood hydrograph for major river basins of NWH, and finally flood inundation modelling is executed using 1-Dimensional (ID) hydro dynamic (HD) and digital elevation models in critical reaches of NWH. The major flood events forecasted in advance are 05-08 August flood of Dharampur, Mandi, HP, 29 June-01 July 2016 floods of Pithoragarh, 05-08 August 2016 floods of HP and 21-23 Sep. 2018 flood of Beas and upper Chenab basins. The glacier lake outburst flood modelling has been done for few major vulnerable glaciers of NWH, Sikkim and Bhutan. The full hydrological and flood mapping study was also done using combination of RS data and hydrological/HD models for 2018 Kerala floods. Flood prone area have been estimated for Beas basin using combination of topographical and HD models.

In 2016, IIRS participated for the first time in 36th Indian Scientific Expedition to Antarctica (ISEA-36) as summer science team member, and validated the remote sensing based ice sheet and glacier products, which were generated from of a high resolution image album using cartosat-2 data for parts of Antarctica, South of Maitri station. During ISEA-36, IIRS and GSI established a long term ice sheet monitoring site covering a stretch of 350 km, having 45 stakes, and three major stake farms for validation of RS based ice sheet velocity and elevation change products. This stretch was monitored by joint teams of GSI and IIRS during ISEA-37 and ISEA-38 as well. During ISEA-37, IIRS installed one digital water level recorder at Priyadarshini Lake for water balance study of the lake. Similarly in March-April 2019, IIRS participated with GSI, SAC and JNU team to make joint field measurements in VestreBroggerbreen glacier at Ny-Alesund, Svalbard, Arctic for snow and glacier mass balance studies.

Studies at the Anna University

Dr. Elango's group in Anna University has been working on various issues of water quality from anthropogenic and geogenic sources as well as Remote Sensing in Hydrological applications. Suganthi *et al*. (2017) assessed the regions of land subsidence

in Kolkata city, India by D-InSAR technique by way of exploiting the phase difference of two temporally separated SAR data. ENVISAT images were acquired to study the temporal evolution of land subsidence in this study. SRTM and MERIS data were used to minimise the topographic and atmospheric errors. This study revealed that the over extraction of groundwater from the confined aquifer is the main cause for land subsidence in this region.

Suganthi *et al*. (2013) delineated the groundwater potential zones in the regions north of Chennai, Tamil Nadu, India by using remote sensing and GIS techniques. IRS 1C LISS III satellite images were used to prepare various thematic layers. Weighted overlay analysis was used to demarcate the groundwater potential zones. The derived groundwater potential map was overlaid with the groundwater level contour map and location of well fields for validation.

Similar study was carried out by Kanagaraj *et al*. (2018) in Vellore District, Tamil Nadu, India and Periyasamy *et al*. (2019) in Rasipuram taluk, Tamil Nadu, India.

Studies at the National Institute of Hydrology, Roorkee

The National Institute of Hydrology, with its Head Quarters at Roorkee (U.P.) and six regional centres located in different parts of the country viz. Belgaum (Karnatka), Jammu (J&K), Guwahati (Assam), Patna (Bihar), Kakinada (A.P.) and Bhopal (M.P.), has been carrying out research on various aspects of hydrology and water resources using remote sensing and GIS techniques. The main areas in which, NIH has worked and working involving remote sensing and GIS are flood studies/river migration, snow/glacier mapping and modelling, rainfall runoff modelling waterlogging and reservoir sedimentation etc.

In the period 2016-20, NIH has carried out a number of studies such as snow/glacier melt runoff modelling, glacier change studies, flood plain zoning, glacial lake outburst flood, reservoir sedimentation including impact of climate change studies. During this period, NIH has carried out various sponsored and consultancy projects in which remote sensing have been used extensively and data base have been prepared using latest satellite data. NIH has significantly contributed in capacity building for Indian and International participants and creation of Human Resource by guiding Ph.D and M.Tech students in the area of remote sensing and GIS applications.

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