THE SIGNIFICANCE OF RIVER GANGA IN ANCIENT INDIAN TRADITIONS

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ABSTRACT

The divine origin of Ganga finds mention in most ancient Indian literature. The episode of Bhagiratha Prayatna finds mention in Mahabharata's Vana Parva, Bal Kand of Ramayana, Brahmanda Purana, Padma Purana and in Bhagwat Purana. Generations after generations, this great story is retold in every Hindu household and children are inspired to make similar sacrifices to achieve great causes. Besides Ramanyan and Mahabharata, Vayu Puran, Agni Purana, Skanda Purana, Matsya Purana, Brahmanda Purana, Vishnu Purana, Devi Purana and Bhagvad Purana shed light on diverse aspects of the mighty river. The holy waters of the river Ganga play a vital role in Hindu ceremonies, in rituals of birth and initiation of marriage and death. As a Goddess, she has moved among the great celestials of Hinduism; at times the child of Brahma, the wife of Shiva, the metaphysical product of Vishnu or mother to the Vasus and to Kartikeya.

Ganga has been a cradle of human civilization since time immemorial. Many Indians depend on this great river for their physical, psychological and spiritual sustenance. Ganga is a perennial river and people have great belief in her powers of healing and regeneration. Ganga known variously as Hiranyagarbha, Amritvahini, Tripathga, Patitpavini is deeply mingled with the Indian psycheand ethos. The role of Ganga in the birth and shaping of the Indian civilization has been recorded in the Vedas and in many modern works on the river. It would be no exaggeration to say that the sacredness and purity of the river is incomparable and unparalleled. It was on the banks of this great river that many beautiful Kingdoms and towns came up. It was here that a complex, fascinating and live historical process of human interfacing was started in the dim distant past. It was on the banks of this mighty river that the Indian race discovered and nurtured its deep philosophical moorings. It can only be an irony of history that with the passage of time this mighty river is today a victim of defilement and pollution by the very human race that finds sustenance by it.

'NIRMAL, AVIRAL' GANGA: AN APPRAISAL

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ABSTRACT

The river Ganga is one of the largest rivers on earth with an annual flow of 525 BCM and a catchment of 8,61,404 sq.kms. 'Ganga water' has been held sacred for its purity and self-cleansing property since time immemorial. It sustains all civilizational needs including food security. Sadly, it is today highly polluted and depleted in flows due to uncontrolled anthropogenic interceptions facing a disaster. From Kannauj to Trighat and below Kolkata to Diamond Harbour the river water is beyond human use, and in some sections beyond use of even animals. Nearly 75 -80% of its pollution comes from the domestic sewage, and the rest from the industrial waste waters and other sources . Reportedly 1.3 billion litres of sewage, 260 million litres of industrial waters, runoff from 6 million tons of fertilizers, 9000 tons of pesticides used in agriculture as also large quantities of solid wastes are daily released to the Ganga. Out of 12410MLD of sewage generated annually in the Class I &II cities in the basin, only 3787 MLD can be treated. Most parts (71-84%) of the cities are not sewered (Source: CPCB), generating huge unestimated sewage to be discharged into the Ganga. River water pollution due to municipal sewage breeds water borne diseases. Kanpur, Allahabad, Varanasi, Kolkata and Howrah on the banks of Ganga, and Delhi, Mathura, Vrindavan, Agra, Ghaziabad Durgapur, Asansol, Bokaro along its tributaries like Yamuna and Damodar are some of the hot spots of pollution. Carcinogenic heavy metals are also reported in the river sediments and water getting access to the food chain, tissues of dolphins, crocodiles and fishes being responsible for their decline.

The health of the river, its environment and ecosystem, is solely dependent on its flow and river water quality i.e. dissolved chemical substances or pollutant load in different seasons. Its self-cleansing capacity depends on its flow and dissolved oxygen. But nearly 100 BCM of Ganga's annual flow and 42 BCM of Yamuna are utilized through construction of dams, and barrages, which have critically affected the magnitude, timing and duration of flow. This impacts wetland life, fish population and pollution assimilation capacity of the river. Hydropower projects in Uttarakhand leave vast stretches of the river dry through diversion of flow. Between Gangotri and Devaprayag 130 dams have been constructed. If all the proposed hydroelectric projects are implemented, then 47% of the total river stretch in the Bhagirathi-Alkananda basin will be adversely affected. Reportedly the dams in the upper Ganga basin and massive diversion of flow at Farakka barrage have impacted its hydrology, sedimentation and ecology negatively in the lower Ganga delta with reduction of freshwater flow and salinization of the rivers and distributaries. Further, outflows from groundwater reservoir sustain the river in nonmonsoon seasons. Its overexploitation poses additional danger. Subjected to heavy withdrawal in the upper Ganga basin, groundwater levels are steeply declining, thereby precluding base flows to the river as is the case of the Yamuna between Tajewala and Wazirabad.

The Himalayas are still tectonically unstable, rendering the hydropower dams vulnerable. Civil constructions and deforestation are all weakening the already unstable mountain slopes, and thus the source of this Great River. Sand mining, stone quarrying and civil constructions in the river banks and beds are all destroying its catchment, environment and ecology. Further, revival of the River basins interlinking Project has also renewed the debate on its grave environmental fall outs on the Ganga.

The adverse impacts of human interference are liable to be exacerbated by climate change and global warming. Glaciers, the source of Himalayan rivers are all melting due to global warming critically affecting its sustainability - aquatic life, drinking water , and all economic as also cultural and religious activities on its bank. With thermal expansion rising sea-level will inundate vast low-lying areas of the lower Ganga delta in Bangladesh and India. Parts of Sunderbans are already submerged . The mangrove forest in the Sunderbans is endangered.

Augmentation of the flow through integrated river basin management, protection of groundwater reservoir from overexploitation, and treatment of municipal and industrial wastewaters are undeniably urgent necessities for rejuvenation of the Ganga. The people of Alwar , Rajasthan have shown the way solving endemic water crisis, and reviving the dead river Arwari through traditional methods of watershed development , including soil conservation, rainwater harvesting and artificial recharge like contour bunding, terracing, check dams, tanks, wells along with crop-water planning . Environmental flow is essential for survival of rivers which helps in self-purification of the rivers, sustains aquatic life and vegetation, recharges groundwater and supports livelihoods. It is high time

The above scenario reveals that environment and ecosystem can not be addressed in isolation for rejuvenation of the River, but these are to be dealt with in their entirety through integrated river basin management with the participation of all stakeholders , all sections of the society.

ON FIELD INVESTIGATION OF SURFACE AND SUBSURFACE WATER INTERACTIONS IN THE GANGA BASIN

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ABSTRACT

Understanding the interactions of surface and subsurface water, and estimation of baseflow are critical for studying the hydrology of the Ganga basin. The literature suggests that the subsurface reservoirs (like groundwater, soil water, bank storage, and transient saturated zones) can not only sustain river flow during no-rain or no-snowmelt period by discharging their storage slowly as baseflow, a little at a time, but also have the potential to discharge a large amount of their storage in very short time as a reaction to rainfall or snowmelt input. Thus, the subsurface reservoirs affect both low-flow and high-flow dynamics of the Ganga river. To study the surface-subsurface interactions in the Ganga basin, first, automated baseflow separation methods were applied and tested on daily discharge data at few gauging sites in the basin, but the results were insufficient to draw any conclusions on surface-subsurface interactions. Next, promising field methods were identified from literature survey to study those interactions in the Ganga basin. The instruments needed for the field investigation were too costly for multiple deployments, so an economic automated interactive multi parameter recorder and water sampler was designed. The instrument can automatically measure stream/well/bank-storage water level, water temperature, air temperature and humidity, and automatically collect water samples from stream/wells for isotope and chemical tracer analysis. The attempt on instrumentation revealed that these low-cost automated field deployable instruments can enable us to overcome the limitations imposed by lack of spatially-dense and temporally-fine field data in hydrological investigation and modelling of Ganga basin.

SCIENCE BASED RBF SCHEMES FOR WATER SUPPLY AT FEW SITES IN GANGETIC ALLUVIUM

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ABSTRACT

India has a lot of potential to use Riverbank Filtration (RBF) based water supply scheme in many areas particularly, in the Indo-Gangetic-Brahmaputra alluvium areas, coastal alluvium tracks and scattered inland pockets in different states where rivers are hydraulically connected to the adjoining aquifer, and aquifers have good soil pores. With the aim to encourage the use of riverbank filtration for sustainable drinking water production, the technical, hydrogeological, water quality, site-investigation, and implementation aspects of few schemes conceived by NIH in the Ganagetc alluvium are discussed in this paper.

A STEP BY STEP PROCEDURE TO EVALUATE PERFORMANCE OF FLOOD PROTECTION SCHEMES USING SATELLITE DATA AND MATHEMATICAL MODEL – A CASE STUDY FOR A REACH IN RIVER GANGA

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ABSTRACT

The case study presented in the paper gives a detailed procedure which can be followed to evaluate performance of flood protection schemes using satellite data and mathematical model. The study evaluates the performance of flood protection work at Arjunpur and Umarpur villages in Buxor district of Bihar. Analysis of temporal satellite data can be an effective, quick and convenient method to assess the performance of flood protection schemes after its construction. Concurrently, evaluation of performance of the structures for probable floods for an intended return period can be studied by developing a mathematical model of the river flows. The model output namely the water surface profile and velocity profile enables to compute the specification of flood protection structure. The study was carried out based on analysis of temporal satellite data and flood frequency analysis of annual maximum floods. Mathematical modeling using HEC RAS was carried out to compute the water surface and velocity profile. This enabled calculation of design parameters for construction of revetments and its comparison with the adopted BIS design specification. The flood protection works was found to be effective in terms of protecting the Buxar-Koelwar Ganga (BKG) embankment on right bank of river Ganga near villages Arjunpur and Umarpur.

PROTECTION MEASURES FOR EROSION ZONE ON RIGHT BANK OF RIVER GANGA IN SAHIBGANJ BLOCK, JHARKHAND

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ABSTRACT

Ganga River Basin basin covers over 10,86,000 sq. km and ranks among the largest in the world in drainage basin area and length. Flowing across the great alluvial Indo-Gangetic plains, the Ganga is bordered by the Himalayas to the north and the Vindhya-Satpura ranges to the south. The river has two main headwaters in the Himalayas - the Bhagirathi and the Alaknanda and others for each of its other tributaries. The Bhagirathi flows from the Gangotri glacier at Gomukh and the latter from a glacier near Alkapuri.

River Ganga has a respect in heart of every Indian citizen. There is a belief that a dip in river helps in cleansing all the sins committed by an individual. However, the present situation of Holy River at some of the cities in Uttar Pradesh is really alarming; mainly near Banaras and Kanpur. There are number of industries along the bank of river that may be contributing in a large way for deteriorating the water quality. In addition, the river is braiding in the plateau leading to change in course of river resulting in damages to valuable human lives and properties and loss of agricultural lands with crops and live stock.

Government of India has taken an initiative to rejuvenate river Ganga through different measures. These measures start with identification of cause and after careful analysis lead to corrective steps towards achieving the goal. The effectual corrective actions could be evolved through an integrated approach that involves series of steps; each taking care of related aspect. The measures are required for improving water quality, identifying the area of erosion and suggesting protection measures.

In this direction, Government of Jharkhand has proposed to evolve measures against the erosion of river bank within the State territory. The aim is to develop erosion free area along the 87 km long right bank of river Ganga within the State. The work was carried out by WAPCOS and Final DPR is submitted. The work was completed through the following components:

a) Carrying out topographic and hydrographic survey for developing Longitudinal and cross sections of river as well as getting first hand information of prevailing situation
b) Identify changes in bank line and channel positions using satellite data
c) Analysis of streamflow data for homogeneity to derive design flood and mean lean flow
d) Calibration of hydrodynamic model to derive hydraulic design parameters
e) Inspection of site to get first hand information on prevailing situation at erosion locations

f) Slope stability analysis
g) Review and finalization of bank protection measures viz pitching with stone in crates, crates integrated with girders at locations with steep slope and porcupine spurs at low bank heights

The total estimated cost of the work is Rs.296.42cr for pitching using stone in crates laid over soil cushion/geobags, toe wall and apron; and geotextile filter in eleven reaches and Rs.25.20 lakhs for porcupine spurs at 21 different locations. Typical layout of bank pitching and porcupine spurs is shown in Figures 1 and 2 respectively.

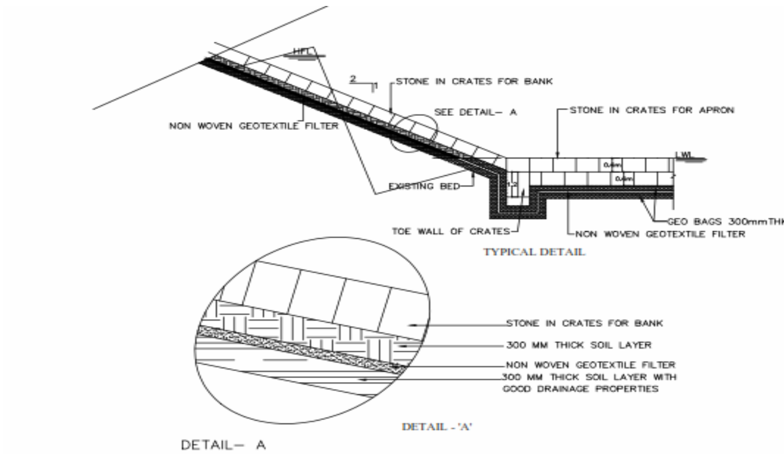

Figure 1: Arrangements of Crates along slope and apron

Figure 2: RCC Porcupine Spur

RECENT GROUNDWATER STATUS IN HARIDWAR DISTRICT, UTTARAKHAND

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ABSTRACT

Groundwater is one of the renewable resources of the earth which is mostly used in agricultural, domestic and industrial sectors and its sustainability is under threat in Indo-Gangetic basin due to the continuous depletion and deterioration of quality. One of the most important Hindu pilgrimage centre, Haridwar lies along the Ganga River where Siwalik hills forms the northern boundary and in the south of which there is sudden decrease in the altitude forming the part of alluvial Indo-Gangetic plains. In the immediate vicinity of Siwaliks, bhabhar-boulder formation occurs. The water supply to the Ganga river is dependent on the precipitation and snow from Himalayan glaciers. District Haridwar is the most densely populated district. Upper Ganga Canal passing through the district has a wide network of distributaries and minors. This makes the surface irrigation prominent in Bahadrabad, Roorkee and Narsan blocks. Khanpur and Laksar blocks which fall in the south-east part of the district, form part of Khadars of Ganga and Solani rivers. There is no canal irrigation in Bhagwanpur block.

The data of 41 hydrograph stations distributed over the whole district are analysed for the year 2015 and the depth to water level during pre-monsoon ranged from 1.96-69.30 m with an average of 10.74 m and in post-monsoon it ranged from 1.57-52.20 m with an average of 10.51 m. In Bhabhar formation depth to water level ranges from 10.91 m to 69.30 m whereas in the Gangetic alluvium it ranged from 2.50 m to 22.69 m. The distribution of water level shows that the water levels are deep in entire Bhagwanpur block. For assessing the groundwater quality, the water samples were collected from 40 sites covering the entire district. The average value of pH was measured 8 and the groundwater was slightly alkaline in nature, EC of groundwater varies from 262 to 1535 µS/cm with an average of 656 µS/cm. Ca^{++} ranged from 28-108 mg/l with an average of 62 mg/l; Mg^{++} ranged from 7-95 mg/l with an average 29 mg/l; Na^{+} ranged from 5-92 mg/l with an average 33 mg/l; K^{+} ranged from 0.5-119 mg/l with an average 33 mg/l. Ca^{2+}, Mg^{2+} are the dominant cations contributing to 67% of the total cation contribution, while Na^{+} and K^{+} contribute about 33%. All the cations are found within the permissible limit of BIS: 10500-2012. NO_3^{-} concentration ranged from 0.1- 86 mg/l with an average 16 mg/l and sample at Libraheri was found above permissible limit of 45 mg/l. HCO_3^{-} ranged from 128-494 mg/l with an average 326 mg/l. The SO_4^{--} ranged from 2.5-310 mg/l with an average 36 mg/l; Cl^{-} ranged from 4-128 mg/l with an average 29 mg/l. Among anions, HCO_3^{-} contributed 81% of the total and the other anions have a contribution of 19%. Higher HCO_3^{-} concentration is indicative of carbonate weathering and decomposition of organic matter. The higher concentrations of NO_3^{-}, Cl^{-} and SO_4^{2-} are generally due to the input from anthropogenic activities, which are local in nature.

STREAMFLOW MODELLING OF BHAGIRATHI RIVER AT GOMUKH

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ABSTRACT

The modelling of streamflow is required in many activities associated with planning and operation of the components of a water resources system. Snow melt runoff is one of the main sources of streamflow in many of Himalayan Rivers. Conceptual models to simulate the snow melt runoff such as Snowmelt Runoff Model (SRM) and Snowmelt Model (SNOWMOD) require a large quantity of data which are generally not available for most locations in India. Applications of Artificial Neural Networks (ANN) in many water resources area have proven its better performance over other traditional models such as conceptual models and black box models. This paper discusses the development of ANN models for the simulation of streamflow at Gomukh in Bhagirathi river basin. Temperature and discharge data at Gomukh were used as input to the models. Different combinations of significant lagged series of temperature and discharge data, determined from statistical parameters such as auto correlation function (ACF), partial auto correlation function (PACF) and cross correlation function (CCF), were used as input to the model. The performance of the model was evaluated using statistical criteria such as coefficient of correlation, root mean squared error (RMSE) and model efficiency. The results of the best ANN model during the calibration indicate that the all ranges of discharge values were simulated fairly well. Multiple Linear Regression (MLR) model for simulating the streamflow was developed using input vector considered for the development ANN model. The percentage error in peak flow estimation of MLR model was higher than ANN model during calibration process. The same trend was not observed during the validation of the models. It can be concluded from the results that the overall performance of ANN model was better than the MLR in simulating the streamflow.

HYDRO-GEOLOGICAL INFORMATION ON RAIN-FED SPRINGS OF MID WESTERN HIMALAYA (UTTARAKHAND)

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ABSTRACT

Since early times, the population of sub-humid regions in Mid Western Himalayan hills has their homes clustered around natural water resources primarily springs. The population settlement in hills is therefore distributed forming clusters depending on availability of springs. The springs of Mid Western Himalayan watersheds provides basis for the settlement of life at mountain around springs. These springs could be discharging too small quantity but the life depends on it in Mid Himalaya. These watersheds are rich in natural resources, provides life in this area and together water to millions at down stream through its perennial river system. Even then some times the availability of natural resources at hills goes to acute shortage in summer especially in low rainfall years. It is, therefore, important to study the existing water resources and its impacts on watershed hydrology. Study area Chandrabhaga lies in 'Mid Western Himalaya' agro-ecological region of Devprayag, Uttarakhand with area around 3.0 km2. Automated hydro meteorological data are collected. Regular (daily) spring flow measurements are taken on almost all springs that are used by the habitat of the area. Spring flow availability is evaluated along with the average ten daily low flow duration curve for the springs of the watershed. The spring flow variability is related with rainfall spring flow lag. A high variability of spring flow suggests that springs are fast responding and turning to low yield during summer. Relationship between total rainfall and total spring flow are also developed.

Although the Mid Western Himalayan watersheds are rich with perennial or non-perennial springs and provides fundamental basis for settlement as well as the existence of life. These water resources are so low discharging that most of springs fall under the lowest flow category flow between 0.82 to 6.55 m3/day and classified as sixth or seventh category of Meinzer's (1918) spring classification. Relative performance of springs by four methods viz. (1) Based on spring flow variability, (2) Based on normalized mass spring flow, (3) Based on rainfall spring flow lag and (4) Based on spring flow gradient has been estimated and presented.

In order to develop the physical models for spring flow some geomorphologic information on springs has been extracted. This includes; (1) defining the equivalent spring order for the springs (2) development of the spring-shed for the springs by assuming that the flow in the aquifer follows the flow direction paths as are on the surface and the flow in the aquifer can not cross the stream path which is normally the lineament and other lineaments present in the watershed. Further the spring shed development is subjected to; the spring shed area must follow the relationship with maximum spring flow and the spring shed area/relief must follow the relationship with maximum spring flow.

AQUIFER SYSTEMS OF THE GANGETIC PLAINS AND DELTAIC REGION

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ABSTRACT

The Gangetic Plains and Deltaic region extend from Aravali-Delhi Ridge in the West to the Bay of Bengal in the east and south-east, through the Garo-Rajmahal Gap. The northern and southern boundaries are Himalayan foothills (Siwalik Hills) in the north and the Indian Peninsular uplands like Bundelkhand- Vindhyan- Hazaribagh plateaux in the South. The plains along with the deltaic region occupies an area of about > 3,00,000 km^2. The Plains (in the east of Garo Rajmahal Gap) aligned in an east-west elongated manner, with a width ranging from 450 to 200 km. Further downstream, the plains merge with the Ganga-Brahmaputra-Megha deltaic plains covering the eastern part of West Bengal, Bangladesh and limited parts of Assam.

The aquifers in the study region forms one of the world's most important, potential and heavily exploited reservoirs of freshwater. The vast plain in the Indian part is formed by the sediments, brought predominantly from the Himalayas in the north and also from the peninsular region of India in the south, during the Quaternary Period. The sediments are redistributed by the Ganges and its left and right hand tributaries. Barring the marginal part, the aquifers are thick and potential. The area represents one of the most intensely exploited aquifer systems of the world. More than 90% of the extraction is used for irrigation, helping the country in food security. The remaining extraction is used for drinking and industrial purposes. The alluvial (locally lacustrine) and deltaic deposits comprises highly permeable aquifer system. This aquifer system has been widely studied up to the depth of 300 m below ground, though at places it goes down to 450 m or even more. The lithology represents alternate layers of sand silt and clay and their mixture at various proportions. In the northern part of the Plains, bordering Nepal, Pre-Plieistocene deposits of Siwalik may figure within the investigated depth, however the southern extension of the Siwaliks is yet to be fully understood and ascertained. Significant lithologic variation as observed within the sediments, has given rise to multiple aquifer system is local and sub-regional scale. Within the depth of 300 m below ground, 2-4 aquifers are encountered. At shallow aquifers ground water occurs under unconfined condition, where as at depth under semi-confined to confined condition. In the deltaic region the aquifer separations are more pronounced because of thick intervening clay beds which are also laterally extensive. Thus the aquifer system of the region is complex and heterogeneous with large spatial differences in groundwater recharge, permeability, storage and water chemistry. The paper addresses the aquifer characteristics in the Gangetic Plains and deltaic regions, dealing with the hydraulic properties, recharge mechanisms and paths, how they respond to abstraction, pollution (anthopogenic and geogenic).

GEOMORPHIC DIVERSITY AND RIVER STYLES IN GANGA RIVER: IMPLICATIONS FOR RIVER MANAGEMENT

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ABSTRACT

The Ganga River is a large, complex river system in India. From the Himalayan mountainous reach to the Bay of Bengal, it shows remarkable landscape heterogeneity as well as geomorphic diversity. As it provides the livelihood platform for about 500 million people of India, it is very important to understand the implications of this diversity for sustainable management of the river. The advent of satellite images has made this much easier not only to map the landforms but also to document the temporal dynamics of planform features. A systematic analysis of the Ganga River system from its source at Gangotri to Farakka has been presented based on the mapping of river channel belt and delineation of active floodplain and valley margin using remotely sensed data and limited field verification. 10 different typologies of river form have been identified using a modified River Style Framework from Gangotri to Farakka based on (a) landscape setting, (b) channel and active floodplain properties, and (c) channel planform parameters. Two river styles are identified in the steep mountainous stretch, characterized by steep valleys and bedrock channels, and 8 different styles are demarcated in the alluvial plain from Haridwar to Farakka. Each river style in the alluvial reaches has a distinctive set of morphological parameters primarily driven by the dominant fluvial process operating in that stretch such as channel instability and river dynamics, channel incision or aggradation and frequent flooding. Specific applications of the River Style Framework have been highlighted for assessment of habitat suitability, environmental flows and flood risk. It is hoped that this framework can be useful for developing a sustainable river habilitation programme to 'work with' the contemporary character and behavior of rivers.

RIVER MORPHOLOGY, FLOODS AND TRAINING OF RIVER GANGA AND ITS TWO TRIBUTARIES

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ABSTRACT

Primary objective of Ganga rejuvenation is to make the river clean and free from pollution. This can be achieved by treatment of effluents from domestic, agricultural and industrial wastes. Another way of pollution control is through the process of dilution of the waste water by ensuring enough river flow all the time so that the concentration of pollutants is within safe limit. Ganga rejuvenation is necessary also to make the river navigable which is an economic mode of transport compared to road and railways. Ganga basin (Fig.1) has a catchment area of 8,61,452 sq.km in India out of the total catchment area of 10, 86,000 sq. km. lying in China, Nepal, India and Bangladesh. Mean annual flow in the river is about 14,000 cumec and it carries sediments of about 140 million tons/year at Farakka barrage. Maximum observed flood discharge at Farakka is 75,000 cumec. Seasonal and yearly distribution of flow are extremely non-uniform (Fig.2) due to highly non-uniform rainfall in monsoon lasting for about 2-3 months in a year.

To meet the above objectives as well as the requirements for irrigation, hydro-power, flood control, domestic, & industrial uses, protection of aquatic life, navigation requirement etc., flood water must be conserved in upstream storage reservoirs in order to ensure guaranteed supply throughout the year. Thorough knowledge of river morphology, floods and river improvement/training is essential for proper planning, designing ,construction and maintenance of all river works. Author wishes to discuss these issues for Ganga (at Farakka) and two of its tributaries, namely, Kosi and Mandakini rivers.

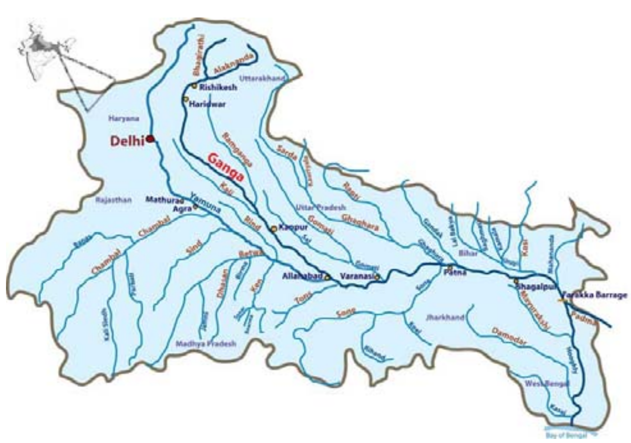

Fig.1: Showing River Ganga and its Tributaries.

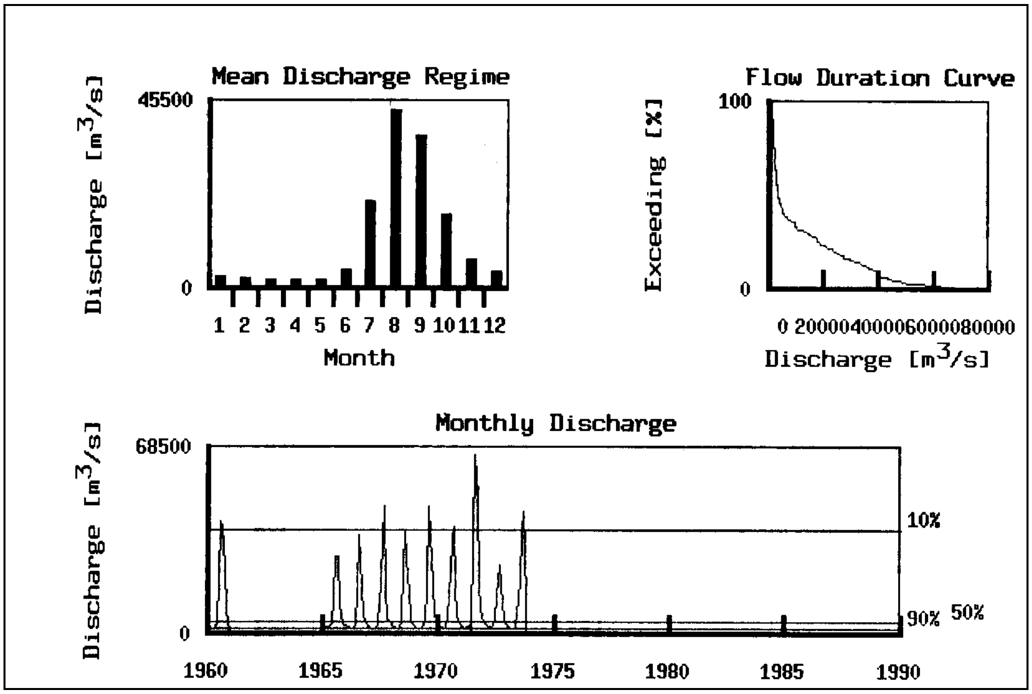

Fig.2: Distribution of mean monthly Flow and Flood Hydrographs of Ganga at Farakka

ASSESSMENT OF SEEPAGE FROM UPPER GANGA CANAL TO GROUNDWATER REGIME IN GANGA-KALI SUB-BASIN, U.P.

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ABSTRACT

The Ganga-Kali sub-basin forms a part of central Ganga basin is lying in Bulandshahar district, Uttar Pradesh, India. Varanasi Older Alluvial plain, Aligarh Older Alluvial Plain, Terrace zones and Ganga recent flood plain are the four geomorphic units and abandoned channel of Ganga river , channel scars and mean scars represent various land forms. Unlined upper Ganga canal and lower Ganga canals are irrigating the area. Seepage losses from these canals have caused water-logging problem. Assessment of seepage losses from canals and river-aquifer interaction have been analysed in a 3 layer aquifer model using visual MODFLOW software. The steady state flow simulation was carried out assuming water level configuration of June 1986 and transient condition was tested up to May 1995. The calibration was achieved through comparison of water levels at 20 observation wells. The seepage losses from canals are worked out as 62 mcm/year whereas the recharge due to rainfall is about 110 mcm/year. The groundwater balance shows that half of seepage losses from the canals leave the basin as groundwater effluence to Ganga River, Chioyya and Nim Rivers.

GROUNDWATER FLOW MODELLING OF THE GANGA – MAHAWA SUB-BASIN IN MORADABAD AND BADAUN DISTRICTS, UTTAR PRADESH

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ABSTRACT

The Ganga–Mahawa sub-basin covering an area of 1280 sq.km forms the western part of the Central Ganga Plain in the Moradabad and Badaun districts of western Uttar Pradesh. The Bundelkhand granite forms the basement complex, overlain unconformably by the upper Vindhyan sequence, which is further overlain by the Neogene (Middle and Upper) Siwalik and finally by Quaternary alluvium. Four geomorphic units, the Varanasi older alluvial plain, Aligarh older alluvial plain, terrace zones and the Ganga recent floodplain, abandoned channels, channel scars and meander scars represent various landforms. The hydrogeological cross sections indicate occurrence of a single aquifer down to 120 m. Some influent seepage from the River Ganga could be seen around Gangeswari, but the rest of the River Ganga is effluent.

Groundwater-flow modeling was carried out to assess degree of Ganga river and aquifer interaction. The River Ganga forms the western boundary; boundaries to the northeast and southeast are set as fixed heads to simulate lateral inflow into and outflow from the sub-basin, respectively. The eastern boundary is simulated as a no-flow boundary. The Mahawa and Badmar rivers are considered to be effluent. The model domain is covered by a grid of 34 rows and 46 columns with three layers, viz., an unconfined aquifer, an aquitard which is underlain by a semi-confined to confined aquifer. The permeability distribution was inferred from morphometric analysis and pumping tests. Natural recharge due to monsoon rainfall forms the main input. The River Ganga stage data at Ahar, Narora and Ramghat has been used for assigning river water levels and river bed elevations in the model. Abstraction from all existing deep and shallow tube wells has been assigned as output in various cells. A steady state flow simulation was carried out and calibrated during June 1986 groundwater level and subsequent transient condition in the model was calibrated up to May 1995. The computed groundwater balance indicated groundwater effluence of ~ 22 mcm (million cubic meters) towards Ganga River and ~ 12 mcim towards Mahawa river and its tributaries from the aquifer. Significant effluent nature all along the River Ganga reach is contrary to the general belief that perennial river contributes to the aquifer system in the area. Irrespective of intensive groundwater exploitation in the Ganges alluvium, some groundwater effluence still occurs to the rivers implying that there is further scope for groundwater development through deep tube wells in the sub-basin.

TREND IN THE TIMING AND MAGNITUDE OF FLOODS IN YAMUNA RIVER BASIN, INDIA

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In this paper a comprehensive flood frequency and severity study of the Yamuna river basin has been attempted on the basis of gauge and discharge data of 9 sites using 35 years data between 1976 and 2010. A close examination of the flood data revealed that a maximum of 15 floods occurred during the year 1978. However, the basin experienced maximum floods in the month of August (103) followed by September (50). The highest flood discharge of 42435 m^3/s was recorded at Auraiya on August 25, 1996. Delhi and Banda are the worst flood hit sites in the basin and experienced about 80 floods (40 each) out of total 182 floods that occurred during the 35 year period. Moreover, the magnitude of flood deviation from the danger level was observed to be highest at Banda site (9.29 m) on July 7, 2005. It was also observed from the flood data that Mawi site experienced 6 floods in 1976 flood season which is the highest occurrence for any recorded site in Yamuna river basin during this period. This enormity of floods in Yamuna basin may be attributed to a host of related causes such as natural, hydrometeorological and anthropogenic. It is hoped that the present study will be valuable for farmers, planners, policy makers and water resource engineers for taking the remedial measures against recurring floods in the basin.

RUNOFF CHARACTERISTICS OF GANGOTRI GLACIER, CENTRAL HIMALAYA, INDIA

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ABSTRACT

Runoff characteristics and the role of monsoonal rainfall in the glacierized Gangotri catchment in the Ganga River headwaters, Garhwal Himalaya, India are examined for the summer ablation period of 2010. Though the rainfall received in the Gangotri catchment is small in comparison to other areas of the region, the monsoonal rainfall over the glacierized area appears to be an important factor controlling the characteristics of the discharge hydrograph. Monsoonal cloud cover reduces the energy input resulting in subdued ice melt. The monsoonal component was separated from the bulk flow hydrograph recorded close to the glacier snout using a mass balance approach. The melt water storage and drainage characteristics are also investigated.
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FLOOD RISK ASSESSMENT STUDY FOR THE GANGES BASIN

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ABSTRACT

An innovative framework was developed to understand probability of flood events of complete Ganges River Basin covering Nepal, India and Bangladesh through a Flood Risk Web Atlas which would be open for all. This has taken into account spatio-temporal characteristic of flood risks using numerous data into account. This study is based on data base management, hydrological analysis and modeling of Ganga river basin. The Ganges Basin is one of the largest river basins of the world, which lies in India, Nepal, China, and Bangladesh with a total drainage area of about 9,84,076 sq. km and a total population of 474.45 million. Out of these four countries, India contributes maximum area around 80 % of total basin area. The major tributaries of the basin are Yamuna, Ramaganga, Gomti, Ghagra, Son, Kosi and Mahananda. Ganges basin is experiencing devastating floods almost every year. The low lying areas of Uttar Pradesh, Bihar, and Bangladesh are severely affected due to floods in this basin and witness huge losses every year, which makes it critical to conduct a detailed flood risk assessment for the basin. The study area extends to entire Ganges Basin (China, Nepal, India and Bangladesh) to understand the trans-boundary and inter-state linkages of flood risks of sub-basins under the Ganges river basin.

Through this paper, authors highlight a comprehensive flood risk assessment study that was carried out for the entire Ganges basin, including development of exposure data, hydrological and hydraulic modeling, and vulnerability and risk assessment. To understand the geographical impacts of floods on various sectors, a comprehensive database (including residential, commercial, industrial, essential facilities, infrastructure, and agriculture) was created at block/district level for the whole Ganges Basin. In order to estimate the financial losses due to floods, these exposures have been further valued in terms of INR based on the appropriate replacements costs. Further, Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) has been used to develop the rainfall-runoff relationship for the basin. Data obtained from the India Meteorological Department (IMD), Department of Hydrology and Meteorology

(DHM), Nepal and other global sources have been used as inputs to the model. In the next step, RMSI experts created Hydraulic (Hec-RAS) models for various probabilistic return period scenarios (2, 5, 10, 25, 50, and 100-years) for more than 400 river segments. Finally, loss estimation (AAL or Average Annual Loss and loss exceedance curve) was carried out using the vulnerability for various exposure types. The probabilistic flood risk assessment is based on analysis of a large number of spatially correlated flood events. The findings of the study was aggregated and presented at sub-district, district, and sub-basin level. This study would be useful in identifying the priority sub-basins and/or states which need immediate attention for flood mitigation measures and flood forecasting. These findings would help minimize the economic losses in these countries and help reduce the impact of floods on the population and other vulnerable assets.

The study findings have also been provided to the general public in the form of a Web Risk Atlas. The atlas has been created on a Web-GIS platform and provides base exposure, modeled and historical flood extents, and risk assessment results. The flood risk economic losses computed is being made assessable online at varied level ranging from Ganges basin/Sub-basins/Districts/Blocks; comprising flood hazard (extent and depth), exposure (assets under risk) and vulnerability to exposure (damage). The atlas helps decision makers, policy planners to reduce flood risks following an ex-ante approach which is grossly incommensurate when 20 Crore of poor living Below Poverty Line and over 1.7 Crore of the people are getting affected every year. This innovative framework provides the probability of flood events of complete Ganges River Basin covering Nepal, India and Bangladesh through a Flood Risk Web Atlas open for all. This has taken into account spatio-temporal characteristic of flood risks using numerous data into account. Finally, the user from various quarters working in the Ganges basin may access this web based flood risk atlas as one stop site for range of users operating in Ganges basin to evaluate areas at risk considering hazard, exposure and vulnerability "on fly" for effective planning and management as necessary. One of the major outcomes of this study shows that the average annual loss due to flood is highest for India (approx INR 1,286 Crore) followed by Bangladesh (approx INR 36.5 Crore), and in the Nepal portion (approx INR 6.8 Crore). These losses are computed as replacement cost for Buildings, Infrastructure (rail and road networks) and major agriculture crops considering only the direct losses to these assets. Content losses and indirect losses, including losses due to business interruption, are not considered in this study. The analysis also shows that the total number of persons affected due to flood in the basin varies from 53 million to 80 million for 2-year and 100-year return period floods respectively. These numbers are 11% and 17% of the total population of the Ganges Basin respectively. The study would help better understand the socio-economic impacts of flooding in the basin and subsequently help the general public, stake holders and decision makers for better flood management and mitigation planning.

This study has been undertaken under the aegis South Asia Water Initiative (SAWI) of the World Bank to guide National Hydrology Project (currently under preparation) for identification and establishment of flood forecasting. The SAWI is designed to support countries improve and deepen trans-boundary dialog, enhance the basin and water resources knowledge base, strengthen water institutions, and support investments that lead to sustainable, fair and inclusive development.

MELTWATER ISOTOPIC COMPOSITION ($\delta^{18}O$ & δ^2H) AND ITS SIGNIFICANCE IN UNDERSTANDING GENERATION OF MELTWATER AT GAUMUKH IN BHAGIRATHI RIVER, UTTARAKHANDd

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ABSTRACT

The snow and glacier melt runoff contributes significantly to all north India Himalayan rivers. However, limited investigations have been carried out to understand the runoff generation process in the headwater region of these rivers. Due to lack of information on runoff generation processes of snow/glacier regime and assured availability of melt water, water resources management policies at lower reaches of the glacier fed rivers are often formulated without considering the impact of snow and glacier on river hydrology. In the present study, an attempt has been made to understand the meltwater runoff generation process in the head water region of Ganga using environmental isotopes.

Melt water samples were collected at the snout of Gangotri Glacier, popularly known as Gaumukh, located in the Garhwal region of Uttarakahnd, India, during ablation period (May to October) of 2004, 2005 and 2006 and analysed for $\delta^{18}O$ and δ^2H at National Institute of Hydrology using Diual Inlet Isotope Ratio Mass spectrometer. The standard procedures were followed for measurement of ^2H and ^{18}O. To determine δ^2H and $\delta^{18}O$, a three-point calibration equation was used with the isotopic water standards V-SMOW, GISP and SLAP obtained from the IAEA, Vienna (Precision: ±1.0‰ and ±0.1‰ for δ^2H and $\delta^{18}O$, respectively).

During the study period, meltwater $\delta^{18}O$ varied from -16.6‰ (August) to -12.36‰ (May) during 2004, -18.1‰ (September) to -12.78‰ (June) during 2005 and -16.71‰ (September) to -12.44‰ (April) during 2006. The weighted average (2004 to 2006) value of $\delta^{18}O$ and δ^2H is -14.66‰ and -101.14‰. The results indicate that isotopic composition of the meltwater enriched during pre-monsoon (April to June) and ranged between -12‰ and -13‰. The $\delta^{18}O$ values depletes slowly in the month of July and maximum depletion observed during August and September months. The enriched isotopic composition during the April, May and June indicate significant contribution from snowmelt dominates in the meltwater runoff. However, the meltwater generated in the month of July to Septemeber bears depleted isotopic signatures ($\delta^{18}O$ & δ^2H) indicate contribution from glacier/ice since ice since it bears depleted isotopic signature in comparison to fresh snow. The glacier/ice gets exposed below the snow line due melting of fresh snow in the months of March April, May and June which results into significant melting of ice. The abrupt depletion of $\delta^{18}O$ in July, August and September months are observed during heavy rainfall events. For example, in the month of September 2005, the pre-rain event $\delta^{18}O$ of meltwater was in range of -14‰ to -16‰ which sharply depletes to -20‰ on the day of rainfall due to depleted rain of -30.3‰. It indicates that rain generated runoff joins to meltwater in significant amount. Using the

two component model, the estimated amount of rain generated runoff come upto 40% of the total discharge of river on the day of rainfall and its total contribution is about 3% during ablation period year 2005. The results of the study show varied amount of runoff generated from snow, ice and rain contribute melt runoff in head water region which varies with time within the ablation period.

APPLICATION OF IOTOPES FOR IDENTIFYING RECHARGE AREAS OF SPINGS : CASE STUDIES FROM UTTARAKHAND

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ABSTRACT

Springs are the major available source of water supply for domestic, agricultural and other uses in mountainous regions. But these resources are meagre and low discharges during summer cause a lot of hardship to the people. As the springs in mountainous region are derived from seepage waters flowing through the weathered and fractured zones, the characteristics of which are prone to change due to natural and anthropogenic activities. Therefore, the knowledge of the recharge area and recharge sources of the springs is essential to take suitable measures for their longer sustainability. Environmental stable isotopes of oxygen (O-18), hydrogen (D) and radioactive isotopes of hydrogen (H-3) can be used to understand the recharge source/s of a spring and to locate its recharge area/s for taking effective measures for its longer sustainability.

The local meteoric water line (LMWL) is developed using the $\delta\ ^{18}O$ and δD values of precipitation. The altitude effect in isotopic composition using either $\delta\ ^{18}O$ or δD of precipitation is established for the study area. The δD and $\delta^{18}O$ of springwater are plotted and compared with the isotope in the springwater signatures of precipitation using local meteoric water line. If any evaporation effect is seen then the actual isotopic values of springwater are determined by extending the isotopic evaporation line towards meteoric water line. After applying the altitude effect with the estimated $\delta\ ^{18}O$ or δD value of springwater, the altitude of the recharge area is estimated. And by comparing the isotopic signatures of springwater with other possible sources of water, the recharge sources are identified. The environmental tritium data is used to estimate the residence time of the spring water to confirm the recharge area.

In the preset paper, a case study of identification of recharge areas of few springs located in the Bhagirathi River Catchment in Garhwal Region of Uttarakhand has been discussed along with an another case study of a success story of rejuvenation of springs in Gaucher area of Chamoli in Uttarakhand.

POLICY AND GOVERNANCE FOR ENERGY AND ENVIRONMENT IN RIVER GANGA BASIN

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ABSTRACT

In spite of Ganga Action plan, National River Conservation Plan and National Mission for Clean Ganga, the water quality and quantity in the river Ganga has not been found suitable even for bathing especially in many stretches and also affecting aquatic life and biodiversity.

With one storage dam and few diversion structures for hydropower in upper reaches and major abstractions from several diversion barrages on river Ganga, absence of regulations on minimum flow have resulted flow variability and almost dry stretch during lean periods respectively.

Steep slopes on one hand has high hydropower potential (over 10 GW) and on other hand unregulated flow in the diverted stretch, poor governance, monitoring of construction activities often being considered are in conflict. In the plains from Haridwar onwards the river Ganga enters in plain and stretches up to Bay of Bengal where high abstractions happen to meet water requirement for irrigation and drinking. The untreated and poorly treated waste water from industries, towns and cities make matter of low flows even worse. High level of pathogens due to untreated waste water, poor interaction of river and ground water due to high ground water withdrawal, encroachment of river flood plain, floating trash are some of the issues require a high level of people participation, cost effective treatment, stringent monitoring, effective governance and innovations at state level rather than centre level.

Due to unprecedented Uttarakhand flood in 2013, the focus on rejuvenation of river Ganga instead of middle reach having the main problems somehow has been shifted to upper reaches due to activism of media, individuals and few interested groups.

The issue related to rejuvenation of river Ganga being multi dimensional activity involves activities in social, economic, management, infrastructure, scientific and technological issues are discussed and presented. Awareness generation, regulatory frame work covering land use of flood plain, uninterrupted power supply to treatment plants, land acquisition, monitoring and integrated approach for conservation are proposed.

DEVELOPMENT OF RIPARIAN ZONE IN GANGA BASIN

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ABSTRACT

A riparian zone or riparian area is the interface between land and a river or stream and also areas that surround water sources. The riparian zone is critical to the health of every stream and its surroundings environment. It connects the upland zone (the area of the watershed that does not receive regular flooding by a stream) to the aquatic zone (the area of the stream channel covered by water, controlling the flow of water, sediment, nutrients, and organisms between the two). Riparian is also the proper nomenclature for one of the fifteen terrestrial biomes of the earth. Plant habitats and communities along the river margins and banks are called riparian vegetation, characterized by hydrophilic plants.They support high soil moisture and associated vegetation. These areas of high biodiversity often provide the necessary elements for wildlife survival - food, water and cover - in the same location. Riparian areas are associated with a high degree of diversity. It is also more structurally complex (plants have a greater variety of shapes and heights). Plants such as sedges and other species requiring more water can be found in the riparian zones.The most important consideration in riparian zone management is avoiding stream bank erosion or soil sediments entering the stream channel. Riparian vegetation along a stream in plains may be small and sparse while the vegetation along a mountain stream may be tall and lush.

Riparian vegetation has an important role in filtering sediment and pollutants. In-situ filtrations of surface runoff water reduce the sediment yield and therefore, maintain actual carrying capacity of river and finally protect the flood in the nearby habitations. Bamboo is sometimes planted in tropical riparian areas to conserve soil and water. However, in a study in the Lao People's Democratic Republic, it was found that bamboo was less effective for this purpose than native grass; grass strip was recommended alongside bamboo stands to enhance the trapping of sediments.

Riparian vegetation contributes shade, food and shelter for aquatic organisms. The riparian zone is also home to many animals that move between land and water, such as insects, amphibians and waterfowl.

GANGES AQUIFER MANAGEMENT: A STUDY ON RAMGANGA SUB-BASIN USING CONCEPT OF GANGES WATER MACHINE

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ABSTRACT

Ganga River is a monsoon-driven system where nearly 80% of annual flow in river occurs during 4 months from July to October. Consequently, the flow in the Ganga River and its tributaries during the lean season in some stretches is insufficient to meet irrigation and other needs of water. About 40 years ago, Revelle and Lakshminarayana (1975) advanced the concept of Ganges Water Machine (GWM) as a solution to growing water scarcity in the Ganga basin. The basic idea behind the concept was that if some of the flood waters can be stored in the basin and used in the dry season then the water shortage in the basin can be largely overcome. Several possible ways were suggested in the concept to enhance storage of flood water in the aquifers, which are: (i) *Increase infiltration by spreading water over the land surface and constructing bunds to force water to stand and infiltrate;(ii) Create additional space in aquifers by pumping groundwater during the pre-monsoon season in the vicinity of major rivers and certain tributaries;(iii) Increase seepage from irrigation canals during the monsoon by extending their network.*

To examine the feasibility of enhancing storage potential in the basin, as a pilot the prospect in the Ramganga sub-basin was studied by a comprehensive analysis of its hydrological and hydrogeological aspects. The SWAT for simulating hydrological responses and MODFLOW for hydrogeological responses was used for modelling the responses of the Ramganga system. The Ramganga basin comprises area of 18,667 sq. km excluding the catchment area of 3,241 sq.km of the Kalagarh dam. It posseses nearly all the hydrological and hydrulic characteristics as of the Ganga basin; it has both surplus monsoon runoffs and groundwater depletion in many pockets; it has prospective futuristics water demands in all sectoral uses, viz. domestic, agriculture, and industries, and the policy framework based on the successful evaluation of the envisaged concept can be replicated to other part of the Ganga basin.

A number of policy framework modelling aimed at monsoon surface runoff conservation for Managed Aquifer Recharge (MAR), and sub-surfaces pumping near the river to create gradient and space to accommodate floodwaters were analyzed and scope of such possibilities was worked out. The presentation will highlights the hydrological, hydrogelogical, supply and demand prospects of the sub-basin together with the results obtained from the analyses of policy framework.

APPLICATION OF ISOTOPES FOR IDENTIFYING RECHARGE AREAS OF SPRINGS: CASE STUDIES FROM UTTARAKHAND

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ABSTRACT

Springs are the major available source of water supply for domestic, agricultural and other uses in mountainous regions. But these resources are meagre and low discharges during summer cause a lot of hardship to the people. As the springs in mountainous region are derived from seepage waters flowing through the weathered and fractured zones, the characteristics of which are prone to change due to natural and anthropogenic activities. Therefore, the knowledge of the recharge area and recharge sources of the springs is essential to take suitable measures for their longer sustainability. Environmental stable isotopes of oxygen (O-18), hydrogen (D) and radioactive isotopes of hydrogen (H-3) can be used to understand the recharge source/s of a spring and to locate its recharge area/s for taking effective measures for its longer sustainability.

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SUKHA RAULA TO GADGANGA: THE TRANSFORMATION OF A RIVER

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ABSTRACT

Uffrainkhal; a village located in the midst of three districts Pauri, Chamoli and Almora in Uttarakhand. It is in the 'Doodhatoli' mountains range to the north of Jim Carbett National Park and at 6000 feet above the sea level. GadGanga; rivulet (a first order stream) originates from Uffrainkhal and flows through Gadhkhark village and feeds Pasol River which merges with Nayar River; a tributary to Ganges. Local's incessant efforts to revive and regenerate the once degraded ecosystems of Doodhatoli with barren hillsides, isolated tree trunks and parched lands to a stretch with lush green forests enough to tract the fodder and fuel needs of villagers without any damage to the ecological niche and not only regenerated the dried and depleting streams, but giving birth to many new waterbodies and streams (locally known as gaghara) resulting in increase of water volume in Ganges' two major tributaries, Pasol and Nayar and regeneation of GadGanga which was once 'Sukharaula' means Dry Ravine. Local Community troops have built more than 30,000 ChaalsKhals in 136 villages. Within these areas there are several patches of thick forests varying in sizes from 30 to 300 hectares. The canopy in general is 100 feet high. High humus in soil, music of wildlife can be felt there. Music of life have revived again and women are saying with proud, "The water in springs of my hills is cool. Do not migrate from this land, O my beloved

HYDRO-GEOLOGICAL INFORMATION ON RAIN-FED SPRINGS OF MID WESTERN HIMALAYA (UTTARAKHAND)

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ABSTRACT

Since early times, the population of sub-humid regions in Mid Western Himalayan hills has their homes clustered around natural water resources primarily springs. The population settlement in hills is therefore distributed forming clusters depending on availability of springs. The springs of Mid Western Himalayan watersheds provides basis for the settlement of life at mountain around springs. These springs could be discharging too small quantity but the life depends on it in Mid Himalaya. These watersheds are rich in natural resources, provides life in this area and together water to millions at down stream through its perennial river system. Even then some times the availability of natural resources at hills goes to acute shortage in summer especially in low rainfall years. It is, therefore, important to study the existing water resources and its impacts on watershed hydrology. Study area Chandrabhaga lies in 'Mid Western Himalaya' agro-ecological region of *Devprayag, Uttarakhand* with area around 3.0 km^2. Automated hydro meteorological data are collected. Regular (daily) spring flow measurements are taken on almost all springs that are used by the habitat of the area. Spring flow availability is evaluated along with the average ten daily low flow duration curve for the springs of the watershed. The spring flow variability is related with rainfall spring flow lag. A high variability of spring flow suggests that springs are fast responding and turning to low yield during summer. Relationship between total rainfall and total spring flow are also developed.

Although the Mid Western Himalayan watersheds are rich with perennial or non-perennial springs and provides fundamental basis for settlement as well as the existence of life. These water resources are so low discharging that most of springs fall under the lowest flow category flow between 0.82 to 6.55 m^3/day and classified as sixth or seventh category of Meinzer's (1918) spring classification. Relative performance of springs by four methods viz. (1) Based on spring flow variability, (2) Based on normalized mass spring flow, (3) Based on rainfall spring flow lag and (4) Based on spring flow gradient has been estimated and presented.

In order to develop the physical models for spring flow some geomorphologic information on springs has been extracted. This includes; (1) defining the equivalent spring order for the springs (2) development of the spring-shed for the springs by assuming that the flow in the aquifer follows the flow direction paths as are on the surface and the flow in the aquifer can not cross the stream path which is normally the lineament and other lineaments present in the watershed. Further the spring shed

development is subjected to; the spring shed area must follow the relationship with maximum spring flow and the spring shed area/relief must follow the relationship with maximum spring flow.

REJUVENATION OF RIVER GANGA IN BHADRESWAR – KONNAGAR STRETCH IN HOOGHLY DISTRICT, WEST BENGAL

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ABSTRACT

Konnagar-Bhadreswar stretch in Hooghly District under Konnagar, Rishra and Bhadreswar Municipalities, has been studied to assess pollution problem caused by big drains in the area. The study area, falling in Survey of India Toposheet No. 79 B/5(pt.) and 79 B/6 (pt.), lies just on the western part of Hooghly River, which flows almost north to south. The whole area is almost flat. The Grand Trunk Road (G T Road) passes through the area from north to south and lies almost on natural levee of this mighty river. These municipalities are characterised by dense urban settlements. Growth rate of human population in last decade in these municipalities ranges between 5% and 10%. In Konngar and Rishra Municipal areas, natural levee and G T Road lie almost on the extreme border of urban settlement; but, in Bhadreswar, there is a sizeable chunk of urban settlements on the eastern part of this road too.

Total door to door sewage network, requirement of additional sewage pumping stations and treatment plant, renovation of existing treatment plants and regulation of treatment by local body in consultation with Pollution Control Board, monitoring of all aspects of environment related to sewerage and drinking water, etc. are some of the possible options of rejuvenation of River Ganga. Scope for river front development is limited to high; some modifications might also be done for beautification. Motorable roads already exist in the municipalities up to river front. Parks could be set up east of G T Road near Bag Khal near Rishra Municipality for beautification.

For rejuvenation of Ganga, all future development plans in Konnagar – Rishra - Bhadreswar stretch, prime consideration should have to be given to local geomorphology, which is extremely location-specific.

STREAMFLOW MODELLING OF BHAGIRATHI RIVER AT GOMUKH

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ABSTRACT

The modelling of streamflow is required in many activities associated with planning and operation of the components of a water resources system. Snow melt runoff is one of the main sources of streamflow in many of Himalayan Rivers. Conceptual models to simulate the snow melt runoff such as Snowmelt Runoff Model (SRM) and Snowmelt Model (SNOWMOD) require a large quantity of data which are generally not available for most locations in India. Applications of Artificial Neural Networks (ANN) in many water resources area have proven its better performance over other traditional models such as conceptual models and black box models. This paper discusses the development of ANN models for the simulation of streamflow at Gomukh in Bhagirathi river basin. Temperature and discharge data at Gomukh were used as input to the models. Different combinations of significant lagged series of temperature and discharge data, determined from statistical parameters such as auto correlation function (ACF), partial auto correlation function (PACF) and cross correlation function (CCF), were used as input to the model. The performance of the model was evaluated using statistical criteria such as coefficient of correlation, root mean squared error (RMSE) and model efficiency. The results of the best ANN model during the calibration indicate that the all ranges of discharge values were simulated fairly well. Multiple Linear Regression (MLR) model for simulating the streamflow was developed using input vector considered for the development ANN model. The percentage error in peak flow estimation of MLR model was higher than ANN model during calibration process. The same trend was not observed during the validation of the models. It can be concluded from the results that the overall performance of ANN model was better than the MLR in simulating the streamflow.

MODELLING SOIL EROSION AND SEDIMENTATION IN WATER BODIES IN PARTS OF SOUTH GANGA BASIN

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ABSTRACT

The soil has been defined by the International Soil Science Society as 'a limited and irreplaceable resource' and the growing degradation and loss of soil means that the expanding population in many parts of the world is pressing this resource to its limits. In its absence the biospheric environments man will collapse with devastating results for humanity. Fertile soils by carrying erosion, fills dam reservoir and reduces dams economical life, hence economy of country get debilitated to big amount. To specify hazard and damage of soil erosion is very important for this reason. Among many environmental hazards, checking land degradation is of utmost importance as it has direct bearing on decline in productivity on arable and non arable lands. It is estimated that India suffers an annual loss of 13.4 million tones in the production of major cereal, oilseed and pulses crops due to water erosion equivalent to about 2.6 billion dollars. Reservoir sedimentation, resulting from degradation of the watersheds in India, is on rise as compared to the rate that was assumed at the time the projects were designed. Hence the operational life of reservoir is diminished. Climate, soil, vegetation, topography and man are the factors that affect soil erosion, and out of these, vegetation and soil to some extent, are the only factors which man can control. To prevent the Erosion and rapid siltation, management of water, soil cover and vegetation resources on watershed is must.

Universal Soil Loss Equation (USLE) is the most widely used empirical formulae for evaluating gross erosion from any basin. Merging the same with recent technology of remote sensing could provide us with more precise results. The model separates the soil erosion process into a water phase and a sediment part. It considers soil erosion to result from the detachment of soil particles by raindrop impact and the transport of those particles by overland flow. The model tries to cover some of the recent advances in perceptive of erosion processes. In this paper the application of USLE model and GIS has been attempted for determining the quantity of soil erosion. Satellite Remote Sensing (SRS) provides important information in terms of present water spread area of the reservoir at specific elevations, which is used for computation of revised capacity of the reservoir. The revised capacity is useful for planning the reservoir operation and scheduling the irrigation water supply in the command area and hydropower generation.

CLIMATE CHANGE IMPACT ASSESSMENT ON THE URBAN FLOODING OF KOLKATA

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ABSTRACT

The World Bank in collaboration with the Asian Development Bank and the JBIC Institute decided to carry out an assessment on the impacts of climate change on major coastal cities in Asia. The city of Kolkata, India was one of the candidate cities. The study was aimed at evaluating the impacts of climate change with respect to flooding and other socio-economic aspects. The possible sources of flooding of Kolkata include riverine flooding from Hooghly River, flooding due to local rainfall, flooding due to storm surges and some combination of these three. One source of inundation of the KMA area is on account of the flooding in the Hooghly River. In the absence of the observed river flow data made available indirect assessment has been made by using the SWAT hydrological model with the daily gridded rainfall and temperature data obtained from India Meteorological Department. Since 35 years of daily rainfall data were available, same length of daily flow series have been generated at various locations along the Hooghly River. The diversions made into Hooghly from Ganga River have also been incorporated while making these assessments. The data series so generated have been used to determine flow statistics, including extreme river flows i.e.,flow of 10, 30, 50 and 100 year return periods. The Gumbel Extreme Value Type I distribution was fitted to the discharge peaks for 35 years to get the flood peaks corresponding to higher return periods. These flood events are not of much use unless they get translated into flood waves moving through the river channel and reflected as inundation whenever the carrying capacity of the channel is exceeded. For this purpose the HECRAS hydraulic model has been used in the present case. The model provides the water surface profiles all along the river along with its temporal variation (change in flow depth during the flood period). The model requires high quality of data on channel geometry and terrain to simulate the water surface profiles and the inundation properly. It also needs data on the manmade changes such as bridges, embankments, etc., so that their effect on the flow can also be simulated.

Apart from the flow received from the catchment of Hooghly River there is another cause of flooding of the Hooghly which is the tidal and storm surge effect. Owing to the distance of the KMA area from the sea coast the tidal and storm surge effect is not very drastic and is being managed effectively through strengthening of the embankments and use of stop gates to control the inundation. However the projected sea level rise and also the enhanced storm surges shall worsen the present situation and shall need strengthening of the present infrastructure. These conditions have been incorporated into the HECRAS model and simulations have been made under present and future scenarios to get the flow profiles and the consequent inundation of the areas in and around KMA. The area inundated due to riverine flood of 100 year return period increased from 6% to 16% after incorporating the storm surge effect bringing population at risk from 10% to 28%. As the surge moves upstream its effect fades away. However, during such period since the Hooghly River shall be flowing full thus inflow from the surrounding drainage areas and tributaries will not be accommodated resulting in backflow and inundation of parts of KMA area. In the case of Kolkata as well, it is the local rain that is the major cause of flooding. The flooding is aggravated because of the natural poor drainage conditions prevailing during the flooding period. Urban hydrological model setup for the Kolkata Municipal Corporation

(KMC) region only has been taken up since this is the area that is having sewerage network implemented in majority of the areas. The SWMM urban hydrological model simulates the flooding due to the local rainfall by incorporating the prevailing urban characteristics of the area as well as the other specific structures such as lock gates, drainage pumps, etc.

Administratively, KMC has been divided into 141 wards and are grouped into 15 decentralized units called Boroughs. The existing sewerage network covers a length of about 1610 km and the length of open drain is about 950 km. The drainage system is about 140 years old and is silted up at places upto 50%. The KMC area is divided into nine major drainage basins some of which even have independent sewer network and terminal pumping stations. Canals are used for final disposal of water. Lock gates control the canal and discharge system therefore coincidence of high tides with heavy rains makes satisfactory drainage difficult and results in flooding. Pumps are used to pump the collected storm water sewage into the discharge canals. Pumps are old, pumping stations are inefficient and unreliable, resulting in frequent failures. These storm water-pumping stations cannot discharge freely into the canal system due to heavy siltation of canals leading to their reduced capacity. Moreover, many canal banks are encroached by settlements and growth of aquatic vegetation which also decreases the carrying capacity of canals. Keeping all the above ground realities in view detailed urban storm water model using SWMM was established and modeling has been performed for the KMC area. The existing sewerage network has been mapped and catchments of these networks have been established. The network connections of the main sewers to the canal systems have been incorporated along with the corresponding pumping stations.

Simulations have been made using the data of storm event of 1978. It has already been established that the 1978 storm is a 100 year storm. The 30 year and 50 year storms have been created by applying the ratio of rainfall histograms between these return periods and the 100 year return period to the 1978 storm. The area affected for 100 year return period is 18.5% thereby taking the population at risk to 28%. In the absence of the short duration rainfall data required for the climate change scenario to be used in the urban hydrological model SWMM, the projected percent increase in precipitation for this area has been used to create the future scenarios. Thus a range of scenarios have been created for which the simulation has been made using the SWMM model. These include present scenarios for different return period storms for silted and non-silted conditions. Similarly the scenarios have been generated for future conditions using A1F1 and B1 scenarios. The percentage area affected increases in A1F1 scenario to 24% and population at risk to 31%. For B1 scenario the percentage of affected area is 22% and population at risk is 29%.

Since the data availability at only the KMC level was adequate therefore the vulnerability and economic analysis were carried out for KMC. A procedure had been evolved to construct the flood vulnerability at the ward level. Main indicator of the impact is obviously the landuse, the duration of water logging, and, depth of the flooding has been built on top of the landuse. Characteristics of the wards with respect to the socio- economics, industries, heritage sites, hospitals, schools, roads etc have been considered for arriving at the vulnerability index of individual wards. The data about the extent of duration of the water logging and depth has been obtained from various scenarios as outputs of the model(s). Combining ward vulnerability, flood depth and duration the wards were classified under different threat level (severity) index. The 10 most wards which were found vulnerable are ward number 58, 57, 79, 63, 74, 45,38, 71, 67 and 59. Estimation of flood damages in the Kolkata Municipal Corporation (KMC) area was then taken up. The analysis involves estimation of damages to the private and public in terms of property, inventories, loss of income, etc. In addition, a focus on intangible losses such as environmental, stagnant economic growth and human population is attempted.

INFRASTRUCTURAL DEVELOPMENT IN UPPER GANGA BASIN FOR FLOOD CONTROL IN UTTARAKHAND

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ABSTRACT

India is one of the most densely populated countries in the world with over one billion people and it is vulnerable to numerous natural hazards, particularly earthquakes, floods, droughts, cyclones, and landslides. Uttarakhand was formed on November 9, 2000 to become the 27th State of India. It is predominantly a hilly State, having international boundaries with the People's Republic of China in the north and Nepal in the east. The Himalayas are one of the youngest mountain ranges on earth and represent a high energy environment very much prone to natural disasters. High relief, steep slopes, complex geological structures with active tectonic processes and continued seismic activities, and a climate characterised by great seasonality in rainfall, all combine to make natural disasters, especially water-induced hazards, common phenomena. Flash floods are among the more devastating types of hazard as they occur rapidly with little lead time for warning, and transport tremendous amounts of water and debris at high velocity. Flash floods affect thousands of people in the Himalayan region every year – their lives, homes, and livelihoods – along with expensive infrastructure.

The monsoon in June 2013 arrived almost two weeks earlier than expected in Uttarakhand. Rapid melting of snow/ice and heavy rainfall resulted in the formation and expansion of moraine-dammed lakes, creating a potential danger from dammed lake outburst floods. On 16th and 17th June 2013, heavy rains together with moraine dammed lake(Chorabari Lake) burst caused flooding of Saraswati and Mandakini Rivers in Rudraprayag district of Uttarakhand. Prolonged heavy down pour on 16th and 17th June 2013 resembled 'cloud burst' (except for amount of precipitation of 100 mm/h) type event in the Kedarnath valley and surrounding areas that damaged the banks of River Mandakini for 18km between Kedarnath and Sonprayag, and completely washed away Gaurikund(1990m asl), Rambara(2740m asl) and Kedarnath(3546m asl) towns. The roads and footpath between Gaurikund and Kedarnath were also damaged. The Chorabari Lake(3960m asl) also known as Gandhi Sarovar Lake is a snow melt and rain fed lake, located about 2 km upstream of Kedarnath town which is approximately 400 m long, 200 m wide having a depth of 15–20 m. The bursting of this lake washed off both the banks of the Mandakini river causing massive devastation to the Kedarnath town. The meteorological observatory of Wadia Institute of Himalayan Geology, Dehradun at Chorabari Glacier camp recorded 210 mm rainfall in 12 hours between 15th June (5:00 p.m.) and 16th June (5:00 a.m.) 2013. On 16th June 2013 alone (from 5:00 a.m. to 5:00 p.m.), 115 mm rainfall was recorded, causing 325 mm rain in 24 hours.

Fig. 1: Damaged Kalimath Temple in Distt. Rudraprayag and Buildings in Distt. Pithoragarh

Fig. 2: Confluence of rivers Mandakini and Alaknanda, before and after disaster at Rudraprayag

The districts of Chamoli, Pithoragarh, Rudraprayag, Uttarkashi and Bageshwar were most affected. This region is one of the most important pilgrimage circuits in India. Since the disaster coincided with the peak tourist and pilgrimage season, it significantly increased the number of casualties, missing, and affected population. A total of 580 human lives were lost; over 5,200 people reported missing; 4,200 villages were affected; 9,200 cattle/livestock were lost; about 3,320 houses were fully damaged; about 995 public buildings were damaged; close to 9,000 km of roads were affected; and 85 motor bridges and 140 bridle bridges were damaged. This event also left over 70,000 tourists and 100,000 local inhabitants stranded in the upper reaches. Landslides and toe erosion by the sediment loaded rivers damaged roads/highways at many locations and washed away multiple bridges (steel girder, beam and suspension bridges). Traffic was disrupted along all national highways and link roads in the region, along with the disruption of telecommunication lines, all adding to the impact of the disaster. Many hotels, rest houses and shops around the temple in Kedarnath were completely destroyed.

Fig. 3 Infrastructural Development in Distt. Rudraprayag and Uttarkashi after 2013 Disaster

The talk discusses in detail damages caused due to floods in the State in June 2013 disaster, especially in Rudraprayag and Uttarkashi districts in Mandakini and Bhagirathi Valleys and reasons of damages and outlines the strategy for the Infrastructural development in the Upper Ganga Basin for flood control in Uttarakhand to reduce loss of life in future flood events in the context of State of Uttarakhand.

HYDROLOGIC EFFECTS OF FORESTS AND THEIR MANAGEMENT

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ABSTRACT

Forests and water are connected by physical and biological processes and therefore, sustainable management of forests has a key role to play in protecting fresh water supplies. Forests affect the hydrology of watersheds in various and complex ways, by increasing evapotranspiration, increasing soil infiltration, intercepting cloud moisture, reducing the nutrient load of runoff, and more. Forests vary due to differences in geography; ecology; and social, economic, and land use histories. These are managed for a range of objectives and goals, using a wide variety of forest management practices. Like forests, water resources are also managed to achieve multiple objectives to sustain agriculture, human settlements, and ecosystem functions. There is a broad scientific agreement that forests and their management practices have the potential to alter the quantity, quality and timing of water moving through catchments. In recent years, concern has also grown of the potentially large but uncertain effects of climate change on forests and their water output. Climate change may cause shift in snow line, increased favourable conditions for forest fires, outbreaks of insects and disease, and changes in forest structure and species composition, producing direct hydrologic effects.

The science of forest hydrology that investigates rates and pathways of water movement through forests has provided a strong evidence base for understanding basic processes and principles of water movement through forests which can be used to predict the general directions and magnitudes of hydrologic effects of changes in forest cover, climate, and land use. The present paper aims at discussing the available information on impacts of forests and their management practices on hydrological behaviour of the catchments and the salient research findings in context of forest-water interface.

INVESTIGATIONS TO UNDERSTAND EFFECTS OF PROJECTS ON RIVER: A CASE STUDY

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ABSTRACT

As societies develop, water resources within a given basin become increasingly diverted, controlled, and used. Water flowing out of sub-basins is often committed to other down-stream uses, and outflow to the sea has several often overlooked functions like flushing out sediments; diluting polluted water; controlling salinity intrusion along coasts and deltas; sustaining estuarine and coastal ecosystems etc. The perception that water surplus from the most down-stream project is 'lost' and water that sustains flood river regime and part of ecosystem functioning and crucial for inland fisheries as not a genuine 'use' has dried up all our rivers and even a moderate rainfall creates disastrous flooding of lands along their reaches. Thus, it calls up for systematic advanced investigations to understand the effects of developments and to plan appropriate interventions.

Errakalva River in Andhra Pradesh drains the eastern parts of West Godavari district for about 180 km and joins the Upputeru river, which takes off from the Kolleru lake and falls into Bay of Bengal. Errakalva enters the Godavari western delta, after draining an area of including that of upstream catchment of 2330.10 km_2, near Nandamuru aqueduct in Tadepalligudem Mandal and emerges as 'Yenamadarru Drain' or Y Drain. It appears that while taking up irrigation projects most of the erstwhile rivers and streams are made part of command area and lost their originality to be treated as part of drainage system. Application of environmental isotope methods is a good investigation tool available to understand the origin of sources of surface and groundwater with respect to its recharge based on the spatial and temporal variability of the isotopic contents of water. In this paper, variation of measurement of stable isotopes of Deuterium and Oxygen i.e, D and $_{18}O_{16}$ in the water samples of precipitation, canal water, stream water, tank water and groundwater of Yanamadurru drain or Y drain that drains an of 394.93 km_2 in deltaic plain is studied and analysed. The results showed that d $_{18}O_{16}$ and its isotope variation and its characterization in different types of water samples can be used as an index to estimate fraction of different sources of water and plan manage impacts of upstream diversion on the lower reaches in river systems elsewhere in similar climates.

CHANGES IN CHANNEL CHARACTERISTICS IN GANGA RIVER IN GHAZIPUR , UTTAR PRADESH, INDIA

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ABSTRACT

The river Ganga flows through the heart of Ghazipur district. The flow in Gjazipur is guided by basement structure. The river valley near Ghazipur city is 2-3 km wide and there are two well defined planation surface (Regional Surface ,T_1) . T_1 surface is 2-3 m and regional surface is 10 m above to T_0 surface. River occupies only 1/4 part of valley in non monsoon season (Nov. to May), while it covers entire valley in monsoon season (June to October) with increase of discharge. Increased rainfall is result of monsoonal rains in basin area. Its monsoon controlled hydrology leaves a number of geomorphological feature i.e. bars, cut of channels, lakes, ponds and ox-bow lake after monsoon season in the valley. A number of depositional bars, i.e. side bars, mid channel bars, transverse bars and point bars. These sand bars erode and modify their shape and size during high discharge and acre in non-monsoon depending upon flow velocity and sediment transport capacity which enhances silting into channel led abandon t of existing course and channel shift into new quite stable path. The above shifting process causes oscillation of river stream in river valley from left bank to right bank. During last ten years it shifted every 2-5 years depending upon the river discharge , monsoonal rain and transport load.

CHANNEL MIGRATION OF DEOHA RIVER, UP : A CASE STUDY BASED ON REMOTE SENSING AND GIS

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ABSTRACT

The changing behavior of river and the resultant problems have been drawing increasing attention of researcher worldwide. The present study incorporates Deoha River, a left bank tributary of Ramganga, occupying Pilibhit district of western U.P. This river shows frequent channel migration due to high water discharge during monsoon period, alluvial tract, presence of several palaeo-channel, and high sinuosity index etc, leading to serious problems to the floodplain inhabitants in terms of flood, loss of fertile land and associated resources and property damage. The aim of the present study is to measure and analyze the spatio-temporal shifting nature of Deoha river. For this purpose we have selected a 98 km segment of the river from Diyoni village to Tihuliya village of Pilibhit district, U.P. Using multi-temporal satellite data and with the application of GIS and statistics we have quantified the channel migration over a period of 8 years since 2006 up to 2014.The study indicates a high shifting in both direction, towards left and right, but the right hand shifting is dominating over the left-ward shift for this particular study reach.

ROLE OF AGRO-FORESTRY SYSTEM TO EFFECTIVELY REDUCED CONTAMINATION OF GROUND WATER

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ABSTRACT

Trees and crops are very important precursor of life as providing clean air, fuel-wood, forage, feed, maintenance of biodiversity, cleaning polluted water, carbon sequestration and many other humankind services to the earth. Agro-forestry systems help in approaching better way of livelihood opportunities as it avoids the loss of crop failure due to any natural and non-natural calamity. One of the important parts that roots of plants play is to purify ground water along with maintaining soil fertility. The dual approach of mitigating excessive toxicity of land by the plants is actually known as phyto-remediation. Major plants include Eucalypts, Poplar, Melia, Bamboo, Maize, Mustard etc.

The top surface of the soil and other lands are degraded with fertilizers, dumping of garbage, solid waste, hazardous waste, chemical and other inorganic pollutants along with waste water generated in heavy industries like BHEL, NTPC, ONGC, SAIL etc. The ground water qualities in the vicinity of these areas are very poor and undrinkable. The populations living in such areas are prone to water borne diseases like, Diarrohea, Tuberculosis, Malaria etc. In the past, thermal, chemical, and physical treatment methods have failed to eliminate the pollution problem because those methods only shift the pollution to a new phase such as air pollution.

Therefore, *In-situ* approach like planting forest trees along with some medicinal plants, cash crops, oil-seed plants helps in controlling the degradation status of soil in farm land and industrial areas. The *in-situ* bioremediation technique involves leaving the soil at its original place and bringing the biological mechanisms to the soil. *In-situ* remediation includes techniques such as bioventing, biosparging, bioslurping and phytoremediation along with physical, chemical, and thermal processes. *In-situ* remediation is less costly due to the lack of excavation and transportation costs, but these remediation techniques are less controllable and less effective.

CONSTRUCTED WETLANDS TECHNOLOGY FOR WATER POLLUTION CONTROL - POTENTIAL & FEASIBILITY FROM RIVERS CONSERVATION PERSPECTIVE

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ABSTRACT

Past two decades, rivers in the developing countries are facing problem of pollution. Over abstraction of water, direct discharge of pollution from municipal & industrial effluents, in-effective wastewater management, in-adequate policies etc. are some of the reasons. The situation in India is more alarming as most of the rivers are source of water supply for towns and cities. Several technological options for wastewater treatment have been in practice to reduce or prevent the pollution of rivers. Each technology has its own merits and demerits. Amongst the options, the constructed wetlands technology offers a very promising solution for wastewater treatment, particularly for rural settings or small towns where energy is scarce. The application of wetlands is very diverse and flexible as these can be used in centralized or decentralized way. The principle of constructed wetlands is based on natural processes. The removal efficiencies for variety of pollutants are very high, without any external energy demand. These are highly cost-effective, requires very low operation and maintenance, sustainable and easy to implement systems. In countries of tropical regions or warm climatic conditions as prevailing in India, constructed wetlands offer enormous potential especially for rural areas, where less attention is given to deal with the pollution from villages. Realizing the importance and need, the Government of India and European Commission took the initiative to face the water challenge through the implementation of natural treatment processes such as Constructed Wetlands in India. This research & development initiative is joint coordinated efforts under the project entitle "SWINGS - Safeguarding Water Resources in India with Green and Sustainable Technologies" within FP7 framework programme. This paper presents the outcome of the result and describes the potential of constructed wetlands technology from river conservation perspective in India and other countries having similar climatic and geographical conditions.

ECOLOGICAL ASPECTS OF REJUVENATION OF GANGA RIVER

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ABSTRACT

The term rejuvenation refers to medical discipline focused on the practical reversal of aging process. The same principle applied to Ganga river, a living system, means reversing the damage to the system without losing integrity and past glory. This however, is a tall order, yet restoration measures can improve the Health of the stream and promote ecosystem goods and services. The goals and objectives of ecorestoration involve providing space to endemic flora and fauna by maintaining longitudinal and lateral connectivity and assuring stress free environment for existence of sensitive and endemic biological population.

The Ganga river system supports a good diversity of biological forms consisting of phytoplankton, periphyton zooplankton, zoobenthos fish population and aquatic vertebrates. The major threats to the river integrity are changes in flow regime, abstractions of large quantities of water for irrigation and domestic purposes, habitat alterations, emergence of invasive species and rampant pollution from domestic and industrial wastes. The restoration measures, including assuring longitudinal, lateral and vertical connectivity by maintaining e-flows in the entire stretch which would provide enough space for endemic species for growth and migration Assuring Nirmal Dhara by concerted efforts to provide stress free conditions to promote and sustain the biodiversity. Identifying all species endemic and exotic including fish and higher vertebrates. Protecting breeding sites of all species. Regulate and restrict fishing and habitat alterations.

PRELIMINARY INSIGHTS INTO SPECIAL PROPERTIES OF RIVER GANGA AND ASSESSMENT OF ITS WATER QUALITY WITH SPECIFIC REFERENCE TO HEAVY METALS

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ABSTRACT

Ganga has been a cradle of human civilization since time immemorial. Millions depend on this great river for physical and spiritual sustenance. People have immense faith in the powers of healing and regeneration of the Ganga. It is one of the most sacred rivers in the world and is deeply revered by the people of this country. The river plays a vital role in religious ceremonies and rituals. It provides water to about 40% of India's population across 11 states, serving an estimated population of 500 million people or more, which is larger than any other river in the world. Moreover, scientists and religious leaders have speculated on the causes of the river's apparent self-purification effect, in which water-borne bacteria such as dysentery and cholera are killed off thus preventing large-scale epidemics. Some studies have reported that the river retains more oxygen than is typical for comparable rivers; this could be a factor leading to fewer disease agents being present in the water. However, today, it is considered to be one of the most polluted rivers in the world.

Ministry of Water Resources, River Development and Ganga Rejuvenation Government of India solicited services of NEERI to undertake a comprehensive study from Gomukh to Gangasagar by identifying critical locations by analyzing rudimentary and specific water quality parameters along with sediment analysis. The objective of the study is to assess the existing seasonal water quality status of Ganga River for one complete cycle (post monsoon and pre monsoon seasons) and to carry out sediment analysis for important physico-chemical, microbial and biological parameters. Another major objective is to get insight into the special properties of Ganga River water including self-purification and medicinal properties. Exhaustive sampling for the pre and post monsoon season have been undertaken and samples from more than 65 locations have been collected throughout the stretch of river Ganga from Gomukh to Gangasagar. These samples have been analysed for a variety of physico-chemical, microbial and biological parameters. Extensive analysis for more than 15 heavy metals has also been conducted and attempts have also been made to fractionate the different fractions namely dissolved, suspended and total metal contents. Further data analysis and its correlation with the pollution load and special properties are in progress.

CHANGES IN TREND OF WATER QUALITY INDICES FOR RIVER GANGA – SPATIALLY AND TEMPORALLY

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ABSTRACT

River Ganga supports more than 40 % of the Indian population directly and/or indirectly. The Government of India has been struggling for past 30 years to find means to control the pollution load on the holy river. However, due to exponential population explosion in the Gangetic belt, all efforts seem to bear lesser fruits than expected. As a matter of fact, 3 out of 5 most populated Indian states i.e. Uttar Pradesh, Bihar and West Bengal lie on the banks of Ganga main stem and also fall completely within Ganga basin. The rapid population growth in this region has led to unplanned horizontal and vertical expansion of the inhabited areas and thus making it difficult to make actual estimation of the volume of the problem. The Ganga basin is agriculturally rich and contributes to a major part of Indian economy through agricultural yield but it is the agriculture sector and human consumption which demands diversion of > 80 % of the water from Ganga. However, it is also the cradle of 764 grossly polluting industries which directly/indirectly discharge untreated/ partially treated effluents in the Ganga. According to Ministry of Social Justice & Empowerment approximately 40 % of the population of U. P. and Bihar fall below poverty line, hence lack access to proper education, sanitation and health facilities. Problem like open defecation and disposal of semi/un cremated dead bodies into the Ganga are also a direct outcome of the above mentioned condition. Together, these and several other factors are contributing factors to the pollution in river Ganga.

To arrest the pollution load on river, the Government of India (GoI) has made several interventions since 1985. These include Ganga Action Plans (GAP)-I & II, National River Conservation Plan (NRCP), National Ganga River Basin Authority (NGRBA) and Namami Gange. Several ministries and other organizations of central and state governments have also been involved in these interventions for last 30 years in different capacities.

This study is aimed to overcome this problem by utilizing the concept of water quality indexing. A Water quality index (WQI) provides a picture of the water quality in the form of simple numbers; even the index values are divided into different bands to represent good, bad, fair and similar classifications of water quality. Thus making it even easier for the decision/policy makers and managers to understand the real impact of pollution at different locations over a period of time. For the current study, the historical water quality data of river Ganga for the parameters- pH, Biological Oxygen Demand (BOD), Dissolved Oxygen (DO) and Faecal Coliform (FC) for more than 56 stations along the maistem of river Ganga from 2009- 2014 has been utilized.

The historical data has been used to derive a trend in the water quality of the main stem of river Ganga over a period of 6 years at 56 different locations utilizing 3 different WQIs namely- Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI), Oregon Water Quality Index (OWQI) and National Sanitation Foundation water Quality Index (NSF-WQI). These 3 indices have been chosen for this purpose due to their wide popularity and acceptability. The results drawn from exercise will highlight the deviations of water quality from the accepted water quality standards in India.

POLLUTION RISC ASSESSMENT OF GROUND WATER QUALITY IN VARANASI CITY, UTTAR PRADESH

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ABSTRACT

Protection of groundwater from surface pollutants needs greater attention as groundwater, once polluted, is very difficult to remediate. In recent years, the increasing threat to groundwater quality due to human activities has become a matter of great concern. A vast majority of groundwater quality problems present today are caused by contamination and over-population, or by combination of both. Rapid urbanization and industrialization in India has result in steep increase of generation of wastes. Due to lack of adequate infrastructure and resources the waste is not properly collected, treated and disposal; leading accumulation and infiltration causing ground water contamination. The problem is more severe in and around large cities as also various clusters of industries. In many of these areas ground is only source of drinking water, thus a large population is exposed to risk of consuming contaminated water. The present study is done in Varanasi City which is one of the fast growing urban areas in India. The groundwater analysis was undertaken by randomly taken collecting around 59 groundwater samples from hand pumps and bore wells covering the entire urban area of the city and also some of the rural areas. Most of groundwater samples are suitable for irrigation. It is founded that over exploitation of groundwater has detrimentally affected groundwater in terms of quality as well as quantity. Although the general quality of groundwater of lower basin is suitable for irrigation purpose but in many samples has concentration of arsenic, fluoride, chloride and nitrate was much higher as specific by BIS, indicating unsuitability of groundwater for drinking purpose.

ASSESSMENT OF WATER QUALITY OF RIVER ALAKNANDA STRETCH AT SRINAGAR, UTTARAKHAND, INDIA

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ABSTRACT

Investigation was conducted to assess the water quality of River Alaknanda. Water samples were collected from 8 different sites selected along the river stretch. Physico-chemical tests *viz.* temperature, pH, total dissolved solid, total alkalinity, dissolved oxygen, conductivity, biochemical oxygen demand, free CO_2, hardness, nitrate and inorganic phosphate along with biological (coliform and periphyton) indicators were analyzed.The results indicated that the water was having high coliform count ranging between 65-270/100 ml and therefore, was not suitable for drinking without treatment. The biochemical tests and staining tests marked species of *Lactobacillus, Bacillus, Clostridium, Streptococcus, Staphylococcus, E.coli, Shigellas, Salmonella* and *Pseudomonas* in the studied stretch of Alaknanda. High range of DO (8-9.8mg/l) and low range of BOD(1.2-2.8mg/l) for the studied river stretch showed its good purification potential. Moreover, algae like *Oscillatoria, Euglena, Chlamydomonas, Navicula, Nitzschia, Fragillaria, Amphora,* and *Synedra* were dominant in organically polluted sites. The periphyton density was recorded maximum 19.9 x 10^{10} /m^2 at S4 site and the periphyton biofilm thickness was recorded maximum 3.8 mm at S4 site. Mostly the sites having high BOD i.e. S4 & S6 harbored high level of bacterial and algal species representing them as a good indicator of organic pollution. The study suggests that the water of studied stretch of the River Alaknanda is not compatible for drinking purpose without treatment as the presence of various pathogenic agents have been observed that may enhance the chances of various diseases and infections to local people of the region.

DISTRIBUTION OF SOME HEAVY METALS IN THE SEDIMENTS OF GANGA (HOOGHLY) ESTUARY

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ABSTRACT

Ganga River ranks among the largest ten rivers in the world in terms of water and sediment flux to the world oceans. Pollution levels in this river of national as well as global importance are closely linked to the well being of more than half the population of India. Suspended sediment samples of Ganga Estuary from Howrah to Gangasagar and nearby deltaic and coastal areas were analysed for the toxic heavy metals Hg, Cd, Pb, Cu and Zn to ascertain their distribution along the estuary. In general, the heavy metal distributions show a decreasing trend towards higher chlorinities with the exception of the confluences of Damodar and Haldi rivers with the Hoogly. These exceptions are suggestive of inputs from the coal belt and Haldia Industrial Complex. Zn, Cu and Cd show good positive relationship with major rock forming elements, viz. Al, Fe and Ti, suggesting dominantly geogenic origin, while Pb and Hg show poor correlation with other metals. Sediments from Sunderban creeks show enrichment of Cu, Zn and Cd, probably owing to tidal influx and finer sediments being locked up in the creeks. Hg is found to be highly enriched in both the suspended and bed sediments of the Ganga estuary. In general, non-monsoon samples gave higher concentrations of heavy metals than the monsoon samples. Fe showed very good correlation with most of the studied heavy metals, suggesting that most of these pollutants are associated with iron oxide complexes. Chemical fractionation of Zn, Cu, Pb, Cd along with Fe in selected sediment samples were carried out using sequential extraction method following Tessier et al (1979). The fractionationation studies revealed that all the metals are dominantly associated with the residual fraction. Among the non-lithogenic fractions the Fe-Mn oxide fraction is dominant for all the metals studied except Cd. The organic fraction which is known to be scavenger of heavy metals has been found to be less significant in Ganga Estuary, exceptions being samples taken from Haldi River where the organic fraction constituted nearly 10% of Cu and Zn. Cu shows a significant association with exchangeable and carbonate fractions in the bed sediments. The study suggests that Ganga estuary is polluted with respect to Hg and Cd in some of the sampled locations. Tidal influence shows a diluting effect with all the heavy metals studied. The mangrove swamps of Sunderbans are found to be a sink to some of the heavy metals.

HUMAN-INDUCED N:P:SI IMBALANCES IN GANGA RIVER: CAUSAL RELATIONSHIPS AND IMPLICATIONS

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ABSTRACT

A connective organized framework to understand nutrients and carbon (C) budget is a critical challenge the scientific communities are facing globally. Anthropogenic activities have dramatically altered the biogeochemical cycle of carbon making it difficult to separate natural aspects of C sequestration from those induced by human perturbations. Since human alteration of carbon cycle is in part linked with other major biogeochemical cycles, particularly that of nitrogen (N) and phosphorus (P), such alterations become more critical for river systems which receives nutrients from watershed as well as from airshed. Air- and watershed contributions of N and P to Ganga River remain relatively uncertain despite recent research highlighting its importance. Further, since the global variations in riverine silicate loading are predominantly controlled by natural factors, disproportionate and relatively high inputs of N and P due to anthropogenic activities may lead to shift N:P:Si stoichiometric ratios shifting trophic cascades and other ecological attributes in rivers in a long run. In this long-term study, conducted along 37km stretch of Ganga River at Varanasi, we show the changing state of atmosphere- land- water transfer of N and P and associated shift in N:P:Si stoichiometry and dissolved organic carbon DOC build- up in Ganga River. This has relevance since about 73.44% area of this largest basin of India constitutes agricultural land. We found a variable but strong linkage between atmospheric deposition and hydrological control of terrestrial C, N and P input to the river. However, these increases were not paralleled by a similar increase in silicate inputs and, consequently, unbalancing the Redfield ratios (N:P:Si:: 16:1:16, cellular requirement for balanced growth of phytoplankton) in the river. Diatom abundance changed with concurrent shifts in elemental ratios with dominance-diversity curves markedly skewed from a log-normal pattern. Since atmosphere-land-water connectivity is central to riverine nutrients and C budgeting, and a balanced N:P:Si is essential for maintain natural trophic cascades, which have been largely a neglected issue in this river system, we suggests that Ganga River rejuvenation strategies should, in addition to sewage treatment and flow regulation, also address significance of critical nutrients especially N and P being added through air- and watershed. Research initiatives integrating these

issues would help policy makers' in river rejuvenation and adopting strategies for integrated river basin management (IRBM).

STRICT DEPENDENT ON C/N, C/P AND RBCOD/SBCOD RATIO FOR ENHANCED BIOLOGICAL NUTRIENT REMOVAL DURING SEWAGE TREATMENT

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ABSTRACT

Normally nutrients (nitrogen and phosphorus: N & P) present in relatively lower concentration in sewage as compared to other pollutants, but the potential impact of their discharge in environment create the real picture. If 1 mg of disposed P & N is completely assimilated by algae and used to manufacture new biomass from photosynthesis, an amount of biomass of 114.5 mg/mg P with a COD of 142.4 mg/mg P and 16 mg of algal biomass/mg N and 19.7 mg of COD/mg N would be produced, assuming algal composition as C106H263O110N16P. Thus, for a discharge of 4 mg P/L & 30 mg N/L (assumed typical average) could potentially result in a COD production equivalent to 854 mg/L and 591 mg/L respectively, which is more than double the COD of organic matter in untreated sewage (Randall et al., 1992). Therefore, the real objective behind wastewater treatment is to bring the water back to quality closed to what it did possess, when supplied initially in a potable form i.e. free from BOD and nutrients. Carbon to nutrient ratio (C/N, C/P) is one of the limiting factors in biological nutrient removal from municipal wastewaters, since denitrifying bacteria are known to compete for a carbon source with other heterotrophs; it results in a rapid carbon deficit, and unbalanced simultaneous nitrification and denitrification. It is not C/N ratio alone but readily biodegradable to slowly biodegradable COD ratio (rbCOD/sbCOD) inter alia governs the process of nutrient removal. At C/N ratio > 6.75 the total nitrogen (TN) removal > 85% is achievable while it reduces to < 35% when C/N ratio is less than 1.25 (Khursheed et al., 2012). An essential prerequisite to EBPR is the combination of anaerobic and aerobic/anoxic conditions so as to facilitate phosphorus accumulating organisms (PAOs) to sequester the electrons (to assimilate rbCOD i.e. VFAs), in the absence of any electron acceptor (DO and NO3) into storage products Poly-β-Hydroxy Alkaonate (PHA) within the cells. The presence of appropriate proportions of C/N in municipal wastewater is important for the efficient performance of any BNR process. However the real challenge is given by low C/N ratio. Abid Ali Khan (2012) reported C/N ratio of around 3.5 on an average in Punjab, UP and Uttrakhand (India). The C/N ratio in another long term study (128 days) varied from 1.15 – 8.27 (avg. = 3.05, σ = ± 1.5) and on 70% occasion C/N was < 4 and on just 5% times it was > 7. The biggest impediment in nutrient removal is low carbon to nutrient contents (C/N & C/P) reported in many parts of India and from our point of view R &D on nutrient removal along with

BOD/COD, TSS and pathogens from low strength (low C/N, C/P and rbCOD/sbCOD) wastewater shall be essentially focused to rejuvenate River Ganga and in order to achieve comprehensive treatment.

ROLE OF SUSPENDED SEDIMENT LOAD ON WEATHERING RATES IN THE MELTWATER OF THE GANGOTRI GLACIER, CENTRAL HIMALAYA, INDIA

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ABSTRACT

Glaciers are considered as a sensitive indicator of climate change. Three great rivers of north India: Ganga, Indus and Brahmaputra are fed by Himalayan glaciers. Transportation of suspended sediment from meltwater of Himalayan glaciers plays an important role for planning of reservoir including establishment of hydropower project. Suspended sediment concentration in the meltwater of Gangotri glacier is highest during monsoon period (July-August) and lowest during post-monsoon period, while it shows increasing trend from morning to evening followed by the decreasing trend in the night. Hence, it follows discharge patters of the study area. The suspended sediment load of Gangotri glacier meltwater is much higher than other Himalayan glacier. This may be due to geology, large quantity of rock debris and high discharge of the investigation area. High ratio of TSM/TDS of the Gangotri glacier meltwater shows varying degree of dominancy of physical weathering over chemical weathering with increasing discharge in the glacier basin. The physical weathering rate of this glacier catchment was much higher than the Indian and world averages of river. The high rates of physical weathering are due to intense monsoonal rainfall, high discharge, lithology, steep valleys with high seismicity.

EFFECT OF MASS BATHING ON RIVER WATER QUALITY OF GANGA DURING SAWAN MELA AT HARIDWAR, UTTARAKHAND

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ABSTRACT

Since Ancient times, River Ganga has been considered as one of the most sacred rivers in the world. Thus, pilgrims from all over the world visit India to take a bath in the holy river Ganga to get rid of their all sins. Mass bathing in a sacred river is an age old ritual in India. The Ganga river water forms the lifeline of almost all the human activities as also most of nature's activities along the gangetic plains. Many of the pilgrims visiting the holy places like Haridwar for bathing carry skin and other communicable diseases that lead to increase in the number of disease causing bacteria in the river water. Also, local people and the pilgrims wash clothes, offer milk, curd, ghee, flowers, ashes of departed ones, body hair and other religious materials into the river Ganga. This all causes a large increase in the number of pathogenic organisms (faecal bacteria) which may cause various skin diseases as well as many water borne diseases. Ultimately, the study highlighted that mass bathing during Sawan Mela caused a change in the river water quality making it unfit for drinking as well as for bathing purposes.

MODELLING SOIL EROSION AND SEDIMENTATION IN WATER BODIES IN PARTS OF SOUTH GANGA BASIN

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ABSTRACT

The soil has been defined by the International Soil Science Society as 'a limited and irreplaceable resource' and the growing degradation and loss of soil means that the expanding population in many parts of the world is pressing this resource to its limits. In its absence the biospheric environments man will collapse with devastating results for humanity. Fertile soils by carrying erosion, fills dam reservoir and reduces dams economical life, hence economy of country get debilitated to big amount. To specify hazard and damage of soil erosion is very important for this reason. Among many environmental hazards, checking land degradation is of utmost importance as it has direct bearing on decline in productivity on arable and non arable lands. It is estimated that India suffers an annual loss of 13.4 million tones in the production of major cereal, oilseed and pulses crops due to water erosion equivalent to about 2.6 billion dollars. Reservoir sedimentation, resulting from degradation of the watersheds in India, is on rise as compared to the rate that was assumed at the time the projects were designed. Hence the operational life of reservoir is diminished. Climate, soil, vegetation, topography and man are the factors that affect soil erosion, and out of these, vegetation and soil to some extent, are the only factors which man can control. To prevent the Erosion and rapid siltation, management of water, soil cover and vegetation resources on watershed is must.

Universal Soil Loss Equation (USLE) is the most widely used empirical formulae for evaluating gross erosion from any basin. Merging the same with recent technology of remote sensing could provide us with more precise results. The model separates the soil erosion process into a water phase and a sediment part. It considers soil erosion to result from the detachment of soil particles by raindrop impact and the transport of those particles by overland flow. The model tries to cover some of the recent advances in perceptive of erosion processes. In this paper the application of USLE model and GIS has been attempted for determining the quantity of soil erosion. Satellite Remote Sensing (SRS) provides important information in terms of present water spread area of the reservoir at specific elevations, which is used for computation of revised capacity of the reservoir. The revised capacity is useful for planning the reservoir operation and scheduling the irrigation water supply in the command area and hydropower generation.

SEDIMENTATION DEPOSITS, SOIL EROSION AND BREAK WATERS

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ABSTRACT

Sedimentation deposits, soil erosion and break waters have been seeking attention now for quite a while. We have been affected slightly or largely by these factors for many decades. The situation has become a bigger threat for the living society and the future generations, due to haphazard and rapid industrialization and urbanization at numerous places. It not only leads to floods but also affects the water courses, thus affecting seriously the flora and fauna abutting the water bodies.

The causes of sedimentation and soil erosion are many but a careful mapping/highlighting of them can bring substantial changes on their re-occurrence. In sedimentation deposit category, construction practices play an important role. In the Construction industry, huge amounts of soil particles become loose after soil erosions on account of quarrying. These detached soil particles find easy access to many places and more especially in water bodies. The results are obvious choking of water bodies, rivulets and life providing rivers. In India, Rivers are treated not only as water bodies but forms a part of the culture and tradition of the inhabitants. Hence, it becomes the need of the hour to study the field of improvement in the current quarrying techniques employed along the length and breadth of the water bodies. A careful study on the practices at the construction sites is also needed, as these also severely affect the areas of discussions. The paper discusses some of the good practices at construction sites for sediment and erosion controls such as (i) Establishing a single stabilized entry point for quarry materials (ii) Installation of geotextile sediment fence or straw embedded in ground on the low side to control soil erosion (iii) Proper stacking of the materials inside the site fence and avoiding placing it alongside the footpaths (iv) Establishing a wash down area on the other side of the sediment control areas (v) Filling up of trenches or dug out areas immediately after laying the services and compacting them to required density (vi) Stabilization and vegetation on the disturbed areas of soil (vii) Fixation of down pipes and channels to the storm water drains and avoidance of free surface flows of rain water before the storm water drains.

The identification and location of breakwaters also assume high significance in the developing countries especially due to increased soil erosions along the banks of water bodies and large rivers. These erosions invite floods besides affecting the flows of water bodies and hence the cultivations along the banks. The break waters not only protect the river banks but also from floods and devastations. Owing to the high cost involved in the construction of break waters however, a careful study is required to identify the precise locations along the sacred river Ganga where immediate implementations are required.

This paper discusses how the construction practices assume significance in sediment build ups, erosion of soils and the need of break waters at the right places along rivers both perineal and non-perineal.

INVESTIGATION OF HYDRODYNAMICS AND WATER QUALITY OF TEHRI RESERVOIR THROUGH NUMERICAL MODELLING PRIOR TO ITS COMMENCEMENT

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ABSTRACT

Multipurpose Tehri hydroelectric project located at the confluence of Bhagirathi and Bhilangna, tributaries of the river Ganga, at Tehri in Uttaranchal State was commissioned in the year 2006 to tap vast potential of water and power resources. The project consists of 260.5 m high earth and rock fill dam called as Tehri dam, resulting into impoundment of a reservoir of gross storage capacity of 3540 Mm^3 out of which about 925 Mm^3 exists below Minimum Drawdown Level (MDDL). The reservoir is popularly known as Tehri Reservoir. The installed hydropower capacity under stage-I of Tehri dam is 1000 MWe. Prior to commencement of Tehri Project, mathematical model studies were carried out at CWPRS, Pune in the year 2001 to assess the flow circulation processes due to inflows of water from the two tributaries of the river Ganga and outflows through power intakes. In addition to these, water quality aspects such as dissolved oxygen (DO), biochemical oxygen demand (BOD) and water temperature of the reservoir were investigated. The flow processes in Tehri Reservoir were expected to be governed by the inflow and outflow induced circulations, temperature induced stratification and density induced flows making it three dimensional in nature. A commercial three dimensional software, MIKE-3 developed by DHI, Denmark was used for the studies and the findings thereof are discussed in the present paper.

The hydrodynamic and water quality model simulations were carried out for the expected area covering the backwater reach of 42 km in river Bhagirathi and 20 km in river Bhilangna discretized into 141x101 grid cells in XY-plane with 250 m square grid spacing. In vertical direction, 11 layers were considered having thickness of 20 m each. Two scenarios considered to be critical were tested in the model; beginning of winter when reservoir was assumed to be full and during summer when reservoir was supposed to be at the lowest level. The major findings of the studies were: (i) The residence time of water in the reservoir varies between 17 to 100 days. (ii) The ratio of total volume and average fresh inflow rate was of the order of 0.45 indicating that the reservoir would be expected to replenish within a year. At the end of monsoon and during winter period when the reservoir level is high, the fresh water would flow in the top layer and would be expected to flow directly towards the outlet with dilution depending on inflow and outflow rate. At the beginning of summer and monsoon

seasons when the reservoir level is lower and the flow is higher, there would be mixing over the entire depth and mixed water would propagate towards the outlet. These flow processes indicate that there is no possibility of significant stagnation of water in the reservoir so as to degrade the water quality.

Model results show that temporal and spatial variation of river water quality parameters like DO, BOD in the reservoir would not change significantly due to impoundment. The studies report was very useful to clarify the apprehensions of the people regarding degradation of Ganga water due to the development of Tehri Project.

REJUVENATION AND ACCRETION OF GANGA RIVER IN AND AROUND HARIDWAR, UTTARAKHAND, INDIA

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ABSTRACT

The famous historical civilizations are discovered along the major river banks. Thus, it is well recognized that the rivers are playing an important role in proper settlement of progressive prosperous civilizations. The Ganga River is one of the major rivers of the country. The Ganga River is originated from Gangotri Glacier and well famous by name Bhagirathi in its extent up to locality Devprayag, Uttarakhand. The part of river after Devprayag is called Ganga which has largest river basin of the country. This river basin houses approximately 40% population of the country. It has a long track of 2525 km and finally encountered with sea at Ganaga Sagar in Bay of Bengal.

Presently, the Ganga River is found highly polluted in conditions due to accumulation of disposed huge quantity of pollutants released from industries, municipal sewages and non-point sources. The active channel of Ganga River is presently unable to disturbs the accumulated pollutants may be either the weakened energy condition of the channel system or increased in pollutants and sediment. The problem may be minimizing ether by change in natural condition or through the technological applications and modifications in channel system. Hence, the proper investigation related to rejuvenation and accretion patterns of Ganga River may provide the details of natural activities going on its flow rout which will relevant for pertinent planning and design of mitigative measures for rejuvenation of Ganga River to maintain its efficient energy levels and achieve its previous status. Therefore, present study is concentrated to recognize natural rejuvenation and accretion processes of Ganga River by using major morphometrical tools on the base of imageries, Google Earth maps and DEM data of the selected region. In connection with the present investigation, migratory path of Ganga River has been analysed through measured stream length gradient (SL) values between the periods ranging from 2005 to 2015 in interval of 5 years along a track length of 55 km and area of 502.75 sq km lying between Motichur to Balawali near Haridwar, Uttarkhand, India. The established migratory path was utilized to identify the neotectonic activities in the area within the above said periods which have close interrelationships with both rejuvenation and accretion patterns of Ganga River. Besides, the demarcated sites and times of neotectonic activities were verified through other evidences also. The values of SL index are supported by sinuosity (SI) index, Asymmetry factor (A_s), and longitudinal profile (L) analysis. In addition, these indices are also supplemented by earthquake data for the purpose.

The results of study reveal the three distinct sites and time frames of neotectonic and seismotectonic activities marked as major rejuvenation and accretion patterns of Ganga River in the area between years 2005 to 2015. Theses inferences of recognized such activities induced energetic processes may be relevant to scientists, technologists and planners involved in cleaning and development works concern to Ganga River in downstream.

IMPACT OF MASS BATHING DURING KUMBHA MELA 2010 ON WATER QUALIY OF RIVER GANGA AT HARDWAR

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The Ganga is the largest and the most important river of India, associated in mythology and present social life with the land and people of India as well as neighbouring countries like Bangladesh. In fact, all along the course of the Ganga, from its source at Gaumukh to its mouth at Sagar Island, the river is considered holy and millions of people take bath in it every day to purge away the sins. For the purpose of bathing, the second highest (Class B) level of quality of water is essential. It, therefore, becomes imperative that strict monitoring of the quality of water along different reaches of the river is maintained and adequate measures are taken to keep the Ganga free from pollution particularly at the bathing ghats, places of pilgrimage and at abstraction points on its course. Maha Kumbha festival was organized in Hardwar in the year 2010. Hardwar hosted the Purna Kumbha mela from Makar Sankranti (14 January 2010) to Shakh Purnima Snan (28 April 2010). During this period, nine main snans (bathe) were held. Millions of Hindu pilgrims attended the mela. On April 14, 2010, alone approximately 10 million people bathed in the River Ganges. According to officials by mid April about 40 million people had bathed since January 14, 2010. To assess the adverse impact of Kumbha mela activities on the water quality of River Ganga at Hardwar, water samples from different locations of River Ganga were collected at fortnight interval of time from January to June 2010 generally just after Sahi Sanan day by doing 11 samplings and analysed for physico-chemical (pH, EC, TDS, Alkalinity, Hardness, COD, BOD, Major Cations (Na, K, Ca, Mg), Major Anions (HCO_3, Cl, SO_4, NO_3), Minor Ions (F, PO_4)) and bacteriological (Total Coliform and Faecal Coliform) and metal concentrations. The results were compared with the baseline data generated on non-pilgrimage day. Data revealed that all the physico-chemical parameters and metal analysed in the collected samples from River Ganga were found within the limit prescribed for drinking water by Bureau of Indian Standards, however, very high bacteriological contamination was observed in the River Ganga during the study period which may be attributed to the impact of mass bathing and other activities due to huge crowd of pilgrimage collected during Kumbha mela period at Hardwar specially on Sahi Snan dates and Ganga river water was found even not fit for bathing purpose at some locations on few dates during the study period. Recommendations have been given to

clean and maintain the purity of river water specially during occasion of mass crowd viz, Kumbha mela, Kawar period etc.

STATE OF WATER, SANITATION AND HEALTH IN THE GANGA BASIN

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ABSTRACT

Water, sanitation, and health are the inter-related issues that need to be addressed in an integrated and holistic manner in the Ganga basin. Inadequate access to safe drinking water and sanitation facilities and poor hygiene practices lead to ill-health. With rising urbanization and industrialization and population pressure in the basin, the demand for water has been constantly increasing in all the sectors, which not only causes depletion of water resources but also contaminates these resources. Untreated industrial wastes, domestic sewage, open defecation, dumping of animal carcasses, bathing and ritualistic practices, including immersion of idols and floral materials in the river and the non-point sources of pollution in the form of seepage of pesticides and chemical fertilizers have become key sources of water pollution, which puts enormous burden of diseases, especially on the poor households, who cannot afford to have costly water-purifying system. Huge amount of out-of-pocket expenditure on medical treatments can be saved if access to safe drinking water and sanitary toilets properly linked with the sewer system is provided. Therefore, maintaining uninterrupted and unpolluted water flow in the Ganga is not only required for sustainability of environment and ecosystem but also for the health of economy of the basin and its people. As water-borne diseases are mostly communicable in nature and have negative externalities; these can be effectively controlled only if improved water, sanitation and drainage system is created in the entire basin. It is in this context that an attempt has been made to examine three inter-related issues—water, sanitation and health—in the Ganga basin and to link them with the water-related/water borne diseases. Although the study presents an overview of existing public healthcare infrastructure and makes detailed discussion on healthcare expenditure, the focus, however, is on water-related health issues and diseases and cost of water treatment and healthcare incurred by the households.

The study is based on the secondary data drawn from various published sources, such as National Health Profile, National Health Account, Rural Health Status Bulletin, Population Census of India and 60th Round of NSSO. The information on the number of households using bottled water and treated water before drinking has also been collected to find out the expenditure incurred by the households on such practices. Information on medical expenditure and loss of household's income due to hospitalisation has also been collected. For some indicators of water borne diseases, data from National Health Profile (NHP) and 60th NSS round have been used. The study indicates that preventive measures may be more cost-effective than the curative ones as they can ensure better human health and prevent loss of productivity and missed educational opportunity that may occur due to illness. The study suggests that major cities and towns should have sewage system properly integrated with toilets and waste treatment plants. Further, as monitoring quality of water and sanitation services by the

government machinery may not be economically viable in the rural areas, there is need to train a group of young persons (4-5) in each village for this purpose. These youths may also be engaged in maintaining socio-economic, demographic and health related database, which is essential for designing and executing an effective planning for water, sanitation and healthcare services.

MUSINGS ON POLICY AND GOVERNANCE ISSUES FOR THE GANGA

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ABSTRACT

The Ganga River drains catchments area of about 862,769 km2 which is nearly 26.2% of the total geographical area of our country. The Ganga River has significant economic, cultural, social and religious importance for India. With respect to water issues, India has decentralized approach in vogue. More than 12 different ministries are directly or indirectly involved to the water issues. Sometimes it makes the water resource planning system very slow and lethargic. Resource managers make management decisions on the basis of their perceptions of the most critical pressures on the resource and the tools they have available to manage. If the perceived pressures are not the real pressures, managers are likely at best to waste time and money addressing less important issues, and at worst to allow significant resource degradation as they fail to respond to real important pressures at hand. In developing countries, data are often sparse, interpretations and analysis uncommon, and management policy is often greatly influenced by consultants from elsewhere who may or may not have a sound appreciation of the local situation. The prime water management issues of the Ganga are as follows: (1) Deteriorating water quality threatens resources and their sustainability. (2) Extensive unabated stream bank erosion and sporadic deposition processes are raison d'être for acute morphological instability of the Ganga River. A SWOT analysis is a structured planning method which can be used to evaluate the Strengths (Quantity, Quality, and Agricultural Support, Biodiversity and Habitants), Weaknesses (Different interests, Complex process, Multiple-Sectoral Involvement, Decentralized Approach, Lack of data to support technical tools and Uncertainty of the political dimension), Opportunities (Socio-economic development, Country development, Ecological Conservation, Institutional support, Water Business, Knowledge Management and Integrated land & river basin management, and Threats (Water Quantity - Sharing and Benefits, Water quality degradation) to support the policy planning and governance mechanism. This process requires the observation of policies' effect on the Ganga River over time using periodically spaced measurements, extraction of features from these measurements and the statistical analysis of these features to determine the current state of water policy health.

TIME SCALE CHANGES IN FISH ASSEMBLAGE, COMPOSITION AND INVASION OF EXOTIC FISHES IN THE RIVER GANGA

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ABSTRACT

The Ganga is the fifth largest river in the world which drains about 1,060,000 km^2 geographical area in India (80 %) and neighbouring countries. The river passes through 2525 km from its origin at Gangotri to confluence with the sea covering varied catchments consisting glacial no-vegetation zone, alpine and broad leaved forests, meadows, agricultural fields, high density human settlements and industrial developments. As a result, the river system harbor about 265 fish species including coldwater from Himalayan stretch, warm water and estuarine fishes. The river Ganga is facing serious consequences from massive anthropogenic activities along the catchments since last few decades. The river along with its tributaries is dammed or proposed for damming at about 70 sites in Uttarakhand. Due to multiple obstructions, abstractions and addition of pollutants from industrial, domestic sources and agricultural run-off , the river is rapidly degrading at many stretches. Accordingly fishery of the river in general and that of the sensitive species in particular is facing serious threats from loss of habitats, barriers on migratory paths, loss of deep pools, drying of feeding and breeding grounds. The obstructions have blocked migratory route of the important Himalayan fishes like mahseer and snow trouts. Other important migratory fishes of the plains also severely affected by river abstractions are *Tenualosa ilisha*, *Bagarius bagarius, Anguilla bengalensis* etc. Since 1970 onwards, fishery from river started declining with sharp changes in stock structure. Indian major carp fishery contributed about 96.0 tons at Allahabad during 1961-68 reduced to 34.77 tons in the year 2014. The total fish yield rate also slipped with drastic decline in catches of Indian major carps and large catfishes. The commissioning of Farakka barrage in the river has exterminated the lucrative hilsa fishery above the barrage, as a result catch at Allahabad is totally exterminated since 2006, while it was 22.0 tons during 1961-68. The altered habitat conditions also result in depletion of sensitive native species and invasion of exotic fishes. The exotic fishes were not recorded in the river at Allahabad till 2000, but registered considerable population later on and contributed 17.32 to 43.0 % in the total catch during 2003-14, comprised by common carp and tilapia. Besides these, 5 other exotic species have made inadvertent access in the river at different stretches. The river Ganga is known as original abode of the valuable Indian major carps, which are major commercial fishery group in the river. Drastic depletion in valuable native fish species;

rapid invasion and establishment of resilient exotic fishes is a matter of great concern and warrant serious efforts for conservation of valuable native species of the river.

POLLUTION BIOMARKER(S) FOR AQUATIC ENVIRONMENT MONITORING IN RIVER GANGA

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The river Ganga is one of the most important rivers in India and pollution of Ganga has been a principal environmental concern. Biomarkers, which are biochemical, physiological or morphological response of living organisms, are important for pollution monitoring, abatement and management. Biomarkers may simply signify exposure to contaminants, may predict future harm or may themselves be harmful effects resulting from pollution. Work in this direction is being carried out studying the gene expression profile and protein abundance of a battery of *stress proteins* (*hsp 27*, 47, 60, 70, 90, hsc 70), *besides the* CYP1A1, CYP1A2, WAP 65 plus few more, under proteogenomics platform in the catfish *Rita rita* collected from different stretches of Ganga (Kanpur, Allahabad, Varanasi, Farakka (reference site), Serampore, Howrah to investigate their potential as pollution biomarker(s). Few stress proteins showing isoforms in heavily polluted stretches like Kanpur, Howrah indicate their potentiality as pollution biomarker(s) and merit further investigation. The paper discusses the various findings.

ESTIMATION OF ARSENIC AND MERCURY IN FISHES FROM RIVER GANGA FOR RIVERINE ECOSYSTEM HEALTH BIOMONITORING AND ASSESSMENT

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ABSTRACT

Periodic monitoring of the environmental quality of riverine ecology is necessary as it supports a wide range of life forms living in it. Environmental quality is often assessed in terms of physical and chemical parameters only. However, the biotic components can also reflect the health of an aquatic ecosystem as water pollution leads to bioaccumulation of the pollutants in fish and other aquatic organisms through the food chain. As fish is placed higher in the aquatic food chain, concentration of pollutants in fish tissues is a true representative of their concentration in the ecosystem. In this regard, concentration of toxic environmental contaminants arsenic (As) and mercury (Hg) in fishes from river Ganga were investigated by inductively-coupled plasma mass spectrometry (ICP-MS) to assess the level of these contaminants in different stretches of the river. Total As concentrations in *Tenualosa ilisha*, *Sperata seenghala*, *Amblypharyngodon mola* and *Puntius sophore* were 0.02-2.9 mg kg^{-1} which is within the permissible limit. Mean Hg content was below the permissible level (0.003-0.05 mg kg^{-1}) in all fishes analyzed from different stretches. This biomonitoring study showed that river Ganga, in the indicated and adjoining stretches, are free from arsenic and mercury contamination. This study demonstrated the dual benefits associated with using fish as biomonitors; it serves as a tool for riverine ecosystem health monitoring and at the same time provides information on food safety as well.

WATER QUALITY MANAGEMENT OF A TROPICAL MONSOON RIVER POLLUTED BY MASS BATHING

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ABSTRACT

River Kshipra is one of the most sacred rivers in India. Millions of pilgrims come and take holy dip in the river during auspicious occasions. The river carries only monsoon runoff and is dry during non-monsoon season (October to May). Stop dams across the river have been constructed to create four pools for bathing purposes. Often river water quality does not meet the quality requirement specified for mass bathing by CPCB.

Based on pollutant mass balance and some logical assumptions, mathematical models have been developed for BOD and coliform management as per CPCB standard. The models have been used to estimate daily, monthly, and annual water requirement of each pool separately during normal year and during Simhasth festival (year 2016). The results show that water requirement for BOD management is more than that for coliform management. Surplus and deficit of water have been worked out considering average monthly flow and 75% dependable flow of river Kshipra(based on 20 years discharge data). The 75% dependable surplus during wet period is not adequate to meet deficit during dry period, whereas 50% dependable surplus is adequate.

ANALYSIS OF DISINFECTION SYSTEM FOR WASTEWATER TREATMENT WITH SPECIALREFERENCE TO TRIHALOMETHANES FORMED DURING CHLORINATION

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ABSTRACT

Disinfection is basically the removal of pathogenic micro-organisms present in treated water that have potential of causing various waterborne diseases. There are various techniques for disinfection i.e. chlorination, ultraviolet disinfection, ozonation, membrane filtration. Chlorination is the most widely used technique for disinfection in India. Chlorine is found to be effective against some of the most common waterborne microbial pathogens particularly bacteria. Disinfection for wastewater water reduces the risk of pathogenic infection but may pose chemical threat to human health due to disinfection residues and their by-products (DBPs) when the organic and inorganic precursors are present in water. Disinfection generally leads to formation of various disinfection byproducts (DBPs) and in case of chlorination DBPs are trihalomethanes and haloacetic acids (HAAs). THMs are highly carcinogenic in nature and can have adverse health effects when used directly or indirectly by humans. Generally treated wastewater is discharged into rivers or is used for agriculture purposes. These activities may or may not have direct human use like drinking, bathing etc. but indirectly they are also being used by humans and can come in human contact through skin exposure or inhalation and can cause serious health issues. UV disinfection generally utilizes electromagnetic energy to inactivate microorganisms and there is no chemical involved and chances of formation of any kind of DBP are extremely low. Nowadays newly established wastewater treatment plants are opting for UV as a method for disinfection and are considered as a better alternative to chlorination which apart from safety and handling issues has issue of DBP toxicity also. This study aimed at analyzing the importance of disinfection in wastewater treatment process including the integrity of technique being used for it. In India use of UV as a method of disinfection is very limited, mostly to industrial wastewater treatment plants or effluent treatment plants. After a search of wastewater treatment plants installed in North Indian states, wastewater treatment plants in Uttrakhand and Haryana state were studied for presence of trihalomethanes in their treated effluent. The effect of technology being used for wastewater treatment on Trihalomethane formation was also analyzed. Trihalomethanes were analyzed using Gas Chromatography-Mass spectroscopy with Purge and Trap technology at Central Pollution Control Board, New Delhi. Highest concentration of THM was obtained in UASB plant and very low concentration of THM was obtained in SBR, OP and ASP technology based plants. Based on annual cost analysis of UV & Chlorination, it has been found that UV is an overall effective technique for disinfection long run despite of its initial capital and operation and maintenance cost.

APPLICATION OF 'MATLAB- NEURAL NET' TO DEVELOP A MODEL FOR WQI FOR PALLA REGION OF YAMUNA RIVER

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ABSTRACT

River Yamuna enters Delhi near Palla village after traversing a route of about 224 Km. The river is again tapped at Wazirabad through a barrage for drinking water supply to Delhi. Based on the water quality, the entire Yamuna river stretches may be segregated into five distinguished stretches i.e. Himalayan stretch, upper stretch, Delhi stretch, mixed stretch and diluted stretch (CPCB, 2006-07). The 22-km stretch of the Yamuna, which is barely 2 per cent of the length of the river basin, continues to contribute over 80 per cent of the pollution load in the entire stretch of the river. A water quality index provides a single number (like a grade) that expresses overall water quality at a certain location and time based on several water quality parameters. The objective of an index is to turn complex water quality data into information that is understandable and useable by the public. This type of index is similar to the index developed for air quality. However, a water index based on some very important parameters can provide a simple indicator of water quality. It gives a general idea to the public for possible problems with the water in the region.

Soft computing techniques are relatively new emerging techniques used in hydrologic and water resources systems. Therefore, new emerging techniques as a tool ANN of MATLAB is frequently used to develop the models. The theory of ANN trained the network using past experiences. During this study, the quality of drinking water by estimating the water quality index of all samples from different sampling stations in Palla region of Yamuna river using Empirical methods, and MATLAB - Neural Net have been analysed.

GANGA RIVER REJUVENATION: SOME SCIENTIFIC ASPECTS

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The “Ganga river” is India’s life line. It is an integral part of our history and cultural ethos. Sadly, the condition of the Ganga has become pitiable over the years. Thousands of tons municipal, industrial and sewage wastes is being dump into Ganga and its tributaries every day which is loaded with various toxins, hazardous materials and heavy metals. The pollution is at discouragingly high levels. Thousands & thousands of crors of rupees are already spend but still without Success. This is mainly because of mismanagement of money, lack of scientific / technical knowledge and bad environmental planning. There are many threats, which we have to carefully understand, plan and propose most suitable solutions required for clean and healthy Ganga. We have to address all the problems effectively, such as - efficient treatment and disposal of sewage, proper management of municipal solid waste, control & elimination of industrial / commercial pollution, check and stop illegal sand and stone mining and agricultural run-off in Ganga. Eutrophication is a natural process of recycling nutrients in aquatic ecosystem by various living organisms. But due to addition of large quantity of nutrients mainly - phosphates, nitrates, etc from sources like - municipal solid waste, wastewater, sludge, animal husbandry, detergents, fertilizers, dead animals, etc the rate of eutrophication increases exponentially. Which lead to algal blooms, this changes aquatic natural food web, reduces dissolved oxygen, increases turbidity - which damages aquatic ecosystem, resulting in dead zones, caused by depletion of oxygen [hypoxia]. This also leads to increase of pathogenic organisms. In addition to this toxins & hazardous materials [from - pesticides, insecticides, herbicides, fungicides, industries, commercial organizations, institutions, households], directly infect & kill aquatic flora & fauna.

REVISITING THE CENTURY OLD CONCEPT 'LANDSCAPE-RIVERSCAPE' FOR REJUVENATING RIVER GANGA

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ABSTRACT

Ganga river is and has been extensively researched in almost every city which it crosses, but the lacunae of these researches lies in viewing the river spatially. Spatial perception of a river provides the framework of researching the river and land in combination. The present study is an attempt with scientific evidence that river physico-chemical properties are affected by the type of land use along which a river flows. The study is confined to the Ganga of Varanasi district. The sites representing two major land use viz. agriculture and urban within 1000 m buffer radii from the river bank were selected. The water samples from six sites representing each land use were collected in pre-monsoon and post-monsoon season and tested for DO, BOD, COD, nitrate and phosphate. The data obtained was subjected to statistical analysis resulting in significant relation between the parameters, land use and season. The study concludes that the water quality of river Ganga in Varanasi is strongly being affected by its catchment buffer zones land uses. The urban landscape impairs the riverine conditions more than that from agriculture landscape. This research brings in for planners and policies makers to look at the river from landscape perspective, as whatever pollutants enter the river find their way through the land. So, the concept of changing land use pattern (along the riparian zones and in the basin) which has been overlooked hitherto needs to be adjudged scientifically.

SEGMENTAL APPROACH FOR FORMULATING THE FRAMEWORK AND POLICIES FOR NAMAMI GANGE

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ABSTRACT

Cleaning of river Ganga has been the mission of the Government and number of steps have been taken in past 30 years to prevent and control pollution of river Ganga and for restoring its sacredness. The overall pollution control efforts require combination of interventions like creation or rehabilitation of the Sewerage infrastructure, river front development, upgradation of cremation process, improved sanitation facilities and providing public amenities as and when required. Despite several actions taken so far, the level of success achieved is being debated and it has been a common understanding that a lot more remains to be done. With the aim of having a fresh approach towards Ganga conservation, Government of India launched the Namami Gange program. Under the new concept, a holistic approach and entire Ganga will be covered. However, it might be emerging out that there may not be any new technology or a concept to be implemented for conservation of Ganga. Hence, it is necessary to introspect and integrate efforts made so far and create a concrete plan with certain elements of flexibility, considering local conditions. It would not only be the financial resources which will be important in conservation, but also other factors like intellectual monitoring and implementing the need based programs, public participation and other needs, depending on the use of Ganga water to link with the national economy. Based on the understanding and assessment of the hydro-geological status of river Ganga and knowing the problem in-terms of pollution, there is a need to evolve segment implementation plan with coordinated efforts of Centre and State Governments. The benefit in-terms of revenue/economic gains should be utilized for public cause and taking more innovative approach. It is well known that the river Ganga receives untreated sewage along with industrial effluents at various locations throughout the length. The water quality of the river is governed by the water flowing in the river and quantity of sewage and trade effluents being disposed. With this background, river Ganga has been divided into segments and the option for segmental characteristics and approach has been explored. This article aims at drawing a conceptual plan for forming the basis of ground implementation of Namami Gange program. It aims at providing grounds for planning step by step execution of Namami Gange program and formulating policies for its execution. The article provides basis for dividing the tasks as wells as the river into segments on the basis of specific problems and priorities of actions required in a particular region.

ENVIRONMENTAL IMPACT ASSESSMENT, CLEARANCE AND MANAGEMENT OF RIVER VALEY PROJECTS

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ABSTRACT

Various river valley projects taken up in India have contributed significantly to the socio-economic development. Besides increase in agricultural production, these have provided benefits like hydro-power, drinking water, flood control and industrial water. However, all developmental activities have certain environmental impacts, both beneficial and adverse, and river valley projects are no exception. The possible adverse impacts of these projects include submergence of forests, degradation of land, impact on water quality, flora & fauna and socio-economic impacts like displacement of people, the last one being particularly sensitive. Lately, the concerns about minimum flows downstream of the dams and emission of green house gases from reservoirs have also emerged. The objective of environmental impact assessment and management is to optimize the benefits while minimizing the adverse impacts.

Integration of environmental concerns into the development process has been a important feature of India's traditions and policies. India is one of the few countries where specific provisions exist in the constitution for environmental conservation. A number of Acts and Legislations have been enacted for the purpose. The National Water Policy of India, 2012 also emphasizes the environmental aspect *"Being inter-disciplinary in nature, water resources projects should be planned considering social and environmental aspects also in addition to techno-economic considerations in consultation with project affected and beneficiary families."* Environmental and forest clearance has been made mandatory and various management measures are insisted, while granting environmental clearance, for reducing the adverse impacts of projects.

An elaborate procedure is followed for according environmental clearance to hydro power projects to ensure that the implementation of the projects leads to improvement of the ecosystem rather than its degradation. The procedure has even been amended, making it mandatory to consider the public opinion regarding the project.

Before 1994, it was an administrative requirement to get environmental clearance for the projects from the Union Ministry of Environment and Forests. In order to assess the impact of the developmental projects/activities on the environment, the Ministry of Environment and forests (MOEF), Govt. of India issued a gazette notification on Environmental Impact Assessment (EIA) during January, 1994 and made environmental clearance statutory for all the projects located in ecologically sensitive/fragile areas as notified by the Govt. of India from time to time, besides 29 categories of the projects as specified in the Schedule 1 of the notification. These also include river valley projects. The notification was further amended in 1997, making a public hearing also mandatory to get environmental clearance. The notification has since been superseded by EIA Notification of 2006.

The paper presents the creation of environmental awareness at national and international level, environmental legislations and policies. It describes environmental impact assessment, procedure for environmental clearance in India, environmental management of river valley projects, environmental monitoring and constraints & solutions in carrying out environmental impact assessment. It also touches on contemporary important issues such as the controversy surrounding the hydro-power projects.

A SYSTEM APPROACH TO ANALYSE ISSUES AND CHALLENGES IN DEVELOPMEN OF GANGA BASIN

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Objective of this study is to investigate role of multilevel hierarchical modeling in the study of water resources systems. The Ganga, Brahmaputra river basins spread over China, Nepal, Bhutan, India, Bangladesh have a number of physical and conceptual interlinkages. Issues for study of the Ganga-Brahmaputra water resources (GBWR) system may be viewed in terms of the geopolitical, temporal and goal functional requirements and multiplicity of independent decision authorities.

Heuristic decomposition-coordination (D-C) approach may be followed in analysis of a large water resources system. The system study involves consideration of interstate, national, bilateral and regional issues. A multilevel hierarchical modeling scheme for the GBWR system is proposed so that the decomposed subsystems have meaningful definition in real life context. Emphasis in this study is on understanding and identifying the technological options, the institutional arrangement and regional coordination.