IWRA (INDIA) JOURNAL

Half Yearly Technical Journal of Indian Geographical Committee of IWRA

ABOUT JOURNAL

Water is among the most precious gifts of the nature to mankind. Benign and life supporting in normal times, menacing during floods, and desperately sought in times of drought, the waters of the rivers, aquifers, springs, lakes, etc., have been part of our daily life. However, with the growing requirements of water for diverse purposes, water is becoming a critical and scarce natural resource and can not be regarded as available in abundance as might had been believed earlier. It is widely recognized that many countries are entering into era of severe water shortage. The increase is not only due to population growth but also due to improved life style of the people.

The dramatic expansion of urbanized areas, which has been witnessed over the last few decades is likely to continue in most countries of the world. Such, often unplanned, growth leading to the emergence of conurbation and mega cities, poses a threat to both the availability and quality of surface and groundwater resources. These threats are both unprecedented and of immense scale when viewed from political, social and economic perspectives.

The aim of the journal is to provide latest information in regard to developments taking place in the field of water resources, besides making aware the readers about the activities being carried out in the field of Water Resources, worldwide, such as technical papers, R&D Activities, and information regarding conferences, training programmes and important news.

EDITORIAL BOARD

INDIAN GEOGRAPHICAL COMMITTEE OF IWRA

IWRA (India) Journal

CONTENTS

Editor

- Dr. G.P. Patel, *Member Secretary & Treasurer, Indian Geographical Committee of IWRA & Secretary (Addl. Charge) and Director (WR) Central Board of Irrigation and Power (CBIP)*

Associate Editor

- Mr. Uday Chander, *Chief Manager, Central Board of Irrigation and Power (CBIP)*

All communications to be addressed to :

The Member Secretary

Indian Geographical Committee of IWRA

CBIP Building, Malcha Marg, Chanakyapuri, New Delhi 110 021

From the Editor's Desk

We trust you and your family are doing well and taking all the necessary precautions to fight the pandemic, COVID-19. No doubt we are living in truly difficult and unpredictable times, but we are confident that this crisis shall also pass. Our earnest prayer for your & your loved one's continued good health, happiness & well-being.

The global spread of COVID-19 coronavirus has infected millions of people around the world, and is continuing at a faster pace. At the moment, it's a challenge to contain the pathogen. This crisis is experienced directly by some and indirectly by all of us. We have to fight together this pandemic and come back stronger as this is the need of the hour.

Climate change is one of the biggest and most complex problem, the development community has ever faced. The impacts of higher/lower temperatures, variable precipitation, and extreme weather events have already begun to impact the economic performance of countries and the lives and livelihoods of millions of poor people. India is among the countries most vulnerable to climate change. One of the most significant way by which climate change will impact the lives of people in India, will be through its water resources.

Keeping in view of limited availability of water resources and rising demand for water, which has acquired critical importance for sustainable management of water resources, the Indian Geographical Committee of International Water Resources Association (IGC-IWRA) and Central Board of Irrigation and Power (CBIP) are adopting new initiatives and strategies to serve our Members as per their customized requirements.

To initiate our efforts in the said direction, a National Level One Day Webinar on "Planning and Design of Piped Irrigation Network", focussing on deliberations on "Piped Irrigation Network Planning and Design" and "Emerging Challenges in Pipe Distribution Network for Irrigation Purpose and Ways & Means to Overcome Them", is being scheduled on 28 August 2020. We invite all of you and your colleagues/fellow professionals to actively participate in the Webinar.

As a part of information service, IGC-IWRA brings out half yearly Technical Journal "IWRA (INDIA)l", in January and July. The aim of the journal is to provide latest information in regard to developments taking place in the field of water resources, besides making aware the readers about the activities being carried out in the field of Water Resources, worldwide, such as technical papers, R&D Activities, and information regarding conferences, training programmes and important news.

I request all the readers for contributing technical papers/articles, news, etc., which would be of interest to others, for publishing in the subsequent issues of the journal.

Dr. G.P. Patel
Member Secretary
Indian Geographical Committee of IWRA

Ferrolite and Zeolite Combination in Reduction of Iron and Manganese Metals in Groundwater

HAYAT TULLOH HUSAINI, SETYO PURWOTO AND HERLANDO EKA PUTRA SETYABUDI

Environmental Engineering, University of PGRI Adi Buana Surabaya, Indonesia

ABSTRACT

Iron (Fe) and manganese (Mn) levels are important parameter components in terms of clean water criteria. Metal processing home industry activities have the potential for heavy metal contamination in groundwater. The purpose of this study was to determine the effect of flow rates on decreasing levels of ferrous metal (Fe) and manganese (Mn) using ferrolite and zeolite in groundwater using flow rates of 0.338 l / min and 3,380 l / min. It was concluded that the combination of ferrolite and zeolite treatment in groundwater can reduce Fe levels by 1,359 mg / l for a flowrate of 0.338 l / min, whereas for a flowrate of 3,380 l / min by 1,323 mg / l, and a decrease in Mn content for a discharge of 0,338 l / minute is 0.871 mg / l, while for debit 3,380 l / min is 0.735 mg / l.

Keywords: *Ferrolite, Zeolite, Iron, Manganese*

INTRODUCTION

Water is a natural resource that has a very important function for human life and other living things as well as a basic capital in development (Hendrawan, 2005). Preliminary research conducted in the area of raw water samples obtained an iron metal content of 3.38 mg / l and manganese metal of 3.15 mg / l. While the permissible threshold value according to the Regulation of the Minister of Health of the Republic of Indonesia Number 32 the Year 2017 for sanitary hygiene needs is that the value of iron metal content is only allowed a maximum of 1.00 mg / l, manganese metal of 0.5 mg / l.

The process of drinking water treatment from groundwater raw materials includes the following steps:

(a) Deposition and coagulation of dissolved particles using coagulant affixing;

(b) Filtration using polypropylene sediment ;

(c) Removal of iron and manganese using ferrolite;

(d) Decreased hardness using manganese greensand;

(e) Decreased cation using anion synthetic resin;

(f) Decreasing anions using synthetic cation resin;

(g) Decrease in the number of coliform bacteria using RO membrane;

(h) Removal of coliform bacteria using UV light (Purwoto et al. 2020).

One alternative water treatment in terms of decreasing Fe and Mn content can use ferrolite and zeolite treatment because the treatment uses ferrolite, manganese zeolite, and ion exchangers in the form of anion resin and cation resin in groundwater capable of boosting turbidity, color, ferrous metals, and other metals (Purwoto, 2016).

The purpose of this study was to determine the effect of flowrate on decreasing levels of ferrous metal (Fe) and manganese (Mn) using ferrolite and zeolite in groundwater.

Ferrolite is a filter media used to reduce or eliminate iron content that is too high in water. The content of high iron content in water causes the water to turn yellow and even red and have a pungent odor (iron odor). Ferrolite can be used as a media for bore well water filtration, ferrolite is an answer to remove the iron and manganese content contained in well water. (Putra, 2013).

Zeolite filter media are compounds with active cations that move and generally act as ion exchangers. While the presence of aluminum atoms in zeolites will cause a negative charge. This negative charge causes zeolites to be able to bind cations, so that they can be used to bind cations to water, such as Fe and Mn. By flowing raw water to the zeolite filter, the cation will be bound by zeolites which have a negative charge. Also, zeolites also easily remove cations and are replaced with other cations. Thus, zeolites function as ion exchangers and adsorbents in water treatment (Kusnaedi, 2004).

Another property of zeolite is as a catalyst. Commonly accepted catalyst definitions today are substances that increase the rate of a chemical reaction without 'themselves' involved in the reaction permanently so that at the end of the reaction the catalyst is not combined with the reaction product compound. The presence of a catalyst can affect the kinetic factors of a reaction such as the reaction rate, activation energy, the nature of the transition state, and others (Augustine in Rosdiana, 2006).

Iron (Fe) has an atomic weight of 55.85. Pure iron is a strong white metal, silver, and clay, which melts at 1,535° C. Iron content in groundwater, especially in well water is common. Groundwater which generally has a high concentration of carbon dioxide can cause anaerobic conditions. This condition causes the concentration of insoluble iron form (Fe^{3+}) reduced to iron which dissolves in the form of two-dimensional ions (Fe^{2+}). The concentration of iron in groundwater varies from 0.01 mg / l - 25 mg / l (Wiyata, 2003).

According to (Ansori, 2001) relative manganese toxicity has been seen at low concentrations. Thus the level of permissible manganese content in water used for domestic purposes is very low, ie below 0.5 mg / l. In the condition of aerobic manganese in the waters found in the form of MnO_2 and at the bottom of the waters reduced to Mn^{2+} or in water that lacks oxygen (low DO).

A combination of water treatment; filtration using polypropylene sediment, absorption by carbon block and manganese zeolite, ion exchange using anion resin and cation resin with a depth of 70 cm, followed by Reverse Osmosis (RO) able to reduce the concentration of parameters according to clean water criteria; total dissolved solids (TDS) 2686 ppm, total hardness 371.43 mg / l $CaCO_3$, Chloride 1144 ppm, total coliform 4 MPN / 100 ml, turbidity 2.02 NTU scale, 37 unit color PtCo, Ammonia 1.35 ppm, Iron 0.18 ppm, fluoride 0.46 ppm, Sodium 737.70 ppm, Zinc 0.08 ppm, sulfate 24.56 ppm, and detergent 0.10 mg / l LAS. (Purwoto, 2014)

According to (Purwoto, 2010) zeolite treatment carried out with an up-flow flow system using a 30 minute time detention (td), zeolite depth of 60 cm to reduce the parameters of clean water obtained remove capacity: total hardness of 185.72 ppm, 100 ppm calcium, magnesium 85.72 ppm, silica 25 ppm, chloride 52 ppm, dissolved solids (TDS) 311 ppm, iron 1.41 ppm, manganese 0.46 ppm.

Research entitled "IPTEK clean water treatment reactor for the community for flood-prone areas" with a reactor model in the form of 7 column tubes namely filter, PAC coagulant, zeolite, resin, chlorine, and activated carbon can reduce several parameters such as hardness up to 89.27%, color 66.67%, and TDS 33.57%. (Purwoto, 2011).

METHOD

The raw water sample is pumped into the reservoir and then flowed using a flow-meter to the reactor which contains a combination of zeolite and ferrolite with a process flow rate of 0.338 liters/minute and 3.38 liters/minute as Figure 1.

Fe and Mn levels were tested before and after treatment.
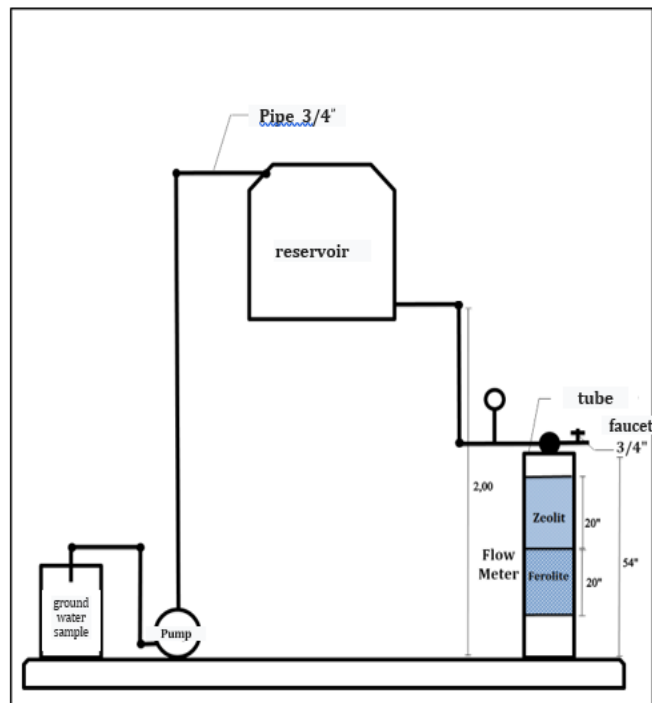
Fig. 1 : Design of a ferrolite and zeolite media installation

The analysis was carried out from day 1 to day 5 using the Atomic Absorption Spectrophotometer which refers to the Standard Methods test method.

RESULTS AND DISCUSSION

Results

The results of the analysis of Fe content tests were carried out before and after the absorption treatment by the zeolite and ferrolite pairs using 0.338 liters/minute and 3.38 liters/minute on the first day to the fifth day, and repetitions are presented in Table 1.

DISCUSSION

In Table 1. it appears that the reduction in Fe content is significant to zero both in the process flow rate of 0.338 liters/minute and 3.38 liters/minute. According to Purwoto et al (2019) polypropylene sediment as a filter

Table 1 : Results of analysis of Fe concentration data after treatment

No	Debit (l/ minute)	days to	Fe results are average (mg/l)		
			Fe concentration before treatment (mg/l)	Replication-1	Replication-2
1	3.380	days to -1	1.160	0.051	0.142
2		days to -2	1.447	0.113	0.065
3		days to -3	1.408	0.176	0
4		days to -4	1.455	0.065	0
5		days to -5	1.447	0	0
6	0.338	days to -1	1.160	0.041	0.101
7		days to -2	1.447	0.060	0.045
8		days to -3	1.408	0	0
9		days to -4	1.455	0	0
10		days to -5	1.447	0	0

of water from the content of mud, sand, soil, and other water-soluble solids dirt particles to produce clear, clean water free from pollution of solids dissolved in water. The function of Ferrolite is to eliminate the high levels of iron (Fe), the stench of iron, manganese (Mn^{2+}), yellow in groundwater.

The average Fe removal is presented in Table 2.

Referring to Table 2. when viewed from the percentage of the mean decrease in Fe content, the flow rate of 0.338 liters/minute is greater than the removal results for 3.38 liters/minute discharge.

Figure 2. illustrates the average graph of repetition of Fe removal treatment from day one to day five for process flow discharges 0.338 liters/minute and 3.38 liters/minute

Table 2. and Figure 2. it appears that Fe removal for small discharges (0.338 liters/minute) is more successful when compared to larger discharges (3.38 liters/minute).

According to Figure 2., the most optimal effectiveness is seen on the 3rd day, in accordance with previous studies conducted by (Putra, 2013) that ferrolite is an answer to eliminate the iron and manganese content contained in well water.
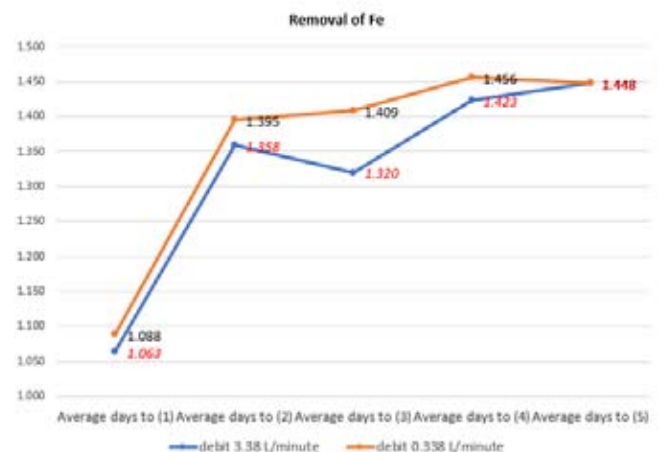
Fig. 2 : Graph of average Fe decreases

Table 2 : Removal Fe after treatment

Debit (l / minute)	remov (1)	remov (2)	Average (1) & (2)	final Average	% remov
3.380	1.109	1.018	1.063	1.323	95.57
	1.334	1.383	1.358		
	1.232	1.409	1.320		
	1.391	1.456	1.423		
	1.448	1.448	1.448		
0.338	1.118	1.058	1.088	1.359	98.20
	1.387	1.402	1.395		
	1.409	1.409	1.409		
	1.456	1.456	1.456		
	1.448	1.448	1.448		

The Groundwater in coastal areas are often found in high levels of salinity, often followed by high turbidity, or contain excessive hardness, also iron (Fe) and Manganese (Mn) that are quite large (Purwoto et al. 2016).

The results of the analysis of the Mn test were carried out before and after the absorption treatment by the zeolite and ferrolite pairs by using a debit of 0.338 liters/minute and 3.38 liters/minute on the first day to the fifth day, and repeated repetitions are presented in Table 3.

Table 3 : Results of analysis of Mn concentration data after treatment

No	Debit (l/minute)	days to	Mn results are average (mg/l)		
			Mn concentration before treatment (mg/l)	Replication-1	Replication-2
1		days to -1	1.753	1.338	1.279
2		days to -2	1.581	1.143	1.171
3	3.38	days to -3	1.851	1.038	1.152
4		days to -4	1.944	0.883	0.896
5		days to -5	1.969	0.998	0.952
6		days to -1	1.753	1.216	1.085
7		days to -2	1.581	1.084	0.870
8	0.338	days to -3	1.851	0.974	0.884
9		days to -4	1.944	0.849	0.780
10		days to -5	1.969	0.840	0.908

The mean Mn removal is presented in Table 4.

Table 4 : Removal Mn after treatment

Debit (l/minute)	remov (1)	remov (2)	Average (1) & (2)	final Average	% remov
3.380	0.415	0.474	0.445	0.735	40.36
	0.438	0.410	0.424		
	0.813	0.699	0.756		
	1.061	1.048	1.054		
	0.971	1.018	0.994		
0.338	0.538	0.668	0.603	0.871	47.84
	0.497	0.711	0.604		
	0.878	0.967	0.922		
	1.095	1.164	1.129		
	1.130	1.061	1.095		

Referring to Table 4. if seen from the percentage of the mean decrease in Mn content, the flow rate of 0.338 liters/minute is more significant compared to the removal results for 3.38 liters/minute discharge.

Table 3. and Table 4. show a significant reduction in Mn content both in the process flow rate of 0.338 liters/minute and 3.38 liters/minute, starting from the first day to the fifth day. According to Purwoto et al (2019) polypropylene sediment as a filter of water from the content of mud, sand, soil, and other water-soluble solids dirt particles to produce clear, clean water free from pollution of solids dissolved in water. The function of Ferrolite is to eliminate the high levels of iron (Fe), the stench of iron, manganese (Mn^{2+}), yellow in groundwater.

Figure 3. illustrates the average repetition of Mn removal treatment from day one to day five for the process flow rate of 0.338 liters/minute and 3.38 liters/minute
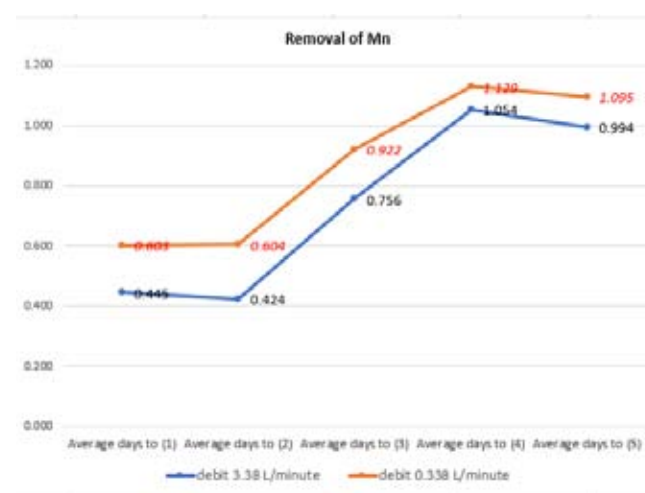
Fig. 3 : Graph of average decrease in Mn

Referring to Figure 2. and Figure 3. it appears that in the difference in days, the longer the day, the higher the percent effectiveness. Also described the mean removal for small discharges is better than large discharges.

In Table 4. and Figure 3. it appears that the removal of Mn for small discharges (0.338 liters/minute) is more successful when compared to larger discharges (3.38 liters/minute).

From the difference in discharge, the results of this study found a decrease in parameters for small discharge is better than large discharges by previous studies conducted by (Maharani, 2017) ie discharge affects the effect of decreasing effectiveness, the smaller the discharge the greater the effectiveness of the decrease. The results of this study for the Fe parameter is more effective than the Mn parameter. When compared with

previous studies conducted by (Purwoto, S. 2016) with the treatment of ferrolite, manganese zeolite, and ion exchanger in the form of anion resin and cation resin, the result was a decrease in ferrous metal (Fe) of 95.3% and manganese (Mn) by 100%. The learning result of assembling the series of water treatment tools can be applied in everyday life to help overcome the water quality problems (Purwoto et al. 2017)

CONCLUSION

The success of Fe and Mn removal in groundwater using a combination of ferrolite and zeolite treatments for small discharges was more significant compared to large discharges, where the reduction in Fe content was 1,359 mg / l for flow discharges of 0.338 l / min, whereas for flow discharges 3,380 l / minutes by 1,323 mg / l, and a decrease in the content of Mn for a discharge of 0.338 l / min by 0.871 mg / l, while for a debit of 3,380 l / min by 0.735 mg / l.

Acknowledgments

REFERENCES

Ansori, C. (2001), "Potensi dan Genesis Mangan Di Kawasan Kars Gombong Selatan Berdasarkan Penelitian Geologi Lapangan Analisis Data Induksi Polarisasi dan Kimia Mineral." Buletin Sumber Daya Geologi. Vol 5(2), 1-9.

Hendrawan, Diana. (2005), "Kualitas Air Sungai dan Situ di DKI Jakarta. Fakultas Arsitektur Lansekap dan Teknologi Lingkungan Universitas Trisakti Jakarta." Makara Teknologi Vol.9 (1), 13-19.

Kusnaedi. (2004), "Mengolah Air Gambut dan Air Kotor Untuk Air Minum." Jakarta: Penerbit Swadaya.

Mahrani, N. (2017), "Penurunan Logam Besi (Fe) dan Mangan (Mn) Pada Air Tanah Menggunakan Filtrasi Media Zeolit dan Manganese Greensand." Jurnal Teknik WAKTU. ISSN: 1412 – 1867 Vol. 15 (02), 57-65.

Peraturan Menteri Kesehatan. (2017), "Standar Baku Mutu Kesehatan Lingkungan Dan Persyaratan Kesehatan Air Untuk Keperluan Higiene Sanitasi, Kolam Renang, Solus Per Aqua, Dan Pemandian Umum." Permenkes RI No.32 Tahun 2017.

Purwoto, S. (2010), "Remove Capacity Treatment Zeolit Untuk Parameter Air Bersih." WAHANA; ISSN: 0853-4403, 55(2), 63-70.

Purwoto, S. (2011), "Reaktor Pengolah Air Bersih IPTEK Bagi Masyarakat Untuk Daerah Rawan Banjir." JURNAL WAKTU; ISSN: 1412-1867 Vol.09 (01), 01-07.

Purwoto, S., Sopandi, T., Kusuma, P.S.W., Nurcahyanie,W.D. (2014), "Removal Parameters of Clean Water using Treatment; Sediment Poly Propylene, Carbon Block, Manganese Zeolite, Ion Exchange, and Reverse Osmosis (RO)." Journal of Environment and Earth Science,ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) 4(23), 72-77.

Purwoto, S., Sutrisno, J. (2016), "Pengolahan Air Tanah Berbasis Treatment Ferrolite, Manganese Zeolite, dan Ion Exchange." WAKTU ; ISSN: 1412-1867 Vol.14(02), 21-31.

Purwoto, S., Sutrisno, J. (2016), "Rekayasa Demineralisasi Air Sungai Berbasis Pre Treatment Coagulant Aid dan Pasir Silika, dan Real Treatment Ferrolite, Manganese Greensand, Resin Sintetis, dan Reverse Osmosis." Surabaya: Universitas PGRI Adi Buana.

Purwoto, S., Sutrisno, J. (2017), "Learning About Water Purification Using Filtration And Reverse Osmosis." The 9th International Conference on Educational Technology of Adi Buana (ICETA 9), 205-211, ISBN ; 9789798559976, http://karyailmiah.unipasby.ac.id/2017/09/22/iceta-9/

Purwoto, S., Rusdiyantoro, Sembodo, B.P., (2019), "Pre Treatment of Raw Water Through the Coagulation Process, Filtration, Absorption, and Ion Exchange in Drinking Water." Water And Energy International. **62**RNI(04), 61-65

Purwoto, S., Rusdiyantoro, Sembodo, B.P., Nurcahyanie, Y.D. (2020), "Drinking water processing using UV rays." IOP Conference Series: Earth and Environmental Science (EES), 1742-6596. https://iopscience.iop.org/journal/1742-596/page/Forthcoming%20volumes#tab3 ; https://elib.its.ac.id/conf/icoee/

Putra, Imade., Purnomo, A. (2013), "Studi Penggunaan *Ferrolite* sebagai Campuran Media Filter untuk Penurunan Besi (Fe) dan Mangan (Mn) Pada Air Sumur." Surabaya: ITS.

Rosdiana, Tina. (2006), "Pencirian Dan Uji Aktivitas Katalitik Zeolit Alam Teraktivasi." Skripsi. Bogor: IPB.

Standard Methods For the Examination of Water and Wastewater. (2012), "Direct Air-Acetylene Flame Method-311B." APHA.

Wiyata, A. T. (2003), "Pelatihan Kualitas Air. Magelang.

Webgis Enabled Integrated Approach for Identifying Groundwater Prospect Zones in Sita-Swarna Basin, Karnataka, India

Anil B AND Shivanna G

Department of Marine Geology, Mangalore University, Mangalagangothri, India

M.S. Vinaya

Sarojini Mohan Academy for Research and Training, Bangalore, India

ABSTRACT

Groundwater is an important natural resource which is used for meeting domestic, industrial and agricultural requirements, but its availability is depleting due to overexploitation, misuse and intensive urbanization. Therefore, the assessment and management of groundwater resource in an integrated method is a need of the hour. The Remote Sensing (RS) and Geographic Information System (GIS) techniques have been used in the present study to estimate the groundwater prospect zones in Sita River and Swarna River basins of Udupi district, Karnataka. The study area falls between Latitudes 13°08'00" & 13°35'00" N and Longitudes 74°41'00" & 75°11'00" E and covers an area of 1228.05 sq. km. The assessment of prospective groundwater zones for the study area is carried out using satellite data in conjunction with conventional methods to characterize the terrain and aquifer parameters, followed by their integration and public serving using GIS tools. A groundwater prospect map has been prepared by considering the major controlling factors, such as geomorphology, geology & structures, lineament density, soil, slope, drainage density, surface runoff and land use/land cover. Based on the contribution to groundwater, all these themes and their individual features were assigned weights and their corresponding normalized weights were obtained based on Saaty`s (1980) analytical hierarchy process (AHP). The thematic layers were finally integrated using weighted overlay analysis in GIS software to yield a groundwater prospect zone map of the study area. Different groundwater potential zones were marked as 'very good', 'good', 'moderate', 'low' and 'very low'. The prospect zones so delineated were validated with the existing borewell data collected from secondary sources. It is concluded from the study that the integration of remote sensing and GIS technologies are very efficient and useful tools for the identification of groundwater prospect zones.

Keywords: Groundwater, GIS, RS, AHP, Weightage, WebGIS.

INTRODUCTION

The remote sensing data with synoptic view, multispectral nature, high resolution and temporal coverage have become very handy in exploration, assessment and management of groundwater resource. Groundwater is the primary source of water for both domestic and agriculture purposes. The human population of the Indian subcontinent is ever-increasing there by increasing the demand for water for domestic, agricultural and industrial use. Majority of the Indian region falls under the semi-arid zone where the availability of surface water is the major issue throughout the year and hence most of the people depend on groundwater resource to meet the various water requirements. This alarming situation calls for a cost and time-effective approach for proper evaluation of groundwater exploration, management and

planning. GIS can provide an appropriate platform for the convergent analysis of diverse datasets towards decision making for optimization of groundwater resource. The geospatial technology has opened up the new paths for monitoring and planning of both surface and groundwater resources. Satellite data due to its repetivity facilitates the identification of groundwater identification signatures and assessment of their changes, whereas, GIS enables user-specific management and integration of multi-thematic data. Mishra et al. (2010) have estimated the individual class weights and map scores through Saaty's analytical hierarchy technique to estimate the groundwater resource evaluation in Bhima River, India. Alrehaili et al. (2011) have identified the artificial recharge points for groundwater using RS and GIS in Riyadh, Saudi Arabia. Narendra et al. (2013) have generated various thematic maps namely geomorphology, geology, lineament

density, drainage density, slope and land use/land cover for delineating groundwater potential zones using weighted index overlay (WIO) technique in Narava basin, Visakhapatnam region, Andhra Pradesh, India. Jainendra et al. (2014) have adopted RS and GIS technologies to estimate groundwater prospect zones using geology, geomorphology, drainage pattern, waterbody, settlement and slope in Kharun Basin, Chhattisgarh, India. Hsin-Fu et al. (2015) have identified lithology, land cover/landuse, lineaments, drainage and slope as the five major contributing factors for groundwater in Hualian River, Taiwan. Sunitha et al. (2016) have evaluated the groundwater resource potential zones using RS and GIS techniques in Kadapa basin, Andhra Pradesh, India. Abdul-Aziz et al. (2016) have evaluated the groundwater potential using geospatial techniques with the integration of eight major biophysical and environmental factors like geomorphology, lithology, slope, rainfall, land use and land cover, soil, lineament density and drainage density in Gerardo River, Northern Ethiopia. Arulbalaji et al. (2019) have delineated the groundwater potential zones using GIS and AHP techniques with the help of twelve thematic layers such as geology, geomorphology, landuse/landcover, lineament density, drainage density, rainfall, soil, slope, roughness, topographic wetness index, topographic position index and curvature in Southern Western Ghats, India.

STUDY AREA

The study area falls under Udupi district of Karnataka state and is located between 13°08′00″ & 13°35′00″ N latitudes and 74°41′00″ &75°11′00″ E longitudes covering an area of 1228.05 sq km. The study area is covered under the "K" and "O" series of Survey of India (SOI) topographical maps of 1:50000 scale namely 48K/10, 48K/11, 48K14, 48K/15, 48K/16,48O/2, 48O/3 and 48O/4. The location map of the study area is shown in Figure 1. Udupi district is bounded in the North by Uttara Kannada district, in the East by the Western Ghats, in the South by Dakshina Kannada district and in the West by the Arabian Sea. Sita and Swarna Rivers originate on the hill ranges of Western Ghats and flow through the Coastal plain for about 10 km before they form a common confluence point and discharge into the Arabian Sea. They discharge an average of 54 m^3 s^{-1} of water into the Arabian Sea annually, of which significant part is being discharged during monsoon

METHODOLOGY

In the present study, the different thematic layers like geomorphology, geology, lineament density, soil, slope, drainage density, surface runoff and landuse/landcover were prepared on a 1:50,000 scale based on digital enhancement & visual interpretation techniques from the remote sensing data, Survey of India (SOI) topographic maps, secondary map resources & field in-puts. Drainage map, structural map and land use/land cover map were updated using LISS-IV image of Resourcesat-1 having spatial resolution of 5.8 m and Web Map Service (WMS) of Bhuvan Geo-portal developed by Indian Space Research Organisation (ISRO). Slope map was prepared from the digital elevation model (DEM) developed from IRS-P5
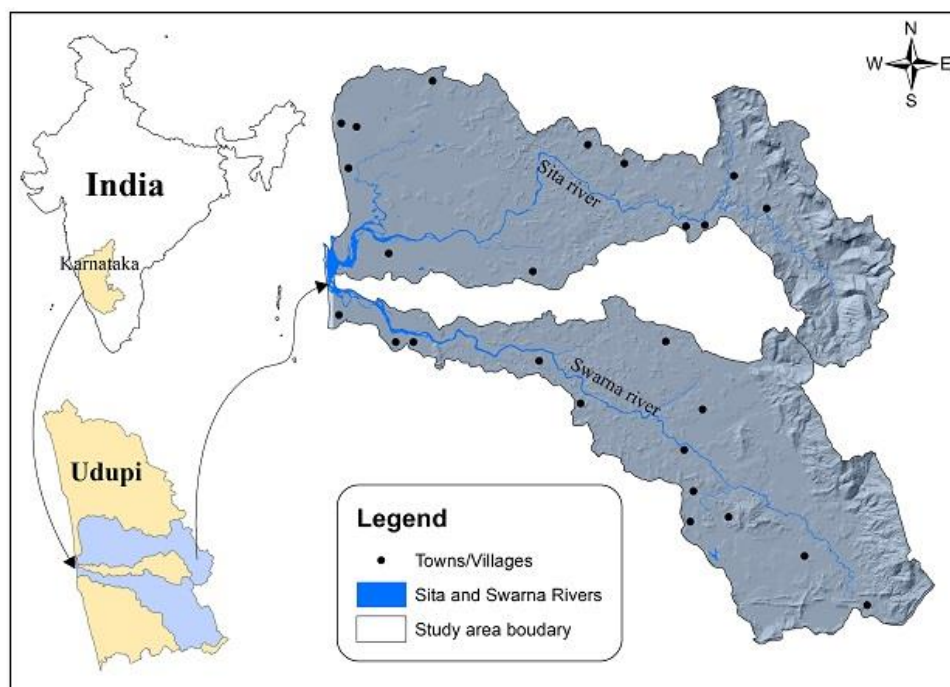

Fig. 1 : Study area map

CartoDEM satellite product having a spatial resolution of 10 m. The details of the satellite and DEM products used for the study are presented in Table 1.

Table 1 : Details of satellite and DEM products

Satellite	Sensor	Spatial Resolution	Acquisition Date
IRS – P6	LISS-IV	5.8 m	02-01-2017
IRS – P5	Cartosat – I	2.5 m	2016-17

The ERDAS imagine software was used to carry out the image rectification, mosaicking and study area extraction. Further, ArcGIS software was used to prepare the different thematic layers which included editing, topology creation, tabulations and density mapping. Based on the contributing potential to the groundwater, all the thematic layers and their individual features were assigned weights and their corresponding normalized weights were derived based on the arithmetic hierarchy process (AHP) model. The thematic layers were finally integrated using weighted overlay analysis to yield a groundwater prospect zone map of the study area. The outputs were finally published using QGIS server & web publishing tools.

Saaty`s AHP Model

The AHP, introduced by Thomas Saaty (1980), is an effective tool for multi-criteria decision analysis and is used to compute weights and ranks for thematic layers. In the present study, different features of each theme were assigned weights on a numerical scale of 1 to 9 based on their influence on groundwater existence. Saaty`s AHP model was used to construct a pair-wise comparison matrix and assign the normalized weights. To determine groundwater prospect zones, the weights were assigned to all the thematic layers and then overlay analysis was carried out using the raster calculator of ArcGIS software. The groundwater prospect zones map was prepared by delineating the study area into five classes: Very good, good, moderate, low and very low. Cumulative Score Index (CSI) was used for this classification. CSI was calculated by multiplying the weight (x) and normalized weight (w) of each thematic layer as expressed in the equation (1).

CSI = Σ (Geomorphology x_i x w_j+ Geology x_i x w_j + Lineament Density x_i x w_j + Soil x_i x w_j +Slope x_i x w_j + Drainage Density x_i x w_j + Surface Runoff x_i x w_j + Land use / Land cover x_i x w_j)

$$CSI = \int_{i=1}^{n} \int_{j=1}^{m} w_j x_i \dots \dots \dots \dots \dots (1)$$

Where, w_j is the normalized weight of the theme j^{th} factor; x_i is the rank of the ith classes/features of thematic layers respectively; m is the total number of thematic layers; and n is the total number of features in a thematic layer (Deepesh et al., 2011; Rose et al., 2009). In the weighted overlay, the individual thematic layers and also their classes were assigned weights on the basis of their relative contribution towards the output. (Table 2)

In the present study, the consistency ratio (CR) value for all the eight layers is found to be less than 0.1 and hence the results of the pair wise comparison within each thematic layer are acceptable (Saaty, 1980).

Geomorphology, geology and lineament density are the three major contributing factors for groundwater occurrence with 23%, 20% and 18% of influence respectively. In table 2, GM refers to geomorphology, G is Geology, LD is lineament density, SOL is soil, SL is slope, DD is drainage density, SF is surface runoff and LULC corresponds to land use/land cover. The weights of the different themes and normalized weight of different classes of each theme are shown in Table 3.

RESULTS AND DISCUSSION

Geomorphology

Demarcation of the geomorphic setup is very important for the identification of groundwater potential. The detailed geomorphological map is shown in Figure 2.

Flood plain is the youngest geomorphological unit in the area composed primarily of unconsolidated river-borne sediments such as pebbles, cobbles, sand, silt and clay. A few isolated hills of moderate dimension are seen in the southern part of the Swarna river basin. The structural configuration is well exhibited in the hills of Western Ghats. Sita-swarna pediplain is well weathered

Table 2 : Pairwise comparison matrix of eight thematic layers

	GM	LT	LD	SOL	SL	DD	SR	LULC	Normalized Weight
GM	1.00	1.13	1.29	1.80	1.80	3.00	4.50	9.00	0.23
G	0.89	1.00	1.14	1.60	1.60	2.67	4.00	8.00	0.20
LD	0.78	0.88	1.00	1.40	1.40	2.33	3.50	7.00	0.18
SOL	0.56	0.63	0.71	1.00	1.00	1.67	2.50	5.00	0.13
SL	0.56	0.63	0.71	1.00	1.00	1.67	2.50	5.00	0.13
DD	0.33	0.38	0.43	0.60	0.60	1.00	1.50	3.00	0.08
SR	0.22	0.25	0.29	0.40	0.40	0.67	1.00	2.00	0.05
LULC	0.11	0.13	0.14	0.20	0.20	0.33	0.50	1.00	0.03

Table 3 : Weights and normalized weights of individual themes

Features	Contribution to groundwater	Area (km²)	Map Weight (Wj)	Normalized Weight (Xi)
Geomorphology				
(a) Alluvial Plain	Very good	2.32	9	0.19
(b) Flood Plain	Good	5.80	8	0.17
(c) Residual Hill	Very poor	21.66	1	0.02
(d) Structural Hill	Very poor	283.69	1	0.02
(e) Coastal Plain	Good	6.37	7	0.15
(f) Pediment	Poor	381.84	3	0.06
(g) Pediplain Weathered	Moderate	459.44	4	0.09
(h) Lateritic Plain Shallow	Good	38.87	8	0.17
(i) Escarpment slope	Very poor	0.19	1	0.02
(j) Lower Plateau	Poor	1.01	3	0.06
(k) Mesa	Very poor	1.59	1	0.02
(l) Butte	Very poor	0.22	1	0.02
Geology				
(a) Alluvium	Very good	7.69	8	0.26
(b) Laterite	Good	51.94	8	0.26
(c) Gneiss	Very good	433.87	7	0.23
(d) Granite	Good	324.51	6	0.19
(e) Hilly Area	Very poor	396.37	1	0.03
(f) Schist	Very poor	66.00	1	0.03
Lineament Density				
(a) 0 - 0.17 km	Very poor	973.09	1	0.04
(b) 0.18 - 0.34 km	Poor	125.98	3	0.12
(c) 0.35 - 0.51 km	Moderate	103.34	5	0.20
(d) 0.52 - 0.68 km	Good	15.66	7	0.28
(e) 0.69 - 0.8489 km	Very high	10.27	9	0.36
Soil				
(a) Fine	Very poor	720.62	1	0.03
(b) Fine Loamy	Very poor	322.05	2	0.07
(c) Loamy	Poor	14.07	3	0.10
(d) Clayey Skeletal	Moderate	65.28	5	0.16
(e) Loamy Skeletal	Moderate	103.72	7	0.23
(f) Sandy	Very good	2.35	9	0.41
Slope				
(a) Nearly Level	Very good	369.09	9	0.33
(b) Very Gentle Slope	Good	207.69	7	0.26
(c) Gentle Slope	Moderate	256.12	5	0.19
(d) Moderate Slope	Very poor	72.89	3	0.11
(e) Strong Slope	Very poor	91.32	1	0.04
(f) Moderate Steep slope	Very poor	56.47	1	0.04
(g) Very Steep slope	Very poor	174.52	1	0.04
Drainage Density				
(a) 0 - 0.8 km	Very good	179.21	9	0.26
(b) 0.9 - 1.6 km	Good	605.88	7	0.20
(c) 1.7 - 2.4 km	Moderate	346.25	5	0.14
(d) 2.5 - 3.2 km	Poor	88.69	3	0.09
(e) 3.3 - 4.0 km	Very poor	9.17	1	0.03

| Surface Runoff				
(a) 36 - 45	Very good	0.19	9	0.27
(b) 46 - 62	Good	37.58	7	0.21
(c) 63 - 74	Moderate	463.25	5	0.15
(d) 75 - 86	Poor	490.75	2	0.06
(e) 87 - 100	Very poor	236.34	1	0.03
LULC				
(a) Waterbody	Very good	0.79	8	0.10
(b) River	Very good	24.35	9	0.12
(c) Evergreen forest	Good	295.92	8	0.10
(d) Deciduous forest	Moderate	15.46	6	0.08
(e) Scrub forest	Moderate	0.92	3	0.04
(f) Degraded forest	Poor	2.18	2	0.03
(g) (a) Tree groves	Moderate	393.46	5	0.06
(h) Mixed vegetation	Moderate	105.66	5	0.06
(i) Grassland	Moderate	9.01	3	0.04
(j) Settlement	Very poor	2.36	1	0.01
(k) Habitation with vegetation	Poor	74.10	2	0.03
(l) Plantation	Good	20.75	7	0.09
(m) Single crop	Moderate	211.87	5	0.06
(n) Double crop	Very good	14.32	7	0.09
(o) Fallow land	Good	2.28	4	0.05
(p) Barren Rocky	Very poor	15.27	1	0.01
(q) Land with scrub	Very poor	31.20	1	0.01
(r) Marshy	Very poor	2.41	1	0.01
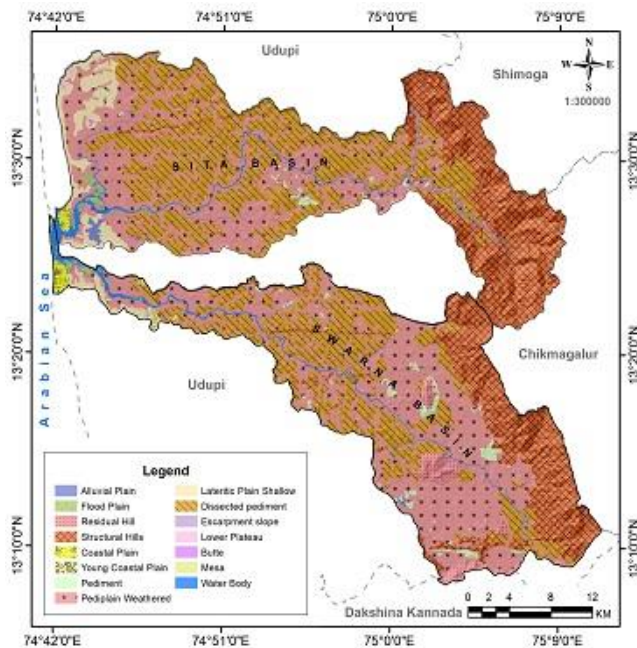
Fig. 2 : Geomorphology map of the study area

and dissected pediments occur in the central part of the study area on either side of the study region. This zone is mainly used for cultivation and habitations.

Geology

Based on the previous works, satellite image interpretation, intensive field works, following lithological and structural units have been mapped. They are shown in Figure 3. Geologically, the rocks like granitic gneisses with occasional laterite capping and marine sediments, occupy
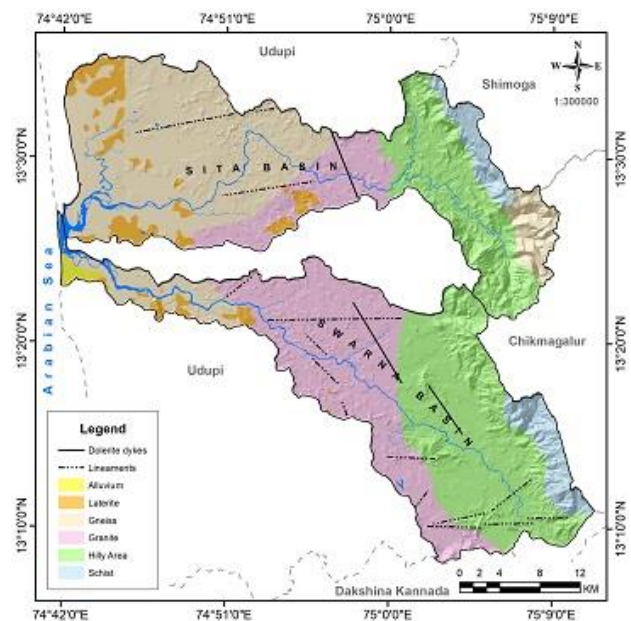

Fig. 3 : Geology map of the study area

the study area. The gneiss and granite are widespread as distinct outcrops at varying magnitude especially along with the Sita-Swarna river courses. The young alluvium and colluvial deposits occur along the riverbanks and seacoast.

Land Use / Land Cover

Resourcesat-1 LISS - IV (5.8m) multispectral data has been subjected to various digital enhancement techniques and then visually interpreted to demarcate the land use/land cover features in the study area. The identified features are agriculture, habitation with vegetation, evergreen forest, scrub forest, open forest, tree groves, dense forest, grass land and barren rocky land. Agricultural plantation is the major land cover in the study area covering 519 sq. km of the total area. Agricultural plantation is a key parameter for groundwater prospect studies. The land use / land cover map is shown in Figure 4.
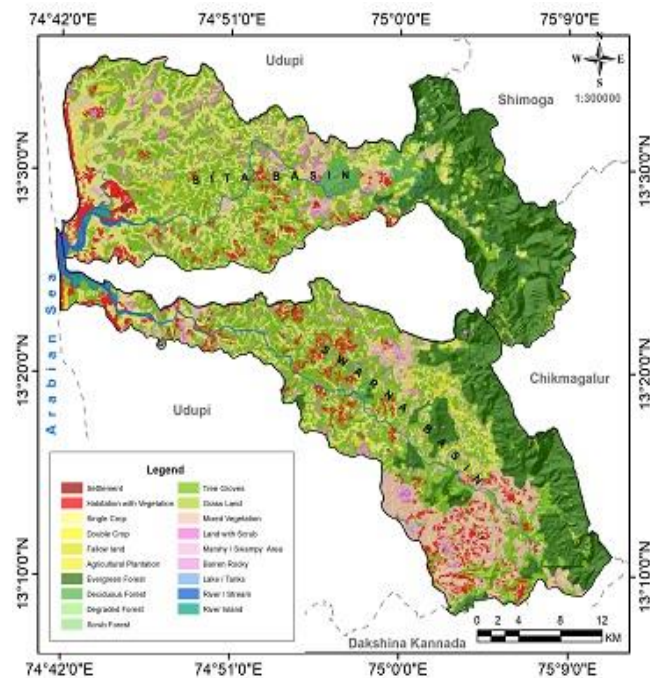

Fig. 4 : Land use / Land cover map of the study area

Soil

Soil is the most essential component for outlining the groundwater prospect zones. The soil map is generated through head-on digitization of secondary data collected from the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP). The soil map is shown in figure 5. The fine and fine loamy soils cover the major portion of the study area, which have slow infiltration rates when thoroughly wetted and consist chiefly of soil layers that impede the downward movement of water.
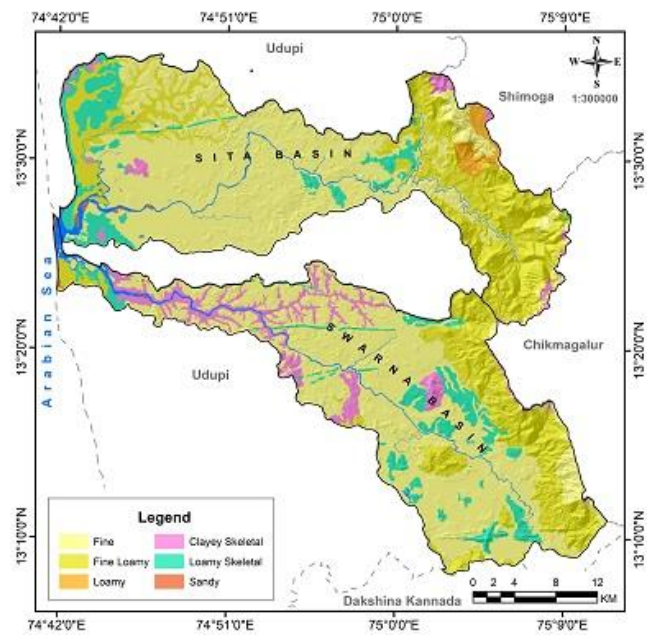
Fig. 5 : Soil map of the study area

Slope

The study area comprises of three distinct physiographic units namely narrow stretch of the coastal tract along the seacoast, up-land area and hilly terrain. The slope is generated by interpolating the 10 m contours using the surface model of ERDAS Imagine software and then classifying the different slopes using ArcGIS software. In the study area, the gradient and slope of the Western Ghats control the genesis of subparallel drainage patterns. The slope map is shown in Figure 6.

Fig. 6 : Slope map of the study area

Most parts of the lateritic capped pediplain have a very steep slope and the up-land pediplain area is intercepted with low hills between the Western Ghats and the Coast which ranges from nearly level to steep slope. Agriculture is the main activity in the slopes between near levels and moderate slope areas. Slope is one of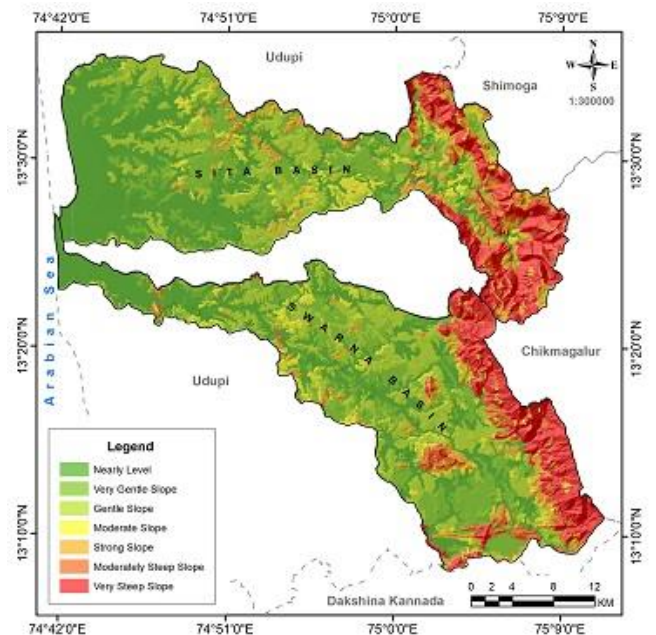 the factors controlling the infiltration of groundwater into the sub surface layers; hence it is an important indicator for the suitability for groundwater prospect.

Lineament Density

Lineament controls groundwater movement and storage. The lineaments present in the study area have been extracted from the LISS-IV satellite imagery and Web Map Services (WMS) map products from the Bhuvan Geo Portal (https://bhuvan.nrsc.gov.in). The lineament density has been determined from the linear density tool using ArcGIS software. Density of the lineaments is good in the Swarna river basin and a few lineaments are also found in either side of the Sita river. The lineament density map is shown in Figure 7. The lineament length varies from a few meters to kilometres. The region is classified into five categories namely very low, low, medium, high and very high. The zones with very high lineament density are classified as high groundwater prospect areas and are assigned higher weightages.
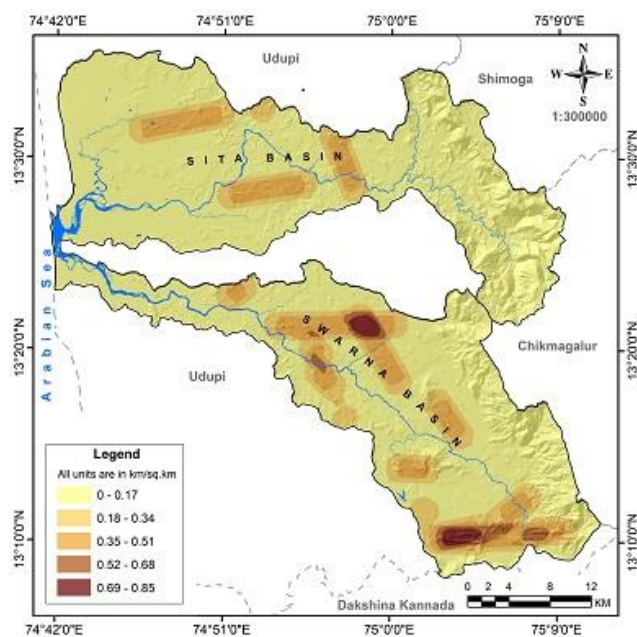

Fig. 7 : Lineament density map of the study area

Drainage Density

Drainage density helps to assess and understand the characteristics of groundwater intrusion and runoff potential. Drainage density values have been calculated using the natural break method (Jenks, 1967). The regions are classified as very low, low, moderate, high and

very high drainage density zones. Areas with low drainage density signify comparatively higher infiltration and low runoff. The zones with low to moderate drainage density are considered as excellent groundwater prospect zones and are assigned with higher weightages. The drainage density map is shown in Figure 8.
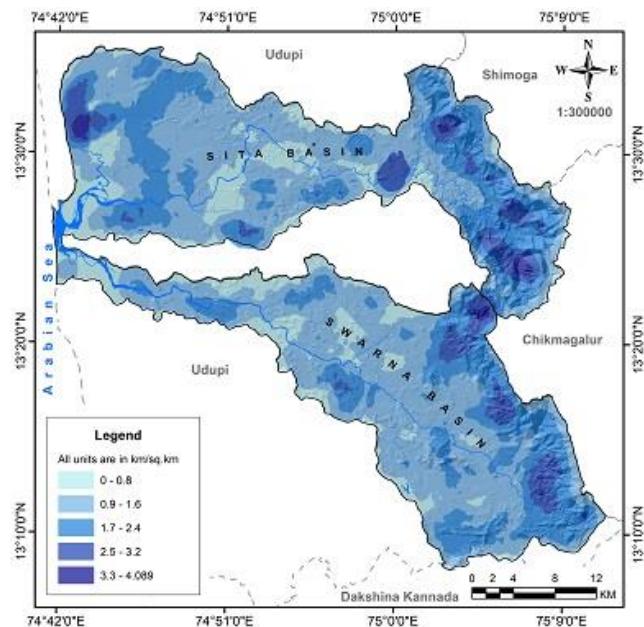

Fig. 8 : Drainage density map of the study area

Surface Runoff

GIS-based surface runoff has been calculated by Soil Conservation Services Curve number (SCS-CN) method for the Sita-Swarna basin. The method is associated with curve numbers derived based on land use/land cover, hydrological soil group (HSG) and Antecedent Moisture Content (AMC) (Anil et al., 2019). The rainfall data collected from four rain gauge stations of Sita-Swarna river basins for the period from 2008 to 2017 was used for the estimation of runoff. From SCS-CN analysis it is found that the runoff varies from 4566.3 mm to 1205.7 mm in the Sita-Swarna river basin. The curve number map of the study area is shown in Figure 9. The regions are classified as very low, low, medium, high and very high surface runoff areas. Areas with high surface runoff indicate lower infiltration and are poor zones for groundwater potential. The areas with low runoff are considered as excellent prospect zones and are assigned with high weightages.

GROUNDWATER PROSPECT ZONES

Geological structures can play an important role in groundwater movement and accumulation in the surface and subsurface layers (Elmahdi & Mohammad, 2014). From a hydrogeological point of view, areas with beach alluvium, coastal sediments, laterites and fractured granitic gneisses are classified under 'very good' category.
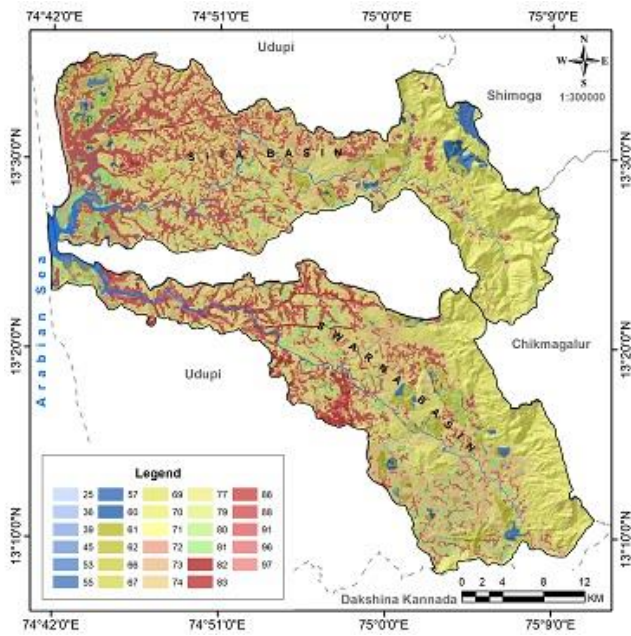
Fig. 9 : Curve Number map of the study area

These areas fall under low drainage density, gentle slope areas associated with water bodies and sandy soil. Chowdary et al. (2009) have suggested that the LULC classes like water body and crop land (Kharif) are good for improving the groundwater and fallow land is poor for groundwater development. The area covered by 'very good' category in the study area is about 48.48 km^2 (4%) in the study area.

The second category 'good' is associated with the parts of coastal plain, forest land, lateritic shallow plains, crop land and agriculture plantations. This zone has a shallow water table and higher aquifer thickness. Rajaveni et al. (2017) have opined that the forest and agriculture lands hold significantly high quantities of water than the built-up land, land without scrub and rocky surfaces. The 'good' category covers an area of 232.66 km^2, which is about 19% of the total area. The 'moderate' category covers an area of 292.50 km^2 (24%) and is associated with the weathered pediplain having gentle slopes where aquifer thickness is average to good. Figure 10 represents the groundwater prospect zones of the study area that is derived from Saaty`s AHP model.

The 'low' category is associated with the dissected pediments, degraded forests and loamy soils where aquifer thickness is poor to average. This category covers an area of 296.62 km^2 (24%). The 'very low' category is associated with the upper parts of the pediments, impervious built-up lands and high relief hilly zones. In the study area, hill categories like residual hills, denudational hills and structural hills belong to the runoff zones.

According to Todd and Mays (2005), the high drainage density is an unfavourable zone for groundwater
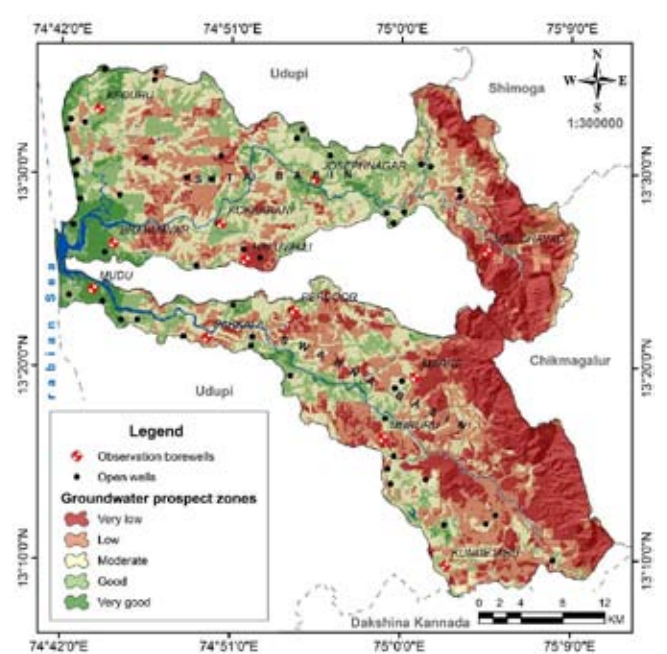
Fig. 10 : Groundwater prospect zones of the study area

occurrence whereas moderate drainage density has a moderate groundwater potential and low drainage density has a high groundwater potential. In the hilly region, the water table occurs in suspended conditions and the groundwater prospect area is limited to the narrow valleys along the faults, fractures and lineaments. The 'very low' category covers an area of 357.80 km^2, which is about 29% of the total area. Figure 11 shows the spatial and seasonal distribution of average decadal depth to water level (mbgl) in the study area.
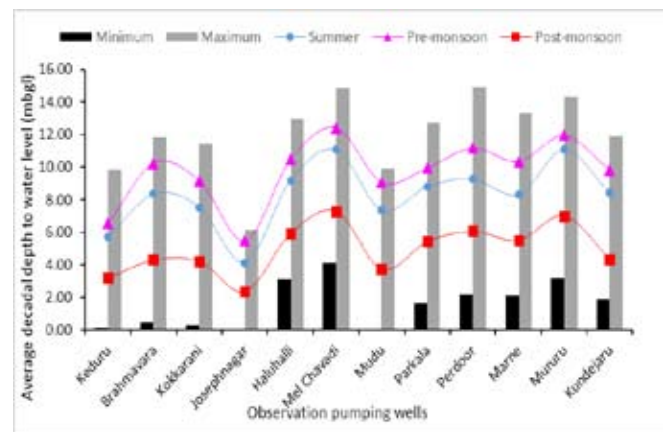
Fig. 11 : Spatial and seasonal distribution of average decadal depth to water level (mbgl)

In order to validate the groundwater prospect map, the depth to groundwater level (mbgl) data collected for observation bore wells from National Hydrograph Station (NHS) has been analysed statistically. The analysis reveals that the regions like Keduru, Josephnagar and Mudu fall under 'very good' to 'good' prospective

zones. Similarly, Brahmavara, Kokkarani, Parkala and Kundejaru fall under 'good' to 'moderate' prospect zones and the 'low' to 'very low' prospect zones are found in the regions like Haluhalli, Melchavadi, Perdoor, Marne and Mururu. The cumulative frequency of the wells falling in the 'good' zone is higher than that of the wells in the 'very good zone'. Similarly, the cumulative frequency of the wells lying in the 'moderate' zone is lower than that of the wells in the 'good' zone and higher than that of the 'very good' zone. Similarly, cumulative frequency of the wells of 'very low' and 'low' zones are lower than that of the wells in the 'moderate', 'good' and 'very good' zones.

At present, WebGIS has become one of the robust technologies to cater the GIS database to various user communities regardless of place and time, which greatly helps the decision-makers to pin point the problematic areas and implement the appropriate remedies.

The WebGIS system developed in the present study enables layer zooming, querying, feature measurement and layer control on top of the spatial data. It provides user to switch on/off between the different layers with a facility to change transparency level. The 'Feature Info' tool shows the spatial and non-spatial data of the selected polygon on the map. A screen shot of the WebGIS browser window is shown in Figure 12.

CONCLUSION

The study reveals that remote sensing and GIS play a crucial role in the assessment of groundwater prospect zones. The study area has only 4% of very good zones and 19% of good prospect zones, which cautions the decision-makers and concerned departments to promote the scientific and sustainable use of groundwater for future needs and also to initiate the appropriate measures for the development of groundwater resources. The Sita-Swarna basin caters to the water demand for the entire Udupi taluk and also for the adjacent villages for both domestic and agricultural purposes, so it is very important to initiate construction of water harvesting and storage structures at the proper locations for efficient recharge of groundwater which can overcome the continuous future demands. It is advised to carry out an integrated study by using remote sensing, GIS and other convention techniques to identify the suitable sites for the construction of check dams and other NRM structures in order to improve the groundwater availability.

REFERENCES

Alrehaili, A.M. and M.T. Hussein, Use of remote sensing, GIS and groundwater monitoring to estimate artificial groundwater recharge in Riyadh, Saudi Arabia. Arabian Journal of Geosciences, 2012. 5(6): p. 1367-1377.

Anil, B., Shivanna, G & Vinaya, M. S. (2019). Curbe Number and GIS based surface runoff estimation in Sita River and Swarna River basins of Udupi District, Karnataka. Journal of Applied Science and Computations. 2019;4(5):1045-1053.

Arulbalaji, P., D. Padmalal, and K. Sreelash, GIS and AHP techniques based delineation of groundwater potential zones: a case study from southern Western Ghats, India. Scientific reports, 2019. 9(1): p. 1-17.
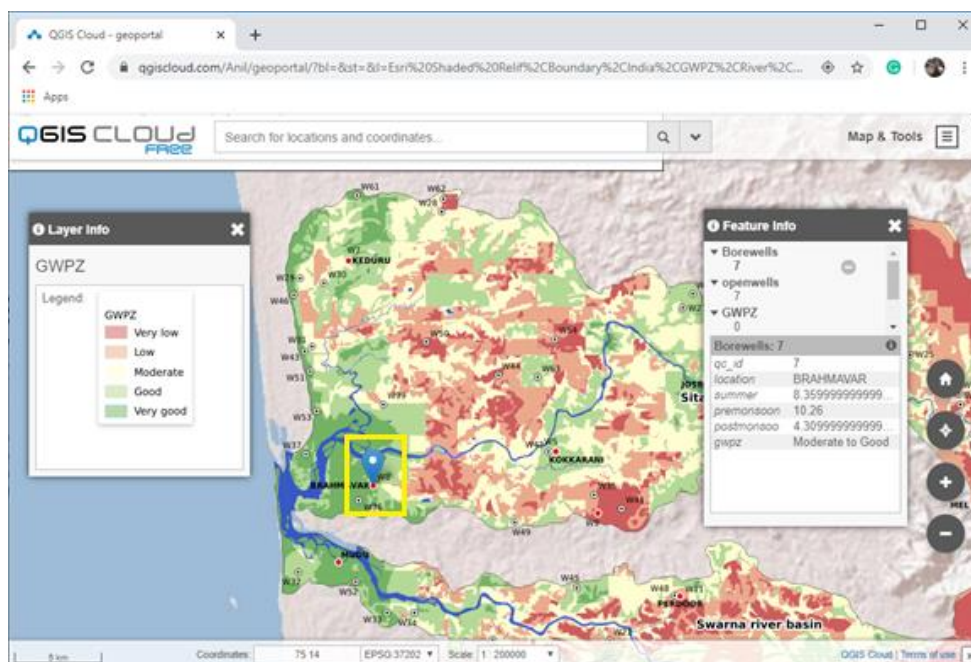

Fig. 12 : WebGIS map of groundwater prospect zones

Chowdhury, A., et al., Integrated remote sensing and GIS, based approach for assessing groundwater potential in West Medinipur district, West Bengal, India. International Journal of Remote Sensing, 2009. 30(1): p. 231-250.

Elmahdy, S.I. and M.M. Mohamed, Relationship between geological structures and groundwater flow and groundwater salinity in Al Jaaw Plain, United Arab Emirates; mapping and analysis by means of remote sensing and GIS. Arabian Journal of Geosciences, 2014. 7(3): p. 1249-1259.

Hussein, A.-A., V. Govindu, and A.G.M. Nigusse, Evaluation of groundwater potential using geospatial techniques. Applied Water Science, 2017. 7(5): p. 2447-2461.

Jenks, G.F., The data model concept in statistical mapping. International yearbook of cartography, 1967. 7: p. 186-190.

Machiwal, D., M.K. Jha, and B.C. Mal, Assessment of groundwater potential in a semi-arid region of India using remote sensing, GIS and MCDM techniques. Water resources management, 2011. 25(5): p. 1359-1386.

Mishra, R.C., B. Chandrasekhar, and R.D. Naik, Remote sensing and GIS for groundwater mapping and identification of artificial recharge sites, in Geoenvironmental Engineering and Geotechnics: Progress in Modeling and Applications. 2010. p. 216-223.

Narendra, K., K.N. Rao, and P.S. Latha, Integrating remote sensing and GIS for identification of groundwater prospective zones in the Narava basin, Visakhapatnam region, Andhra Pradesh. Journal of the Geological Society of India, 2013. 81(2): p. 248-260.

Rajaveni, S., K. Brindha, and L. Elango, Geological and geomorphological controls on groundwater occurrence in a hard rock region. Applied Water Science, 2017. 7(3): p. 1377-1389.

Rose, R.S. and N. Krishnan, Spatial analysis of groundwater potential using remote sensing and GIS in the Kanyakumari and Nambiyar basins, India. Journal of the Indian Society of Remote Sensing, 2009. 37(4): p. 681-692.

Saaty, T.L., P.C. Rogers, and R. Pell, Portfolio selection through hierarchies. The journal of portfolio management, 1980. 6(3): p. 16-21.

Sunitha, V., et al., Assessment of groundwater quality in parts of Kadapa and Anantapur districts, Andhra Pradesh, India. Indian Journal of Advances in Chemical Science, 2014. 3: p. 96-101.

Todd, D.K. and L.W. Mays, Groundwater hydrology edition. Welly Inte, 2005.

Vishwakarma, J., et al., Application of remote sensing and GIS in ground water prospect mapping. Int J Engineering Res & Technology, 2014. 10(3): p. 549-555.

Yeh, H.-F., et al., Mapping groundwater recharge potential zone using a GIS approach in Hualian River, Taiwan. Sustainable Environment Research, 2016. 26(1): p. 33-43.

Synthetic Alkali Soluble Lignin Supplementation to Sucrose-rich Wastewater Fed MFC

Subramaniapillai Niju and Elangovan Elakkiya
Department of Biotechnology, PSG College of Technology, Coimbatore, Tamilnadu, India

ABSTRACT

Microbial Fuel Cells are bioelectrochemical devices exploiting exo-electrogenic bacteria for conversion of chemical energy in wastewater to electrical energy directly. Low power production is viewed as one of important bottle-neck in scaling-up microbial fuel cells. Rate of electron transfer by microbes to anode determines the total power produced from these units. Addition of external redox mediators capable of shuttling electrons from bacteria to anode had be extensively studied. But the toxicity and cost of operation discriminates its use in practical system. Lignin a plant polymer found abundant in agro-residues, ethanol hydrolysate and paper and pulp industry wastewater could mediate electrons from bacteria to anode. In our study we have utilised organics rich sugarcane baggase wash water from paper industry as primary substrate for microbial growth in anode chamber of MFC. Synthetic alkali soluble lignin was tested as mediator. There was a minor reduction in the peak Open Circuit Voltage (OCV) compared to 720mV for Baggase Wash Water (BWW) to 702mV for BWW+0.1mol/l lignin. The highest power density and current density with lignin addition was 93mW/m^2 and 273mA/m^2 respectively. The COD removal efficiency was 61%, whereas the Columbic efficiency was 22%. The increase in CE from 6% to 22% could be an effect electron mediating capacity and methanogen suppression by lignin in anode chamber.

Keywords*: Bagasse wash water; electron mediators; columbic efficiency; wastewater treatment; chemical oxygen demand*

INTRODUCTION

Microbial Fuel Cells are bio-electrochemical devices capable of converting the chemical energy available in the wastewater to electrical energy. Simultaneous wastewater treatment and power production empower these units to facilitate energy sufficiency in waste management[1].

In MFC, conversion of organic waste to electricity requires the microbes to transfer electrons to the anode. The rate of electron transfer is one of the primary factors influencing power production[2]. Bacteria transfer electrons by both direct and mediated mechanisms. Direct Electron Transfer (DET) is facilitated by conductive pili and c-type cytochromes present on the cell membrane. On the other hand, Mediated Electron Transfer (MET) occurs via mediators capable of shuttling electrons between bacteria and anode[3]. Mediators are redox compounds which could be externally added or a compound naturally present in wastewater or a secondary metabolite produced from bacterial metabolism[4].

A good redox mediator must be non-toxic to anode microbes and must remain stable throughout MFC operation. 2-hydroxy-1,4-naphthoquinone, thionine, methylene blue, bromocresol blue, neutral red, methylene red and methyl orange have been prominently explored as electron mediators[4]. The common quinine functional group present in these compounds is held responsible for the electron mediating properties[5]. Though mediated MFC proved to produce higher power, mediator addition resulted in increased cost of operation and was toxic to microbial growth questioning its application in practical systems. The exploitation of indigenous mediators naturally occurring in wastewater could circumvent the disadvantages in external mediator addition[6]and[7].

Existing literature on MFC operated with agro-based substrates has revealed that the presence of lignin and other phenolic compounds capable of mediating electrons contributed to increased power production[8]. Further, lignin could suppress methanogens in anode chamber leading to better energy conversion efficiency[9]. Wang et al have explored the feasibility of using corn stover as a substrate for MFC operation. It was found that steam-exploded corn stover produced higher power than raw corn stover[10]. Studies by Thygesen et al showed that wheat straw hydrolysate could produce higher power and Coulombic efficiency than nutrient-media fed MFC. The enhancement of power production was due to the presence of phenolic compounds in hydrolysate capable of shuttling electrons (Thygesen et al, 2013). Gurung et al and Hassan et al worked on using rice straw as substrate for MFC and observed high CE of 37% and

47-53% respectively[12]and[13]. External addition of lignin to ethanol stillage wastewater fed MFC had resulted in 90% increase in power density without affecting the COD removal efficiency[14]. These studies open up new arena of utilizing lignin rich wastewater as mediator to existing MFC for high energy recovery.

Tamilnadu Newsprint and Paper limited is one of the leading paper producers in India. Sugarcane bagasse is utilized as raw material for paper making due to limited availability of wood. These units generate two organic-rich wastewater from Bagasse storage units known as Bagasse wash water (BWW) and complex lignin-rich cellulose pulping wastewater (CPW). In our study we investigate the feasibility of utilizing sucrose-rich bagasse wash water as substrate for microbes growth in MFC and evaluate the effect of lignin supplementation to enhance power production.

MATERIALS AND METHODS

Wastewater Collection

Bagasse wash water and pulping wastewater was collected in sterile containers from Tamilnadu Newsprint and Papers Limited, Karur. The collected wastewater was stored at 4°C and was thawed to room temperature prior to use.

Microbial Fuel Cell construction

Dual chambered MFC was fabricated using plexiglass material, plain graphite plates (38cm^2) without any modifications were used as anode and cathode. Nafion 117 (15cm^2) was used as a separator and was pre-treated prior to use to improve proton conductivity. The anolyte was stirred to obtain uniform anolyte concentration. 50mM Potassium Ferricyanide in 50mM Phosphate buffer at pH 7 was used as catholyte[15]. 10mM phosphate buffer was used to maintain anolyte pH at 7. MFC was operated in fed-batch mode; each cycle was terminated when the Open Circuit Voltage (OCV) was lower than 100mV. The film on the anode surface was not disturbed and was used as such in the consecutive cycles of operation.

Measurements and calculations

Chemical Oxygen Demand was measured using closed reflux method digestion followed by titration against 0.1 M Ferrous Ammonium Sulphate and ferroin indicator. Due to low current production it could not be measured directly and hence the voltage (V) produced across a known resistance (R) was measured using a multimeter and current (I) was calculated by ohms law I=V/R. The power and current density were calculated using the anode surface area. Polarization and power curves were generated by connecting series of resistance from 33000 Ω to 330Ω. The Coulombic efficiency was calculated by

$$CE= \frac{M \int_0^t Idt}{Fbv\Delta COD}$$

Where M is molecular weight of oxygen, I is the current in amperes, t is the cycle time, F is Faradays constant, b is the number of electrons transferred for reduction of one molecule of oxygen, v is the volume of wastewater and Δ COD is the change in chemical oxygen demand. Treatment efficiency is expressed in terms of COD removal.

RESULTS AND DISCUSSION

Bagasse wash water fed MFC

Biofilm formation on anode was facilitated by operating initial batches of MFC with full strength BWW. In the initial cycle, OCV gradually increased and reached 520 mV on 4th day of operation and it later decreased to 320mV on 8th day OCV later regained to 404 mV on 14th day. The batch was terminated at 18th day when the OCV reached 79mV. In the subsequent cycles, the peak OCV increased and was 542, 587, 624 and 720 mV for second, third, fourth and fifth cycles of operation respectively. The increase in peak OCV indicates the enrichment of exoelectrogens in anode biofilm with increase in time of operation. The treatment efficiency improved from 53% in the first cycle to 80% in later cycles though the batch time remained nearly the same. Acclimation of microbes to wastewater and establishment of biofilm enhances the substrate utilisation rate and hence the treatment efficiency [16]. Further studies were performed in the same reactor.

After 78 days of operation, a stable peak OCV of 720 mV was observed at 5th cycle. The batch was initiated in the month of December when the temperature was 28/20°C and it increased to 36/20°C in February. Increase in external temperature influences the reaction kinetics, thermodynamics, nature and distribution of bacterial species in anode biofilm resulting in high OCV [17] and [18]. In the later cycles the peak OCV ranged between 706 to 769mV and the external temperature ranged between 36 to 40°C. The maximum power and current produced was 91mW/m^2 and 225mA/m^2. The CE and treatment efficiency of the system was 13% and 84% respectively.

Synthetic lignin addition and its effect on MFC performance

To assess the influence of lignin addition to MFC, BWW in anode chamber was supplemented with 0.1 mol/l of commercially available standard alkali lignin. There was a minor reduction in the peak OCV compared to 720mV for BWW to 702mV for BWW+0.1mol/l lignin. The highest power density and current density was 93mW/m^2 and 273mA/m^2 respectively. Figure 1 represents the

polarisation behaviour and power curves of MFC with synthetic lignin addition. The COD removal efficiency was 61%, whereas the CE was 22%. Lignin has proved to be toxic to methanogens in the anaerobic treatment of paper and pulp industry wastewater [19]. Analogous suppression of methanogens could have favoured exoelectrogens growth in anode chamber resulting in higher energy conversion efficiency (CE). Previous study on addition of lignin as a mediator to ethanol hydrolysate in MFC increased the power production by 90%[14]. Surprisingly the results in our study show a very minor increase in power and drastic reduction in treatment efficiency. Ethanol stillage wastewater used by Sakdaronnarong et al consists of lignin and its degradation products and hence the anode biofilm could have tolerated lignin addition. In our case, BWW is primarily composed of residual sugars and simple organics and hence lignin addition might have caused toxicity to microbes in anode biofilm. The reduction in microbial activity resulted in low treatment efficiency.

The activity of exogenously added mediators is strongly affected by the mediator structure, electrolyte, and biochemistry [20]. Alkali soluble lignin was dissolved in 0.1 M NaOH and was added to MFC operating with BWW at pH 7. To check the effect of pH on the mediator addition and MFC operation, BWW modified with phosphate buffer to pH 8 was supplemented with 0.1mol/l of synthetic alkali lignin. There was a drastic drop in peak (606mV) OCV,

(11.71mW/m^2) power density and (27.8mA/m^2) current density. The pH widely affected the microbial growth leading to low MFC performance, making it difficult to assess the effect of pH on mediator properties. The system could regain its actual performance once the BWW at neutral pH was replaced.
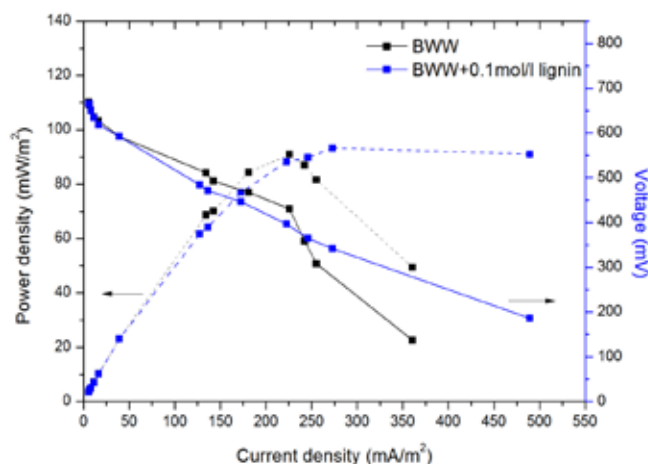
Fig. 1 : Polarization and power curves of BWW-MFC with 0.1 mol/l of lignin

The table 1 compares various available literatures on MFC operating with lignin containing wastewater. The power production efficiency is substantial in our current work. The reduction in COD removal may be due the addition

Table 1 : MFC operating with lignin rich wastewater as substrate

Wastewater	OCV (V)	CE%	Pmax mW/m^2	Lignin and related compounds removal	Reference
Rice mill wastewater	0.304	21.1	48.46	Lignin 84 % Phenol 81%	[21]
Corn Stover **Biomass powder**	0.33	22 % higher than CSRS	406	Lignin 4 % Cellulose 17%	[10]
Corn Stover **Residual solids after steam explosion**	0.437	-	331	Lignin 11% Cellulose 60%	[10]
Domestic wastewater + Glucose + humic acid	0.611	-	52	-	[5]
Domestic wastewater + Acetate + humic acid	0.706	-	107	-	
Domestic wastewater + Xylose + humic acid	0.666	-	42	-	
Rice straw	0.601	-	190	-	[12]
Wheat straw hydrolysate + domestic wastewater	0.654	25	116	-	[23]
BWW + synthetic lignin	0.702	22	93	0.1mol/l of synthetic lignin	Current study

of exogenous mediator. Hence it is important to further study the efficiency of CPW addition with BWW to study the effect of natural mediators in MFC performance.

CONCLUSION

The study enumerates that, addition of lignin increased the CE and power density of the system. It also led to reduced COD removal efficiency. Further increasing the pH of the wastewater widely affected the power production. The feasibility of testing the actual CPW as mediator could is important as the presence of other electron acceptors such as nitrates in CPW may reduce the CE of the system.

REFERENCES

[1] Y. Gu *et al.*, "The feasibility and challenges of energy self-sufficient wastewater treatment plants," *Appl. Energy*, vol. 204, pp. 1463–1475, 2017.

[2] S. Venkata Mohan, G. Velvizhi, J. Annie Modestra, and S. Srikanth, "Microbial fuel cell: Critical factors regulating bio-catalyzed electrochemical process and recent advancements," *Renew. Sustain. Energy Rev.*, vol. 40, pp. 779–797, 2014.

[3] R. Kumar, L. Singh, Z. A. Wahid, and M. F. Din, "Exoelectrogens in microbial fuel cells toward bioelectricity generation : a review," *Int. J. ENERGY Res.*, vol. 39, no. 8, pp. 1048–1067, 2015.

[4] A. D. Tharali, N. Sain, and W. J. Osborne, "Microbial fuel cells in bioelectricity production," *Front. Life Sci.*, vol. 9, no. 4, pp. 252–266, 2016.

[5] A. Thygesen, F. W. Poulsen, B. Min, I. Angelidaki, and A. B. Thomsen, "The effect of different substrates and humic acid on power generation in microbial fuel cell operation," *Bioresour. Technol.*, vol. 100, no. 3, pp. 1186–1191, 2009.

[6] L. Huang and I. Angelidaki, "Effect of Humic Acids on Electricity Generation Integrated With Xylose Degradation in Microbial Fuel Cells," *Biotechnol. Bioeng.*, vol. 100, no. 3, pp. 413–422, 2008.

[7] S. Rajeswari *et al.*, "Utilization of soak liquor in microbial fuel cell," *FUEL*, vol. 181, pp. 148–156, 2016.

[8] P. Pandey, V. N. Shinde, R. L. Deopurkar, S. P. Kale, S. A. Patil, and D. Pant, "Recent advances in the use of different substrates in microbial fuel cells toward wastewater treatment and simultaneous energy recovery," *Appl. Energy*, vol. 168, pp. 706–723, 2016.

[9] C. Krongtaew, S. Thanosawan, S. Chaithong, N. Sinbuathong, and C. Jeraputra, "Electricity production from ethanol stillage in two-compartment MFC," *Fuel*, vol. 107, pp. 382–386, 2013.

[10] X. Wang *et al.*, "Bioaugmentation for Electricity Generation from Corn Stover Biomass Using Microbial Fuel Cells," *Environ. Sci. Technol.*, vol. 43, no. 15, pp. 6088–6093, 2009.

[11] A. Thygesen, F. W. Poulsen, I. Angelidaki, B. Min, and A.-B. Bjerre, "Electricity generation by microbial fuel cells fuelled with wheat straw hydrolysate," *Biomass and Bioenergy*, vol. 35, pp. 4732–4739, 2011.

[12] A. Gurung and S.-E. Oh, "Rice Straw as a Potential Biomass for Generation of Bioelectrical Energy Using Microbial Fuel Cells (MFCs)," *Energy Sources, Part A Recover. Util. Environ. Eff.*, vol. 37, no. 24, pp. 2625–2631, 2015.

[13] S. H. A. Hassan *et al.*, "Electricity generation from rice straw using a microbial fuel cell," *Int. J. Hydrogen Energy*, vol. 39, no. 17, pp. 1–7, 2014.

[14] C. Sakdaronnarong, A. Ittitanakam, and W. Tanubumrungsuk, "Potential of lignin as a mediator in combined systems for biomethane and electricity production from ethanol stillage wastewater," *Renew. Energy*, vol. 76, pp. 242–248, 2015.

[15] S. P. N. Venkata Mohan S., Saravanan R., Veer Raghavulu S., Mohanakrishna G., "Bioelectricity production from wastewater treatment in dual chambered microbial fuel cell (MFC) using selectively enriched mixed micro flora : Effect of catholyte," *Bioresour. Technol.*, vol. 99, pp. 596–603, 2008.

[16] K. V. Krishna, O. Sarkar, and S. Venkata Mohan, "Bioelectrochemical treatment of paper and pulp wastewater in comparison with anaerobic process: Integrating chemical coagulation with simultaneous power production," *Bioresour. Technol.*, vol. 174, pp. 142–151, 2014.

[17] P. Taylor, L. H. Li, Y. M. Sun, Z. H. Yuan, X. Y. Kong, and Y. Li, "Effect of temperature change on power generation of microbial fuel cell," *Environ. Technol.*, vol. 34, pp. 37–41, 2013.

[18] A. Larrosa-guerrero, K. Scott, I. M. Head, F. Mateo, A. Ginesta, and C. Godinez, "Effect of temperature on the performance of microbial fuel cells," *Fuel*, vol. 89, no. 12, pp. 3985–3994, 2010.

[19] L. G. Sierra-Alvarez R. , Field J. A., Kortekaas S., "Overview of the anaerobic toxicity caused by organic forest industry wastewater pollutants," vol. 29, no. 5, pp. 353–363, 1994.

[20] C. J. Sund, S. Mcmasters, S. R. Crittenden, L. E. Harrell, and J. J. Sumner, "Effect of electron mediators on current generation and fermentation in a microbial fuel cell," *Appl Microbiol Biotechnol*, vol. 76, pp. 561–568, 2007.

[21] M. Behera, P. S. Jana, T. T. More, and M. M. Ghangrekar, "Rice mill wastewater treatment in microbial fuel cells fabricated using proton exchange membrane and earthen pot at different pH," *Bioelectrochemistry*, vol. 79, pp. 228–233, 2010.

[22] S. Cheng and B. E. Logan, "Ammonia treatment of carbon cloth anodes to enhance power generation of microbial fuel cells," vol. 9, pp. 492–496, 2007.

[23] A. Thygesen, F. W. Poulsen, I. Angelidaki, B. Min, and A. B. Bjerre, "Electricity Generation by Microbial Fuel Cells Fuelled with Enteromorpha Prolifera Hydrolysis," *Biomass and Bioenergy*, vol. 35, no. 11, pp. 4732–4739, 2011.

Assessment and Comparison of Physio-Chemical Parameters of Drinking Water of Delhi Region

Dr. Amit Chauhan, Varsha Chauhan and Aman Singh
Amity Institute of Forensic Sciences, Amity University, (Noida) Uttar Pradesh, India

ABSTRACT

Pure and safe drinking water is the potion of life. People on the globe are under huge danger because of unwanted changes within the physical, biological, and chemical characteristics of air, water, and soil. Due to the increased human population, industrialization, use of fertilizers, and human activities, water is highly polluted with various harmful contaminants. Natural water contaminates due to the enduring of rocks and leaching of soils, mining processing, and others. The quality of drinking water must be checked at regular time intervals because, because of the use of contaminated drinking water, the human population suffers from varied water-borne diseases. The accessibility of good quality water is a vital element for forestalling infections and improving personal satisfaction. It is necessary to know details about various Physico-chemical parameters like color, temperature, acidity, Hardness, pH, Sulphate, Chloride, Dissolved Oxygen, alkalinity used for testing of water quality. Some water analysis reports with physio-chemical parameters have been given for the investigating parameter study. Guidelines of distinct physio-chemical parameters also have been given for comparing the value of real drinking water samples of Delhi- NCR. Samples were convened from 7 different localities of Delhi-NCR. Now, the data convened in both years 2017 and 2018 were compared. The objective of the research paper is to study the quality of water over time so that we can understand the quality of drinking water every individual is consuming throughout the years in Delhi and other National capital regions.

Keywords *: Water, Physio-chemical, Parameters, Water Quality, Hardness, Sulphate, Chloride.*

INTRODUCTION

In ancient times, people were well-informed of the indispensability of water for life on earth is next time. According to ancient beliefs, the universe comprised of five essential elements; Earth, water, light/heat, air, and space. According to the Rig Veda, All life evolved from water. Pure water was called Divyajal due to its properties of cold to touch (Sheetam), clean (Suchihi), replete with useful minerals and elements (Shivam), transparent (Ishtham) and acidic balance should not exceed reasonable limits (Vimalam Lahu Shadgunam). Besides, there are copious references to the medicinal properties of water[1].

Water is a vital component not only for agriculture, industry, transportation but also for forestry, recreation, and environment. However, contrary to the past, modern society has become apathetic towards this boon of life[2]. On a larger scale, while interlinking of rivers expected to help by channelizing excess water in some rivers to the day river beds in other regions without disturbing the ecology, storage dams across major can absorb excess water during floods which can be used for irrigation, electricity generation, various other purposes. It is time that the bugle call sounded to make everyone realize that the water cycle and the life are one. Therefore, from today let all of us start saving every drop of water and conserve this priceless resource[3].

Globally, only 0.4 percent of the total water on mother earth is at our disposal for meeting our requirements, for which roughly 70 percent needed for agriculture. According to a published work on water resources entitled "characterizing our Water Future" shows that the global freshwater demand would be about 40 percent above the existing reliable and sustainable supply of freshwater by 2030. Due to environmental change, there could also be the variability of water availability across nations over time[4].

India's water sector is showing any indication of water stress in terms of per capita availability and heading towards water shortage shortly. Sever water crisis would imply, among other things, more water born disease, low agricultural and industrial productivity, and drinking water shortage. Today, the water sector in India presents a dismal scenario when one looks at its quality, which decreases the further availability of safe water. About 70 percent of the surface water and the groundwater are contaminated[5].

The quality of water measured by the presence of some "beyond threshold level" parameters of water. The

river water gets contaminated mainly due to inefficient functioning of ETPs, CETPs, STPs resulting in dumping of untreated industrial waste into the rivers; discharging of untreated municipal wastes into rivers; lack of onsite treatment of contaminations; non-point sources of pollution including pesticide-contaminated agricultural runoff, piling up materials at most rivers banks for religious uses, etc.[6].

Many questions have aroused concerning the quality of the water provided by the Municipality (Delhi Jal Board). The current study thus planned with the principal aim of determining the extent of chemical contamination in drinking water samples collected from different selected sites of Delhi-NCR. Seven drinking water samples collected from across the city as well as its surrounding areas7. A few parameters examined by using Indian Standards (IS 10500, 2004) to determine their sustainability for drinking purposes. During this assessment, mainly the physio-chemical parameters were taken into consideration. Since Delhi is quickly becoming a world-class city, it is crucial to screen the toxicity of its drinking water routinely to match the standards laid by the Bureau of Indian Standards (BIS) and the World Health Organization (WHO) for the drinking water quality[8]. Mainly, the portability of the collected water samples assessed, and the presence of chemical constituents was detected[9]. Our finding may have a significant effect on the society due to its role in spreading mass awareness regarding the importance of potable drinking water, and at the same time, to effectively compare different techniques available in the market for water purification, empowering people to decide their method of choice for water purification[10].

Among the essential elements for the existence of human beings, animals, and plants, water-rated to be of the most significant importance. Without food, humans can survive for several days, but water is such an essential that without it, one cannot survive. Water is not only crucial for the lives of living creatures, but it also occupies a unique position in industries. Probably, its most important use of an engineering material is in the steam generation[11].

METHODOLOGY

Delhi, the capital of India, is situated at the bank of the Yamuna river, in the middle of the latitudes 280 12" -280 53" N and the longitudes 760 50"- 770 23". It is one of the essential business centers in the country and, at the same time, highly populated. In the past few years, drinking water issues have created havoc in this city[12].

Sampling

It is a familiar saying that the aftereffect of any testing strategy can be no better than the example on which it performed. It is past the extent of this distribution to determine specific methods for the assortment of all examples due to different purposes and logical procedures[13].

The goal of testing was to gather a segment of material little enough in volume to be shipped advantageously but then enormous enough for explanatory purposes while still precisely speaking to the material inspected. This goal suggests that the relative extents or centralizations of every single relevant segment will be the equivalent in the examples as in the material inspected and that the example will be taken care of so that no considerable changes in organization happen before the tests made.

In 2017, the samples collected from various regions of Delhi. In this study, the sampling has been conducted from Delhi as well as from the National Capital regions as well, which includes Noida, Ghaziabad, and Gurugram[14].

Sample Collection

The kind of test container utilized is of most extreme significance. Test sample containers and document that they are free of the analyte of interest, especially when sampling and analyzing for shallow analyte levels. Containers usually are made of plastic or glass, yet one material may be favored over the other.

Drinking water samples from residential units aseptically collected, from seven selected localities across Delhi-NCR [North Delhi, South Delhi, East Delhi, West Delhi, Noida, Ghaziabad, and Gurugram]; in sterile plastic bottles (2 L capacity) using standard methodology and sealed by screw cap along with the Cello tape to secure the leakage and appropriately labeled. All of these were then transported carefully to the laboratory, and various tests are performed[15].

Analysis of Samples

The samples were analyzed by following the methods given in the APHA manual and referring to BSI Manual. Measurements of temperature and pH made with a pH electrode. Electrical Conductivity (EC) was determined using digital EC Meter. Total dissolved solids (TDS) was determined by filtering a known volume of water and then drying it at 180ºC. Alkalinity was determined by titration with 0.02 N sulphuric acids: total, calcium, and magnesium hardness determined by EDTA titration method. Chloride determined by argentometric titration method[16].

RESULT AND DISCUSSION

As per the earlier discussion, all the drinking water samples were collected from various areas of Delhi to examine for different physicochemical parameters. Parameters, such as pH, Conductivity, Total Dissolved Solids (TDS), Turbidity, Total Hardness, Calcium, Chloride, Total Alkalinity, Sulphate, Fluoride, were conducted in these samples. The obtained parameters from various parts are given below in a graphical presentation of tables:
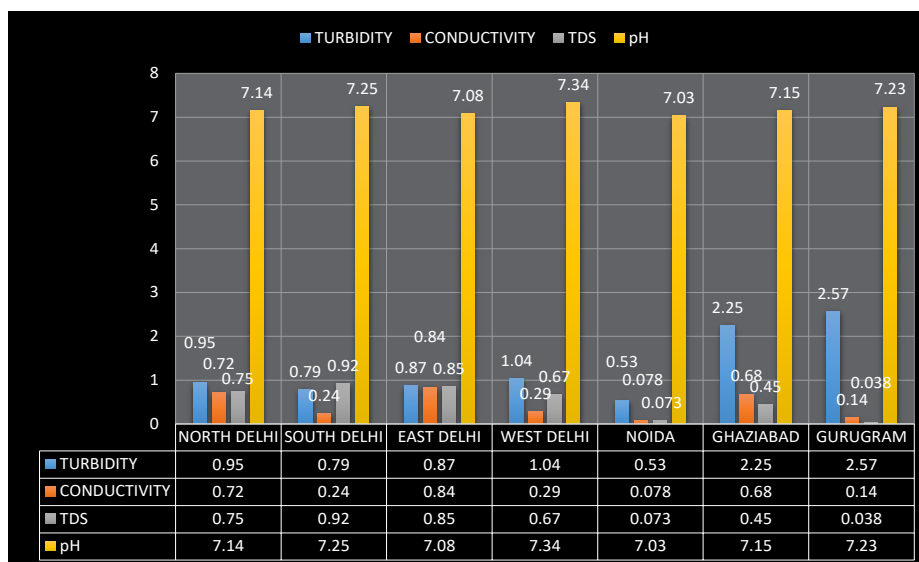
Graph 1 : The obtained pH, Turbidity, Conductivity, and TDS of the water samples collected from Delhi and the National Capital Region
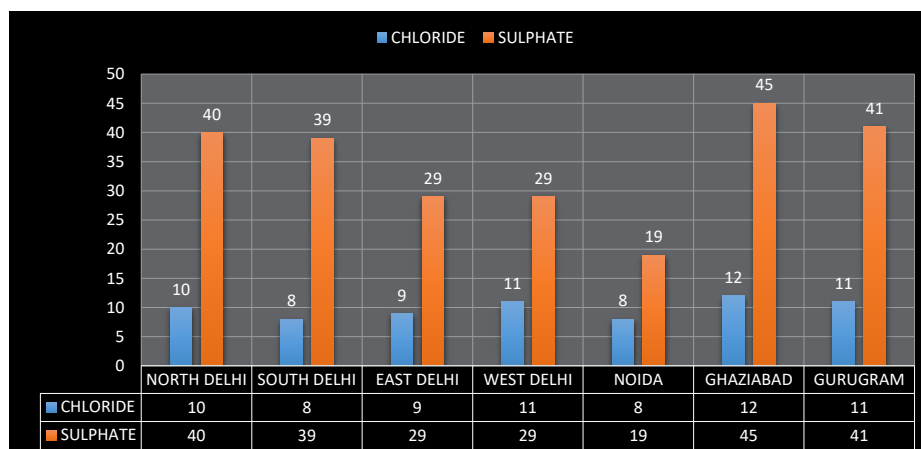
Graph 2 : The obtained Sulphate and Chloride of the water samples collected from Delhi and the National Capital Region
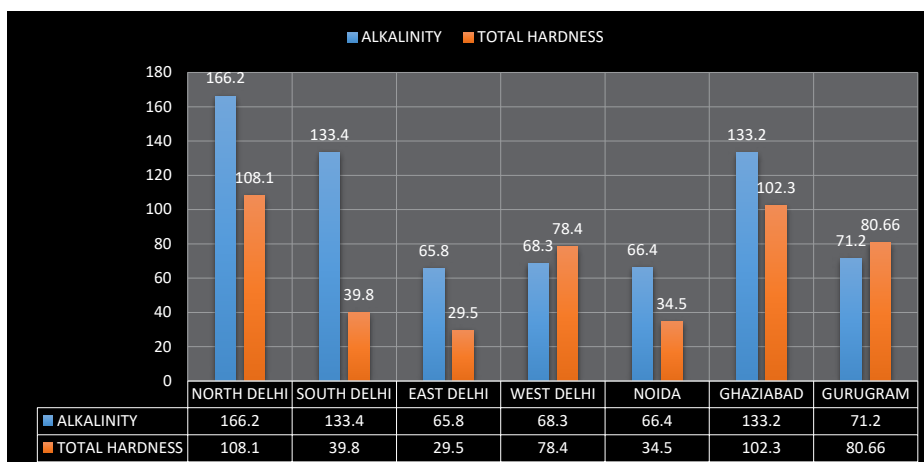
Graph 3 : The obtained Alkalinity and Total Hardness of the water samples collected from Delhi and the National Capital Region

Graph 4 : The obtained Iron and Fluoride of the water samples collected from Delhi and the National Capital Region
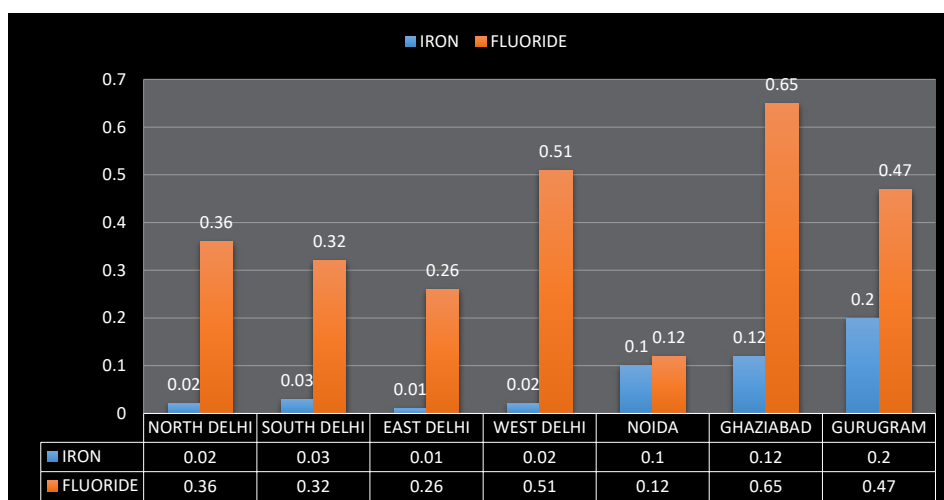
After examination of all the physical parameters in the drinking water. Now, all the samples subjected to the analysis of chemical parameters. The test results concluded that the pH level ranges from 7.03 to 7.25. In the study, we have found maximum pH value in the South Delhi region that is 7.25 and least in the Noida region that is 7.03, and both the min and max values lie in between the acceptable limit that is 6.5 to 8.5 as per IS: 10500 2012.

The study previouslty conducted from 2017 to 2018. As per the results, the pH level is maximum in the South Delhi only17. The test results concluded that the TDS level ranges from 0.038 to 0.92. In the study, we have found maximum pH value in the South Delhi region that is 0.92 and least in the Gurugram region that is 0.038, and both the min and max values lie in between the acceptable limit that is 500 mg/L as per IS: 10500 2012.

The most important chemical parameters, such as pH, alkalinity, TDS (Total Dissolved Solids), conductivity, total hardness, and turbidity values of all drinking water samples collected from Delhi-NCR regions, are presented in Tables. The pH values of South Delhi and West Delhi control water were found to fall well within the World Health Organization limits (6.5-8.5), but are somewhat alkaline. The control water of Ghaziabad, Gurgaon, and Faridabad were found to be highly alkaline and exceeded the permissible pH limits. The alkalinity of any fluid is closely related to its pH value, which in the term is a measure of free hydrogen ions in it. As the alkalinity of any water sample decreases, its pH value approaches neutrality (pH 7), which is desirable. However, beyond a limit, the same feature renders the water acidic. This makes the water non-potable and unacceptable. The present study verified in general that as the drinking water sample passed through progressively more efficient and costly water

purifying technologies, its quality indeed improved, and reached almost neutrality in the end. Besides imparting an undesirable salty taste to the water, a high concentration of TDS also affects plumbing appliances. Evaluation of Total Dissolved Solids of water samples collected from different regions of Delhi-NCR presented in the above graphs. The TDS content of the drinking water samples collected from various sites found to range between 345 mg/L to 2400 mg/L. It was heartening to discover that all water samples showed TDS values falling within the Indian Standard of Drinking Water Specification, i.e., 500 mg/L to 2000 mg/L. The electrical conductivity of water relates to the total concentration of dissolved ions. The hardness of water caused by the presence of multivalent metallic cations in it and is mainly due to the presence of calcium and magnesium ions.

Hardness conventionally reported in terms of the presence of calcium carbonate in the water. Its presence adversely affects the capacity of this water sample to react with soap. In other words, if the water is "hard," it requires considerably more soap to produce the same quantity of lather, as it would have produced as soft water. It influenced by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cation. The total hardness of water samples within the range of 108 mg/L and 423 mg/L, but the picture got substantially better following treatment through different water purifying technologies. One of the good points observed was that the hardness values of all water samples collected across Delhi-NCR not seen to be crossing the WHO prescribed limit of 500 mg/L. Although hard water is generally not recommended for drinking and washing purposes, the noteworthy fact remains that slightly hard water may be acceptable and superior to its soft counterpart. Soft water is tasteless, corrosive, and is known to dissolve metals

readily. Moderately hard water is preferred to soft water for irrigation purposes too. Based on the WHO limits, the alkalinity and hardness of the water samples from Delhi-NCR may conclude to be safe and acceptable. The turbidity of all the water samples analyses ranged between 0.5 – 2.57 NTU; this was within the WHO limit of 0 – 5 NTU.

CONCLUSION

It was relieving and reassuring that the treated drinking water supply across Delhi-NCR found to be of sensibly good quality, adequately treated, and safe for consumption. Physio-chemical parameters like pH, total hardness, conductivity, turbidity, and TDS values of the Munciple Corporation of Delhi water supplies found to be mostly within permissible limits. As expected, the Reverse Osmosis technique proved to be the best technology towards engraving water portability, chemically, and microbiologically, as compared to other techniques. Nevertheless, taking into consideration the ease of operation, cost/maintenance, and versatility of the equipment, the utilization of at least an inexpensive tap connection may be recommended to the end-users, mainly if they have not been utilizing water purifiers till now due to financial constraints or lack of awareness. As mentioned above, drinking water samples collected from across the city and NCR regions. Different parameters examined using Indian Standards to find their suitability for drinking purposes.

During this examination, mainly the physio-chemical parameters were taken into consideration. Since Delhi is fast becoming a world-class city, it is essential to monitor the toxicity of its drinking water regularly to match the standards laid by the Bureau of Indian Standards (BIS) and the World Health Organization (WHO) for the drinking water quality. Mainly, the portability of the collected water samples surveyed and the presence of chemical constituents were detected. As regards physical-chemical parameters, the result was that drinking water sources have a sensibly good chemical quality, the Municipality treated drinking water supply across Delhi was found to be of good quality compared to the NCR region, adequately treated and safe for consumption. Physio-chemical parameters like total hardness, turbidity, alkalinity, TDS, Chlorides, and heavy metals like copper, cobalt, nickel, boron, chromium and, zinc values of the MCD water supplies found to be mostly within permissible limits. Based on various chemical tests, the quality of drinking water supply in most localities within proper Delhi found to be generally equal. The average value of all observations was under permissible limit.

CONFLICT OF INTEREST   : NA

SOURCE OF FUNDING   : NA

ETHICAL CONSIDERATION   : NA

REFERENCES

1. Kim EJ, Herrera JE, Huggins D, Braam J, Koshowski S. Effect of pH on the concentrations of lead and trace contaminants in drinking water: a combined batch, pipe loop, and sentinel home study. Water Res. 2011 Apr; 45(9):2763–74.

2. Honorine NT, Emile T, Thomas N. Physico-Chemical and Bacteriological Quality of the Vegetable Watering Water in the Dschang Town, Cameroon. Journal of Environmental Protection. 2012; 03(08):949–55.

3. R. A. Archana, Dr. Parvinder Kaur, Dr. Saraswati Kanodia, Dr. Seema Gupta Priyanka, Purnati Khuntia, Kumar Anadi Anant, Manti Kumar Saha, Shweta Jaiswal, Ayush Sharma, AshishTiwari, Anju Mehra, Anjali Panchal, and Sumit Kuma. Evaluating Microbial and Chemical Quality of Delhi-NCR Drinking Water, Enhancing its Standard & Spreading Mass Awareness. DU Journal Of Undergraduate Research And Publications.

4. Adeyeye, E.I. Determination of trace heavy metals in Illisha Africana fish and associated water and soil sediments from some fish ponds. International Journal of Environmental Studies. 1994 Apr; 45(3–4):231–8.

5. Smith SV, Hollibaugh JT. Annual Cycle And Interannual Variability Of Ecosystem Metabolism In A Temperate Climate Embayment. Ecological Monographs. 1997 Nov;67(4):509–33.

6. S OA, E EA. Determination of Physico-chemical parameters and heavy metals in water samples from Itaogbolu area of Ondo-State, Nigeria. African Journal of Environmental Science and Technology. 2010 Mar 31; 4(3):145–8.

7. Pehkonen SO, Palit A, Zhang X. Effect of Specific Water Quality Parameters on Copper Corrosion. CORROSION. 2002 Feb; 58(2):156–65.

8. WHO; UNICEF. Progress on Sanitation and Drinking Water: 2012 Update; World WHO; UNICEF. JPM Technical Task Force Meeting on Monitoring Drinking-water Quality.

9. Sharma V, Walia Y. Water Quality Assessment Using Physico-Chemical Parameters and Heavy Metals of Gobind Sagar Lake, Himachal Pradesh (India). Current World Environment. 2015 Dec 27; 10(3):967–74.

10. M. Awoyemi O, C. Achudume A, A. Okoya A. The Physicochemical Quality of Groundwater in Relation to Surface Water Pollution in Majidun Area of Ikorodu, Lagos State, Nigeria. American Journal of Water Resources. 2014 Oct 27;2(5):126–33.

11. APHA, (1985), Standard Methods for Examination of Water and Wastewater, 20th Edition, American Public Health Association, Washington D. C.

12. Wagh V, Ghole V, Wavde P, V Todkar V, K Kokate K. Assessment of Water Quality of Mutha River in Pune City. 2008.

13. Singhal V, Kumar A, Rai JPN. Bioremediation of pulp and paper mill effluent with Phanerochaete chrysosporium. J Environ Biol. 2005 Jul;26(3):525–9.

14. Moss B. Studies on Gull Lake, Michigan. Freshwater Biology. 1972 Dec;2(4):309–20.

15. Rahman IMM, Islam MM, Hossain MM, Hossain MS, Begum ZA, Chowdhury DA, et al. Stagnant surface water bodies (SSWBs) as an alternative water resource for the Chittagong metropolitan area of Bangladesh: physicochemical characterization in terms of water quality indices. Environ Monit Assess. 2011 Feb;173(1–4):669–84.

16. Amit Chauhan, Varsha Chauhan, and Shukla S. K. Assessment of physicochemical parameters of drinking water in Delhi. International Journal of Current Advanced Research; Vol 8; Issue 03(B), pp: 17710-17714, March 2019.

17. Sharma SC, Srinivasan S. Gel filtration, and related studies on the reconstitution of bacteriophage T4. Indian J Biochem Biophys. 1975 Sep;12(3):233–7.

Don't let the Water Run in the Sink, our Life's on the Brink!.

Assessment of Coastal Pollution and its effects, Southwest Coast of India

Kiran D A and H K Ramaraju

*Department of Civil Engineering, Dayananda Sagar College of Engineering (DSCE),
Bangalore, Karnataka, India*

ABSTRACT

Indiscriminate releases of partially treated or untreated wastes into the receiving water bodies have resulted in the water pollution, public health risks and loss of biodiversity. Gurupura river is situated very adjacent to the baikampady industrial cluster towards north of the Mangaluru city and it will end up with Arabian sea forming a estuary with Nethravathi river i.e., located at a distance of 20 km from the Baikampady Industrial cluster towards South. This study was carried out to know the impacts of anthropogenic activities along the Gurupura river. The study reveals that, the concentration of TDS, Conductivity, Chlorides, BOD and COD in the collected water samples exceeds the IS standards both in the post monsoon and pre monsoon seasons and also large numbers of dead fishes were found in Nethravathi-Gurupura estuary point during the sampling time due to the industrial discharges.

***Keywords** - Gurupura river; baikampady industrial cluster; water pollution; conductivity; industrial discharge.*

INTRODUCTION

The coasts, the dynamic function of oceans, atmosphere and land, undergo changes in shape and position due to natural forces and anthropogenic activities. Coastal environment serve a wide variety of functions including fishing, recreation, commerce, navigation and are characterized by a variety of factors like wave energy, tidal range, sediment supply, sediment type and tectonic movement. The coastal zone has become the major site for extensive and diverse economic activities. Many of the coastal developing countries depend heavily on the scarce coastal resources for their economic growth. Among the coastal resources, water is the most essential material and increasing demand with urbanization and industrialization. Anthropogenic nutrient loads from coastal watersheds to the near shore waters are dramatically altering aquatic habitats[8]

In recent years, because of continuous growth in urbanization, rapid industrialization and various agricultural activities in and around coastal areas significant amount of pollutants are introducing into the surrounding aquatic ecosystem such as estuary, river, sea, seashore and coastal wetlands. This causes ecological degradation. The analysis of surface water quality is an important and sensitive issue.

The available information shows that Mangalore Refineries and Petrochemical Ltd (MRPL) discharges 7,200 m³/d, BASF India Ltd., discharges 3,600 m³/d, Mangalore Chemicals and Fertilizers (MCF) discharges 13,000 m³/d, south of Mangalore harbor. All these wastes are likely to have an effect on the coastal environment[14]. Pollution load from the various industries situated nearby coastal area were discharging into the ocean directly or indirectly through the rivers.

Since the present study area (Fig. 1 & 2) is very near to the Baikampady Industrial Cluster, it is one of the most polluted industrial clusters in Karnataka state with a CEPI score of more than 70. It includes large number of highly polluting industries; it may cause ill effects on the nearby surface water and ground water through its discharges. Many streams are flowing in the area carrying waste waters from the industries; they are going to end up with the Gurupura River near Total Oil India Limited (TOIL) and Arabian Sea directly or indirectly. So this study was conducted to check the pollution status of the Gurupura river by considering various physico chemical parameters.

MATERIALS AND METHODOLOGY

Mangaluru is located at 12.87°N 74.88°E in the Dakshina Kannada district of Karnataka. Mangaluru coastal belt spreads about 22 Kms with Western Ghats in the Eastren side and Arabian Sea in the Western side. It has an average elevation of 22 m above mean sea level. The average rainfall of Dakshina Kannada district is 3882 mm and is received mainly during the southwest monsoon season extending from June to September.[5]

Baikampady Industrial cluster is located on Northern side of Mangalore city, this area is nearby coastal belt of Netravathi-Gurupur river mouth. The Baikampady Industrial area consists of a major refinery, LPG storage & bottling, storage of crude and finished petroleum products, fertilizer plant, Brewery, Edible oil processing units, Pharmaceutical industry Sea food processing units, Paint & Dispersion unit and Iron ore pelletization plant etc.

The study area for the present work includes Gurupura river near TOIL, Gurupura River near HLL and Gurupura-Nethravathi estuary point (Table 1). Three River Water samples were collected from selected locations of the study area during the post monsoon and pre monsoon seasons of 2018 and 2019. The sampling was done during the morning hours and samples were protected from direct sunlight during transportation. The water samples from the sampling locations were collected in well cleaned polythene bottles. Before collection of the water samples, the bottles were washed with freshwater. Finally, the bottles were tightly closed and brought to the laboratory for further analysis. Physicochemical analysis of the collected water samples was done by adopting standard methods[1]. (Table 2)
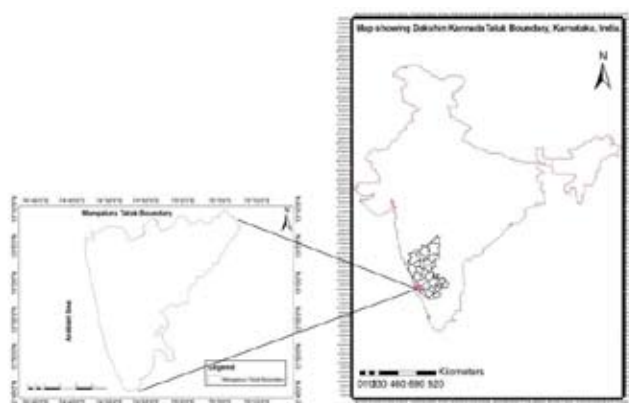

Fig. 1 : Map Showing the study area-Mangaluru

Fig. 2 : Map Showing the River water sampling locations

Table 1 : Surface Water Sampling Details

Sl. No.	Sample Code	Sampling Locations	Geographical Position	
			Latitude	Longitude
1	RW1	Gurupura river near Total Oil India Limited, TOIL	12º 56 ' 35" N	74º 50 ' 5" E
2	RW2	Gurupura river near Hindustan Unilever Limited, HLL	12º 52 ' 54.7" N	74º 49 ' 29.7" E
3	RW3	Gurupura-Nethravathi Estuary ,G-N Estuary	12º 50 ' 52.46" N	74º 49 ' 47.42" E

RESULTS AND DISCUSSIONS

Physicochemical Characteristics of the Surface Water Samples

Table 2 : Physico Chemical Characteristics Of The River Water Samples

Sample code	pH	EC, µs/cm	TDS, mg/l	Alkalinity, mg/l	Hardness, mg/l	Chlorides, mg/l	Sulphates, mg/l	DO, mg/l	BOD, mg/l	COD, mg/l
Post monsoon season										
RW1	7.84	28800	18720	235	4212.3	9603.3	726.3	5.1	45	854
RW2	7.70	33100	21515	100.5	3045.3	10944.1	821.1	5	32	763
RW3	8.2	15040	9776	252	5985	12602.3	731.8	3.1	12	997
Pre monsoon season										
RW1	7.89	36900	23985	196	2662	8401.2	665	4.8	32	654
RW2	8.10	29600	19240	240	3461	7265.3	710.3	5.1	28	509
RW3	8.22	38700	25155	208	6550	10365.2	560.2	5.3	8	408

(1) *pH* : It is a measure of hydrogen ion concentration in water. Its value determines whether water is acidic or alkaline. In the present study pH ranges between 7.7 to 8.2 in post monsoon season and 7.89 to 8.22 in the pre monsoon season.

(2) *Electrical Conductivity (EC)* : Conductivity is a measurement of the ability of an aqueous solution to carry an electrical current. An ion is an atom of an element that has gained or lost an electron which will create a negative or positive state. Conductivity and temperature are directly related[4]. Its values range between 15040 µs/cm to 33100 µs/cm and 29000 to 36900 µs/cm during post and pre monsoon season. High values of E.C. was found in the sample RW3 (38700 µs/cm) of pre monsoon season. Usually the large variation in E.C. is mainly attributed to geochemical process like ion exchange, reverse exchange, evaporation silicate weathering, rock water interaction, sulfate reduction and oxidation processes[13].

(3) *Total Dissolved Solids (TDS)* : The various kinds of minerals present in the water denote the amount of dissolved solids. The total dissolved solids varied from 9776 mg/l to 25155 mg/l. High values of TDS is recorded in the sample RW3 (25155 mg/l) of pre monsoon season Total dissolved solids describes the amount of inorganic salts of calcium, magnesium, sodium etc. and small proportion of organic matter present in the water, where a high value of the same have been reported to be related to acute myocardial infarction as well as ischemic heart diseases in few studies[16].

(4) *Alkalinity* : Alkalinity is the sum total of components in the water that tend to elevate the pH to the alkaline side of neutrality. Higher alkalinity favours the growth of phytoplankton7. In the present study the total alkalinity ranges from 100.5 mg/l to 252 mg/l and high value is observed in the sample RW3 (252 mg/l) of post monsoon season.

(5) *Total Hardness*: Hardness of water is an important consideration in determining the suitability of water for domestic and industrial uses. Hardness is caused by multivalent metallic cations and with certain anions present in the water to form scale. The principal hardness-causing cations are the divalent calcium, magnesium, strontium, ferrous iron and mangnous ions. The total hardness in the study varies between 2662 mg/l to 6550 mg/l. High value of total hardness was observed in the sample RW3 (6550 mg/l) of pre monsoon season. The high levels of hardness increases toxicity of zinc to fish 10.

(6) *Chlorides* : It occurs naturally in all types of waters. High concentration of chlorides is considered to be the indicators of pollution due to organic wastes of animal or industrial origin. Chlorides are troublesome in irrigation water and also harmful to aquatic life12. The chloride content in the water sample varied from 7265.3 mg/l to 12602.3 mg/l. Highest chloride content was recorded in the sample RW3 (12602.3 mg/l) of post monsoon season.

(7) *Sulphates* : Natural water contains sulphate ions and most of these ions are also soluble in water. Many sulphate ions are produce by oxidation process of their ores, they also present in industrial wastes. Contaminated water and waste water has high sulphate concentration. Gastro intestinal irritation are produced due to high concentration of sulphate. In this study sulphates concentration varies from 560.2 mg/l to 821.1 mg/l.

(8) *Dissolved Oxygen* : The dissolved oxygen content is one of the most important factors in stream health. Its deficiency directly affects the ecosystem of a river due to bioaccumulation and biomagnifications. The oxygen content in water samples depends on a number of physical, chemical, biological and microbiological processes. DO values also show lateral, spatial and seasonal changes depending on industrial, human and thermal activity2. In the present study DO values ranged from 3.1 mg/l to 5.3 mg/l. Water sample near G-N estuary was recorded lowest DO value of 3.1 mg/l. A minimum DO level of 4–5 mg/l is desirable for the survival of aquatic life[11]. The minimum value observed was may be due to the discharge of untreated sewage that causes Eutrophication and other harm effects.

(9) *Biochemical Oxygen Demand (BOD)*: is a measure of the oxygen in the water that is required by the aerobic organisms. The biodegradation of organic materials exerts oxygen tension in the water and increases the biochemical oxygen demand 3. In the present study BOD ranges from 8 mg/l to 45 mg/l and high value of BOD was observed in the sample RW1 (45 mg/l) of post monsoon season.

(10) *Chemical Oxygen Demand*: COD is a measure of oxygen equivalent of the organic matter content of water that is susceptible to oxidation by a strong chemical oxidant. Thus, COD is a reliable parameter for judging the extent of pollution in water15. In the present study COD values ranged from 408 mg/l to 997 mg/l. High value of COD is recorded in the RW3 (997 mg/l) of post monsoon season. High COD may cause oxygen depletion on account of decomposition of microbes to a level detrimental to aquatic life.

Fig. 3 : Dead fishes on the banks of Gurupura-Nethravathi Estuary point

CONCLUSIONS

The analysis of physical and chemical properties of water quality helps in determination of the current pollution level of aquatic ecosystems. The study reveals that Electrical conductivity, Total Dissolved Solids and Chlorides concentration of most of water samples were met above the standard limits as per IS: 2296-1982 Standard: Inland Surface Water Class – E. High values of BOD and COD were also found in almost all the collected water samples. Figure 3 shows Dead fishes on the banks of Gurupura-Nethravathi Estuary point

It is also evident that, Pollution level in Post monsoon season is more severe than the pre monsoon season by considering various parameters. Regular monitoring of different water bodies need to be carried out more rigorously and Creation of public awareness is very important. It is evident from study that anthropogenic activities near the coastal region have resulted in the deviation in the values of physicochemical characteristics of the samples. Thus there is an urgent need to arrest the spread of pollution of water near the coastal area.

Acknowledgment

Conflict of interest- Nil

REFERENCES

1. APHA, Methods for the Examination of Water and Waste Water, (American Public Health Association, American Water Works Association, Water Environment Federation) 23rd Edition 2017.

2. Appavu, A., Thangavelu, S., Muthukannan, S., Jesudoss, J.S. & Pandi, B., Study of water quality parameters of cauvery river water in erode region, Journal of Global Biosciences, 5 (2016) 4556-4567.

3. Begum, A., Study on the quality of water in some streams of Cauvery River, Journal of chemistry, 5(2) (2008) 377-384.

4. Bhardwaj, D. & Verma, N., Research Paper on Analysing impact of Various Parameters on Water Quality Index, International Journal of Advanced Research in Computer Science, 8 (2017) 2496-2498

5. CGWB, Ground Water Information Booklet-Dakshina Kannada District, (CGWB) 2012.

6. Dohare, D., Deshpande, S. & Kotiya, A., Analysis of ground water quality parameters: a Review, Research Journal of Engineering Sciences, 3(2014) 26-31.

7. Francis Andrade, H., Aravinda, B. & Puttaiah, E.T., Studies on Mangalore coastal water pollution and its sources, Ind. J. Sci and Technol, 4(2011) 553-557.

8. GESAMP, the State of the Marine Environment (Blackwell Scientific Publication, Oxford, UK) 1990, pp. 146.

9. Jhingran, A.G., Optical Appearance And Interpretation Of Annceli On Scales Of Gadeesia Chapra (Ham). J. Inland Fish Soc. Ind, 91 (1997) 138-153.

10. Lloyd, R., The toxicity of zinc sulphate to rainbow trout. Annals of Applied Biology, 48(1960) 84-94.

11. Mathew, R.A., Lavanya, V., Rasiga, S. & Abraham, M., Bioremediation of marine oil spill using beeswax, Indian Journal of Geo Marine Sciences, 48(2019) 1227-1231.

12. Rajakumar, S., Velmurugan, P., Shanthi, K., Ayyasamy, P.M. & Lakshmanaperumalsamy, P., Water quality of Kodaikanal Lake, Tamilnadu in relation to physico-chemical and bacteriological characteristics, Lake and Coastal Wetlands: Conservation, Restoration and Management., (2007) 339-346.

13. Ramesh, K., Hydrochemical studies and effect of irrigation on groundwater quality Tondiar basin Tamilnadu, Ph.D. thesis, Anna University, Chennai, Tamilnadu, 2008.

14. Shirodkar, P.V., Mesquita, A., Pradhan, U.K., Verlekar, X.N., Babu, M.T. & Vethamony, P., Factors controlling physico-chemical characteristics in the coastal waters off Mangalore-a multivariate approach, Environmental Research, 109 (2009) 245-257.

15. Shrivastava, V.S. & Patil, P.R., Tapti river water pollution by industrial wastes: A statistical approach, Nature Environment and Pollution Technology, 1(2002) 279-283.

16. Sneka, K., A. & Dheenadayalan, M.S. Seasonal variation of Cauvery river due to discharged Industrial effluents at Pallipalayam in Namakkal. 8(2005) 380 – 388.

Key Developments in Indian Irrigation Sector

Sabarna Roy

*Business Development, Applications Technology, Engineering and Strategy Department,
Senior Vice President, Electrosteel Group, Kolkata, India*

ABSTRACT

The key developments in Indian Irrigation sector have been presented by briefly discussing the following topics:

1. Present Indian Irrigation Challenges and Way Forward.

2. Regulatory Interventions in Water Sector in India (Maharashtra's Example).

3. Roles and Activities of Maharashtra Water Resource Regulatory Authority (MWRRA).

4. Major Achievements of MWRRA.

Indian National Committee On Irrigation and Drainage (INCID).

5. Irrigation, Command Area Development and Micro Irrigation in India.

6. Flood Management and Its Measures.

7. Capacity Building.

Keywords *: Irrigation, developments, MWRRA, INCID, CWC, water efficiency, flood forecasting, sustainability, Micro-Irrigation.*

1. PRESENT INDIAN IRRIGATION CHALLENGES AND WAY FORWARD

It is known that 89% of water in India is consumed for irrigation. Today, the major concern is the lack of sustainability of water in India. Indian Government has adopted the path of self-sufficiency in food grains through Irrigation by creating large number of dams and canals. India has extracted colossal amount of groundwater which accumulates to 25% of the World's Ground Water Storage, resulted in construction of around 50 million water retaining structure [1]. The ways that should be adopted for water sustainability and Water Asset Management are:

- India needs to put emphasis on modernization of water systems to increase the water efficiency.
- It is now becoming important to put some yardstick to measure the efficiency of irrigation projects.
- The cropping pattern needs to be carefully selected based on water availability of that particular region.
- Focus on Micro Irrigation should be increased.
- To channelize and utilize efficiently the rain water available during the 3 months' monsoon period for the remaining 9 months [1].
- India is the greatest extractor of Ground Water in the World (combined that of the USA and China). This is creating drying up of the aquifer. Ground Water Management programs are being taken up by the Government.
- New schemes like Atal Bhujal Yojana has been started to involve participatory ground water management on demand side so that there is a parity between supply side and demand side.
- Finally – emphasis is to be given by all the States as to how to irrigate more area with less water.

2. REGULATORY INTERVENTIONS IN WATER SECTOR IN INDIA (MAHARASHTRA'S EXAMPLE)

Water Regulatory Authorities in India have resulted in State Water Policy in different states of Maharashtra, Uttar Pradesh and Jammu and Kashmir which has helped better to control the water usage.

Key features of State Water Policy of Maharashtra were the incorporation of the following points: -

- Separate water tariffs were issued for agricultural sector, domestic sector and industrial sector.
- Implementation of Water entitlement was another major inclusion.
- Integration of regulatory guidelines in three different levels, i.e., Policy level, Institutional level and Administrative level.

3. ROLES AND ACTIVITIES OF MAHARASHTRA WATER RESOURCE REGULATORY AUTHORITY (MWRRA)

Maharashtra Water Resource Regulatory Authority (MWRRA) was established in June 2005, enacted and

functional since August 2006. The organisation has a Chairman and 4 expert members covering (Water Resource Engineering, Law, Water Economy and Ground Water) [2].

The roles and activities of the organization which aims to provide sustainable water security to the State of Maharashtra are:

- Regulating both surface water and ground water of the state.
- To determine bulk water tariff for agriculture, industrial domestic and other purposes.
- To accord clearances to water resources projects.
- To act as the State Ground Water Authority.
- To support enhancement and preservation of Water Quality.

4. MAJOR ACHIEVEMENTS OF MWRRA

The major achievements of Maharashtra Water Resource Regulatory Authority (MWRRA) [3] are:

- Regulatory interventions for sharing deficit in dry years by devising formulae and methodologies for judicious sharing among different sectors, and thus reducing the conflicts between various stakeholders.
- Regulatory interventions for promoting efficient water use and reducing wastage in non-irrigation sector through proper tariff policies, budgeting and audit reports which increases conservation awareness among users.
- Regulatory interventions for promoting efficient water use and reducing wastage in agriculture sector through promotion of micro irrigation by tariff incentives and thereby increasing the area under micro irrigation systems.
- Adjudication of Water Disputes by constituting transparent and trustworthy platforms for addressing grievances caused improvement of water governance in Maharashtra. MWRRA has disposed total 41 disputes in 14 years.
- Capacity building, knowledge sharing and motivation for action through collaboration with various governments in both national and international scale, academic institutions in conjunction to organizing various conferences

Although water reforms take place in a slow rate due to conflicts and domination of the socio-political system, MWRRA has done extensive work in bulk water tariff, equitable distribution of water in sub-basin and dispute resolutions. In its 14 year long journey the organization has improved water governance in Maharashtra, reduced water conflicts and has enhanced the water use efficiency in agriculture significantly.

5. INDIAN NATIONAL COMMITTEE ON IRRIGATION AND DRAINAGE (INCID)

- Central Water Commission (CWC) [4] is hosting the Indian National Committee on Irrigation and Drainage (INCID). INCID, CWC and ICID [5] closely cooperate in water resources sector contributing towards knowledge dissemination: workshops, conferences, seminars etc.
- Ministry of Jal Shakti, in August 2019, re-constituted INCID as a dedicated national committee with representation from various states and union ministries, training and research institutes, NGOs, private sector, etc. for bringing ICID to the doorsteps of country level development.
- INCID have developed a number of guidelines, manuals and books for consolidating knowledge in irrigation management field.

In line with the objectives of ICID, CWC is engaged in various activities in the fields of:

- Irrigation, development and management.
- Development of Hydropower.
- Flood Forecasting.
- Rehabilitation and modernization of dams and irrigation projects.
- Trans-boundary and inter-state water management issues.
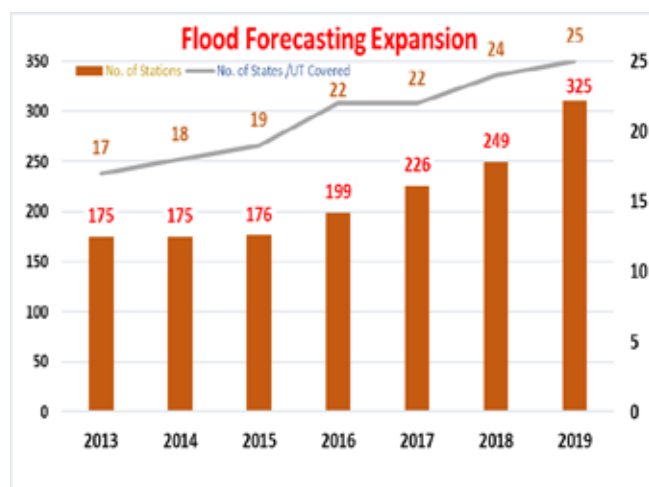- Capacity Building.

6. IRRIGATION, COMMAND AREA DEVELOPMENT AND MICRO IRRIGATION IN INDIA

- Irrigation Potential has increased from 22.6 Mha in (1951) to 126.73 Mha by the end of 2017.
- Food Grain Production increased from 51 MMT (1950-51) to 295 MMT (about 6 times) by the end of 2017 [6].
- Accelerated Irrigation Benefit Program (AIBP) [7]: Initiative of Government of India for last mile funding and technology support for early completion of irrigation projects Flood Forecasting.
- Command Area Development (CAD) Program was launched by Government of India in 1974-75. Restructured and renamed as Command Area Development and Water Management (CADWM) in 2004. Objectives of CADWM Program are to bridge the gap between Irrigation Potential Created (IPC) and Irrigation Potential Utilized (IPU). It also improves Water-Use efficiency and increase agriculture productivity and production. It provides last mile connectivity in delivery of irrigation water and Participatory Irrigation Management (PIM).

- National Mission on Micro Irrigation (NMMI) under Ministry of Agriculture (as part of National Mission on Sustainable Agriculture) [8] provides financial support to farmers. Potential for Micro Irrigation was 69.5 M ha and achieved till now is 10 M ha.

- Recent initiatives on improving irrigation efficiency involves:
  - Mandatory implementation of micro irrigation in at least 10% of the Command Area in AIBP and CADWM Programmes.
  - Emphasis on Pipe Distribution Network in order to avoid Land Acquisition as well to avoid wastage of water. CWC has prepared Guideline on Planning and Design of Pipe Irrigation regarding this.

7. FLOOD MANAGEMENT AND ITS MEASURES

- Extensive Flood Management is taking place by increasing construction of Embankments, Channel/ Drainage Improvement, Flood Plain Zoning as per model bill of 1975- circulated by Ministry of irrigation.

- Increase in number of Flood Forecasting Stations and Flood Forecasting Expansion (Fig. 1).

- Modernization in Flood Forecasting by collecting Automatic Real time data and communication. Three days' advisory forecast based on rainfall runoff modeling and collaboration with Google for inundation forecast (7 levels forecast stations- 11000 km2), this is planned to increase to 3 times during this year.

- Establishment of Water Resources Information System (India-WRIS) for easy availability of water related data for planning, development and research.

8. CAPACITY BUILDING

- In view of COVID, National Water Academy (NWA) [6] (training institute of CWC) and ICID have recently joined hands to use Digital Learning tools for trainings [2]:

- Principally it has been agreed to collaborate for conducting Training and Capacity building through Digital Learning in:

- Irrigation and Water management including Micro irrigation.

- Water use efficiency, Flood and Drainage.

- It is under the process of development and training material is provided by NWA, and CWC is under review.

- Modular Object-Oriented Dynamic Learning Environment (MOODLE) platform available with ICID would be used.

- The target Audience for the Distance Learning would be Water Resources and Irrigation professionals, farmers, NGOs, Agriculture extension staff, Students, International participants especially from the member countries of ICID etc.

State/UT	Level Forecast Station	Inflow Forecast Station	Total
Andhra Pradesh	10	9	19
Arunachal Pradesh	3	0	3
Assam	30	0	30
Bihar	40	3	43
Chhattisgarh	1	2	3
Gujarat	6	7	13
Haryana	1	1	2
Himachal Pradesh	1	0	1
Jammu & Kashmir	3	0	3
Jharkhand	2	15	17
Karnataka	1	14	15
Kerala	3	2	5
Madhya Pradesh	2	9	11
Maharashtra	8	15	23
Odisha	12	7	19
Rajasthan	2	11	13
Sikkim	3	5	8
Tamil Nadu	4	11	15
Telangana	5	7	12
Tripura	2	0	2
Uttar Pradesh	39	4	43
Uttarakhand	4	2	6
West Bengal	12	4	16
NCT Delhi	2	0	2
Daman & Diu	1	0	1
Total	197	128	325

Fig. 1 : Flood Forecasting Expansion

9. CONCLUSION

Regulatory policies in India are changing towards a more sustainable environment with implementation of water entitlement in the agricultural sector. Modernization in tools to account water efficiency, data collection, storage and mapping and hands on training of water resources personnel are to be executed. Regulations on bulk water tariff, equitable distribution of water in sub-basin and dispute resolutions are being handled on a serious note. Importance and mandatory implementation of Micro-Irrigation and Flood Forecasting with the help of innovative technologies will be a keystone in the forthcoming years.

REFERENCES

[1] Keynote Address by Shri U.P. Singh, Secretary, Ministry of Water Resources/Minister of Jal Shakti, Government of India on webinar titled "Agricultural Water Management Strategies in Changing Situation" organised by International Commission on Irrigation and Drainage (ICID).

[2] https://mwrra.org/.

[3] Presentation on 'Regulatory Interventions in Water Sector in India – Maharashtra's Examples' by Shri K.P. Bakshi, MWRRA Chairperson, Mumbai on webinar titled "Agricultural Water Management Strategies in Changing Situation" organised by International Commission on Irrigation and Drainage (ICID).

[4] http://cwc.gov.in/.

[5] http://icid-ciid.org/.

[6] https://nwa.mah.nic.in/.

[7] http://mowr.gov.in/.

[8] National Mission on Micro Irrigation, Government of India, Ministry of Agriculture.

Water Quality in Kunigal Taluk by using Spatial Analysis and Interpretation of Data

Ravindranath.C
Research Scholar Department of Civil Engineering, Siddaganga Institute of Technology, Tumkur, Karnataka India

Nandeesha
Professor SIT Tumkur, Karnataka, India

Veerappa Devaru.G.
Professor SIT Tumkur, Karnataka, India

ABSTRACT

Water is and universal solvent for all the living and nonliving things in the earth crust. The contamination and pollution of surface and groundwater is by industries and usage of water both in the industrial sector and house hold sector for daily activities. Contamination of drinking water may leads the health issues in both human life, animals and birds in the regional area . Due to this loss of animal life and bird life even through it affects the agricultural activates and also yield will be reduced from the contanimatntion of the crops also happens and also contamination of food products also happen for the above problems need to find the remedy for the solve the problems in the taluk.

Key words : *Groundwater, surface water, contamination, pollution, health issues.*

INTRODUCTION

In the context of local or national environmental, social, economic and cultural conditions. The main reason for promoting the adoption of international standards for drinking-water quality is the advantage provided by the use of a risk–benefit approach (qualitative or quantitative) in the establishment of national standards and regulations. Further, the guidelines are best implemented through an integrated preventive management framework for safety applied from catchment to consumer. The method is followed in these guidelines is intended to lead to national standards and regulations that can be readily implemented and enforced and are protective of public health by controlling of pollution and set up treatment plants and also implementation of the water treatment process with in the kunigal taluk.

STUDY AREA

The study is bound 57 C/16, 57 G/4, 57 D/13, and 57 H/1 and 57H/2 (Survey of India ; 1:50,000 ratio of scale). The software Arc GIS ver*9.2.* Were used for area of interested to perform the morphometric analysis for overall study in Kunigal Taluk as shown in Figure 1. The boundary of drainage basin and drainage network including the contour was delineated using the SOI top sheet. Kunigal is a town and Taluk is located in South India in Tumkur district, Karnataka State, India. Kunigal Taluk is bounded by latitude N $12^0 44'38''$ to $13^0 8'1''$ and longitude E $76^0 49'43''$ to $77^0 9'57''''$, covering an area of 981.55 km^2.

Fig.1 : Location Map of Study Area

Table 1 : Standards for parameters present in drinking water

S. No.	TESTS	Maxi Acceptable Limits (In Mg/l)	Maxi Permissible Limits (In Mg/l)
		(As per WHO)	
1	Odour	Agreeable	Agreeable
2	Turbidity,NTU	1	5
3	pH Value	6.5 – 8.5	No Relaxation
4	Total Hardness as CaCO$_3$ mg/l	200	600
5	Calcium as Ca, mg/l	75	200
6	Magnesium, as Mg, mg/l	30	100

7	Chloride as Cl, mg/l	250	1000
8	Total Dissolved solids, mg/l	500	2000
9	Sulphate as SO_4, mg/l	200	400
10	Nitrate as NO_3, mg/l	45	No Relaxation
11	Fluoride as F, mg/l	0.5	1.5
12	Iron as Fe, mg/l	0.3	No Relaxation
13	Total Alkalinity as $CaCO_3$, mg/l	200	600
14	Sodium Na mg/l	1	60
15	Potassium K mg/l	1	5
16	Electrical conductivity	750	2000

WATER SAMPLING LOCATIONS

Road map, location map and topographical map of Kunigal taluk were collected from Survey Of India (SOI). Using location map and topographical map water sampling locations were determined. Using road map the route for water collection was determined. The Plastic cans of 1 liter capacity with stopper were used for collecting samples entire taluk. Preparing the road map and collated water samples in entire kunigal taluk using four wheeler. The bottles were filled leaving no air space, and then they were sealed to prevent any leakage. Each can was clearly marked with the name and date of sampling done in environmental laboratory as shown in Figure 2 .

Water samples were collected from bore wells as well as hand pumps, people available nearby during sampling were interviewed to get the details about the bore well depth and period of its existence water level and contamination. Table 1 is used for the contamination analysis of water.

RESULTS OF WATER QUALITY ANALYSIS

After conduction of the tests the results are tabulated. For rapid analysis Mean, Median, Standard Deviation and Variance of the values of the chemical parameters tested are determined in table 2 and 3.

From the table 2 the maximum values obtained for magnesium, chloride, iron and nitrate are exceeding the maximum acceptable limits provided by World Health Organization. The small values in the variance indicates that the test values are spread out around the mean value obtained which means that the test values of most of the samples are approximately equal to the mean values.

The values in tables 2 and 3 clearly indicates the changes that occur during the rain. The chemical parameter concentrations in ground water reduces as the rain water added to the initial water which dilutes it. There are some cases where the concentration remains constant or it may increase, because the infiltration in that area is less compared to others. The main reason could be the rain itself, if the rain fall is less the concentrations remains the same which explains the constant values. The average of the values clearly shows the reduction in concentration in post monsoon season compared to pre - monsoon season for exisatance of water quality.

ANALYSIS METHODS AND GRAPHICAL REPRESENTATION

Analysis to determine water quality can be done in many ways

• Trilinear/Piper Diagram Method

• ISO - contour Method

Since the number of water samples is comparably with Piper diagram method and Iso-contour method are suitable.

Figure 2 : Location map Collected water samples and testing

Table 2 : Maximum and minimum values obtained during pre - monsoon season

Parameters mg/l	Minimum	Maximum	Mean	Standard Deviation	Variance
Ca	8.02	110.62	59.32	8.23	13.88
Mg	27.18	190.57	53.54	17.57	32.81
Na	15.00	120.00	44.70	21.81	48.79
K	1.00	111.00	20.50	28.32	138.14
CO_3	0.00	0.00	0.00	0.00	0.00
HCO_3	139.84	483.12	311.48	62.82	20.17
Cl	51.98	475.85	263.92	66.22	25.09
NO_3	4.00	110.00	57.00	22.92	40.21
SO_4	7.00	67.00	37.00	16.65	45.00
F	0.16	1.50	0.83	0.19	22.61
TH	176.00	836.00	506.00	94.78	18.73
TDS	286.00	1570.00	928.00	250.41	26.98
EC	363.00	2460.00	1411.50	384.09	27.21
pH	6.16	6.98	6.57	0.18	2.74
Fe	0.10	1.20	0.65	0.18	27.69

Table 3 : Maximum and minimum values obtained during post monsoon season

Parameters Mg/l	Minimum	Maximum	Mean	Standard Deviation	Variance
Ca	14.45	49.47	31.96	24.17	75.61
Mg	15.25	106.08	60.67	34.04	56.11
Na	6.00	77.00	41.50	21.97	52.95
K	2.00	40.00	21.00	20.58	98.02
CO_3	0.00	38.40	19.20	8.33	43.37
HCO_3	73.20	417.20	245.20	67.12	27.37
Cl	37.99	419.87	228.93	84.92	37.09
NO_3	5.00	90.00	47.50	20.70	43.58
SO_4	1.00	106.00	53.50	21.07	39.38
F	0.02	1.10	0.56	0.36	64.94
TH	128.00	680.00	404.00	133.53	33.05
TDS	255.36	1126.40	690.88	159.73	23.12
EC	399.00	1170.00	784.50	249.57	31.81
pH	7.11	7.70	7.41	0.13	1.79
Fe	0.03	0.70	0.37	0.18	50.52

TRILINEAR/PIPER DIAGRAMS

Charts shows the general centralizations of six to seven particles in arrangements, for this situation, the cations Ca, Mg, and Na+, K, and the anions Cl, SO4, and HCO3. In most normal waters, these particles make up 95 to 100% of the particles in arrangement. The graph incorporates two trilinear charts, one for anions (on the lower right) and one for cations (on the lower left). For each example, the data from each trilinear outline is anticipated up into the focal quadrilateral. Subsequently, each example will plot in each edge of the trinlinear, once represented to cations, and anions, and once speaking to the blend to asses the nature of water, as water quality examination and speaking to the equivalent.

Cations (in the lower left) are perused with values expanding clockwise along every leg of the trilinear outline from 0% to 100% with the pivot restarting at 0% at every zenith of the triangle. Ca is on the base hub running

from 0% on the correct end to 100% on the left finish of the hub. Mg is on the left leg of the trilinear graph going clockwise from 0% on the base of the leg to 100% on the highest point of the trilinear chart. Additionally, Na+ and K are included together and spoke to the correct side of the cation trilinear and increment a clockwise way.

Anions in the lower right trilinear are perused in a counter-clockwise bearing along every pivot likewise. For this situation, Cl is spoken to along the base leg, SO4 along the correct leg, and HCO3 along the left leg of the trilinear diagram.The area of the information point in each of the trilinear outlines is then anticipated up into the quadrilateral, and plotted where the two projections meet. The upper right half of the quadrilateral outline is the total of Ca+ Mg. The upper left side is the aggregate of Cl+ SO4 as appeared in the Figure 4 and as appeared in the figures 3, 4 and 5.
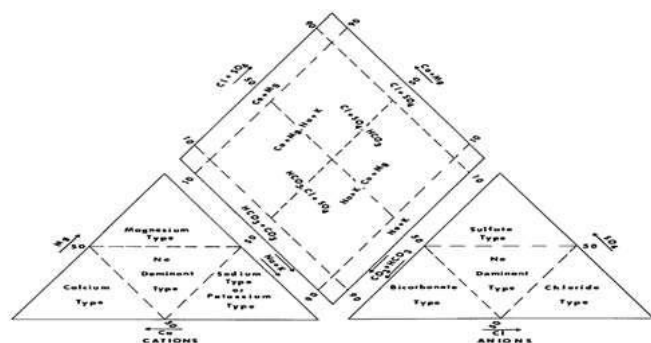
Fig. 3 : Trainer/Piper diagram

PIPER DIAGRAM OF PRE - MONSOON SEA-SON TEST VALUES
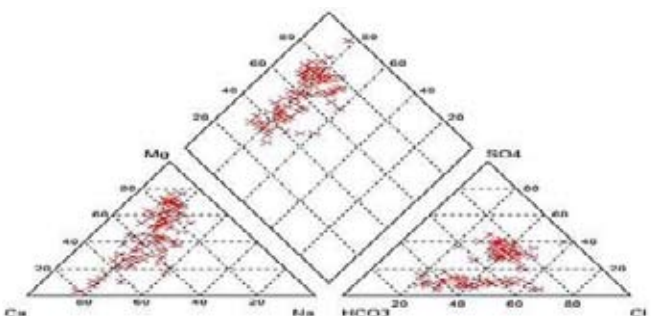
Fig. 4 : Piper Diagram of pre monsoon test values

The Piper diagram for the Pre monsoon season shows that groundwater samples from many location are of magnesium type which means they contain magnesium in comparably higher proportion when compared to Calcium and Sodium. In anion side it is evident that bicarbonate and carbonate have equal effect on the water samples and the remaining are in no dominate type which means that they are neither rich in bicarbonate nor carbonate.
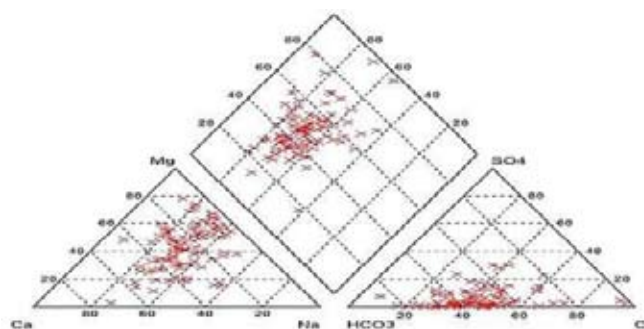
PIPER DIAGRAM OF POST MONSOON SEASON TEST VALUES

Fig. 5 : Piper Diagram of post monsoon test Values

The marking in the Diamond shape of the piper diagram are concentrated in the middle of it which shows that concentrations of Calcium, Magnesium, Sodium, Bicarbonate, Carbonate, Chloride and Sulphate are in unequal proportion. But it is clearly identifiable that two of the water sample are extremely Chloride type which have to be treated properly before using it for drinking purpose.

ISO-CONTOURS

GIS is used to assess the water quality parameter, is to facilitate integrate and repitative analysis of large volumes of multidisciplinary data both spatial and non – spatial within the same geo-reference . Spatial analysis extension of GIS allows interpolation of the water quality parameter at unknown location from known values to create a continuous surface which will help us to understand the scenarios of water quality parameters. There are various interpolation techniques such as Inverse Distance weighted (IDW), spline, trend surface analysis, and contour mapping by Kriging available in Arc GIS Spatial Analysis extension and in Surfer-8. Isocontour mapping is used to analyze the spatial variation of kunigal taluk groundwater quality as shown in the figues 6(a) to 6(p).
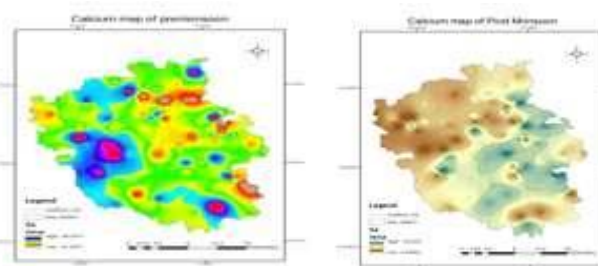
Pre monsoon   **Post monsoon**

Fig. 6(a) : Iso Contours map of calcium.

In the pre – monsoon season calcium ranges from 14.5 to 49.43 mg/l North east and north west region has less concentration of calcium and in post monsoon season calcium ranges from 6.44 to 110.075 mg/l, the more
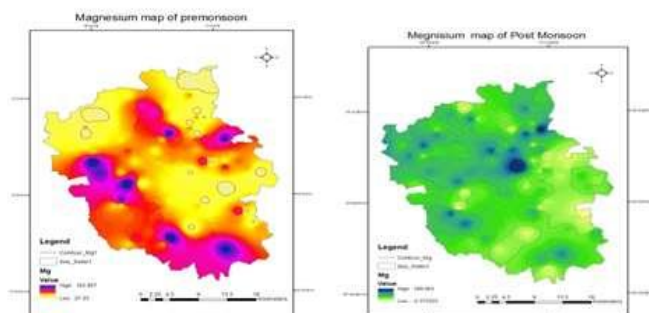
concentration is spread evenly throughout the study area due to usage of anthropogenic sources for the agricultural activities.

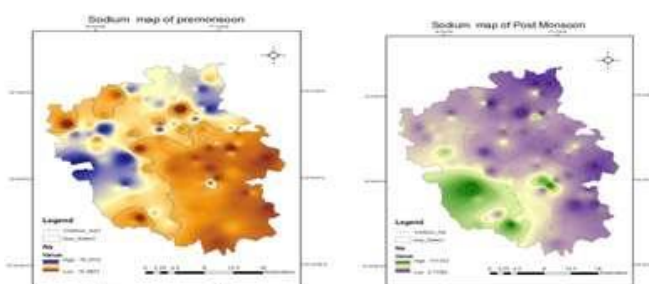**Pre monsoon**   **Post monsoon**

Fig. 6(b) : Iso Contours map of magnesium

Magnesium concentration is ranges from in premonsoon season 27.23 to 105.89 mg/l, found less at Johnson and HP industries in premonsoon and in post monsoon the magnesium consentration is 0.37 to 188.26mg/l, is more and it diluted in pre monsoon season due to rain and some part more in concentration due to contamination of magnesium ions.
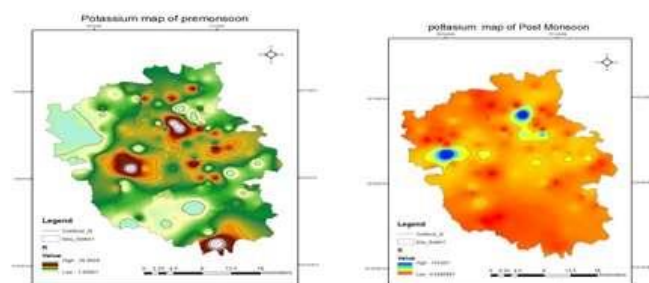
Pre monsoon   **Post monsoon**

Figure 6(c) : Iso Contours map of sodium

Sodium concentration is ranges from 15.08 to 76.23mg/l, in premonsoon and in postmonsoon season it ranges from 6.17 to 117.93 mg/l. In premonsoon it is less and more in post monsoon . Sodium is more in the South east region as the agriculture is more in that area,use of fertilizers has caused this rise in concentration.
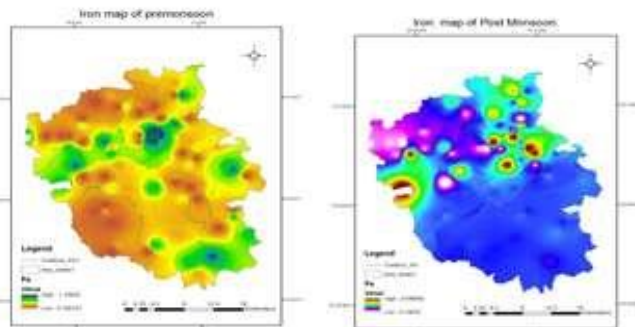
Pre monsoon   **Post monsoon**

Fig. 6(d) : Iso Contours map of potassium

In premonsoon potassium is ranges from 1.0 to 39.84 mg/l, spread equally across all directions. But in postmonsoon season the potassium is ranges from 0.02 to 110.60 mg/l, Industrial areas are having high concentrations of potassium.

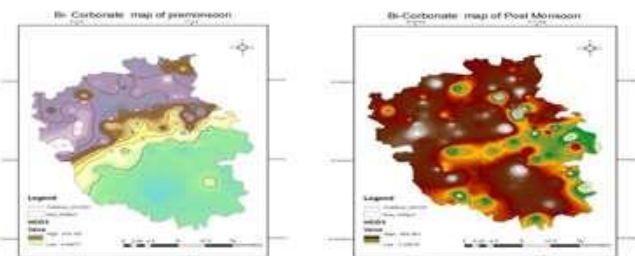**Pre monsoon**   **Post monsoon**

Fig. 6(e) : Iso Contours map of Iron

Iron concentration in premonsoon is ranges from 0.1 to 1.19 mg/l. Iron concentration is very high in North East side of Kunigal during premonsoon season and it is less in post monsoon season ranges from 0.1 to 0.6 mg/l .
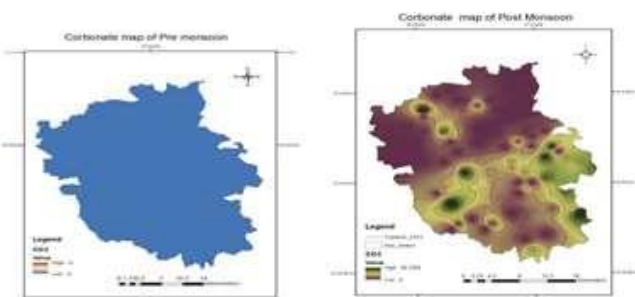
Pre monsoon   **Post monsoon**

Fig. 6(f) : Iso Contours map of Bi-corbonate

In premonsoon season Bi corbonate ranges from 4.064 to 416 mg/l, and the south side of Kunigal is having very less concentration of Bi-carbonate and more in north side and in postmonsoon it is ranges from 7.49 to 494.26 mg/l is equaly distributed.

Pre monsoon   **Post monsoon**
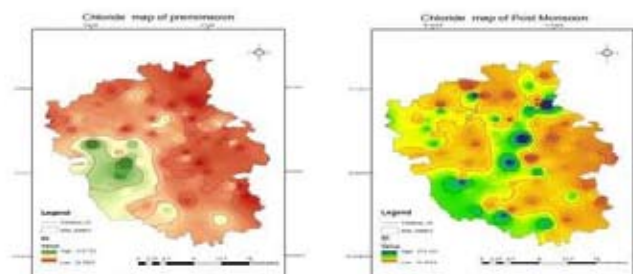

Fig. 6 (g) : Iso Contours map of corbonate

Concentration of carbonate in premonsoon is nil and in post monsoon season corbonate is ranges from 0 to

38.33mg/l, more concentration is found in few places where agricultural activities is more.
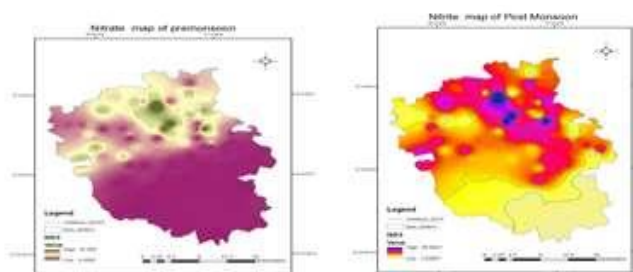
Pre monsoon   **Post monsoon**

Fig. 6 (h) : Iso Contours map of chloride

Chloride concentration is spread widely in north east and north west during premonsoon season ranges from 52.09 to 419.13 mg/l, and postmonsoon season ranges from 12.85 to 475.14 mg/l the chloride concentration in equaly spread in the study area.
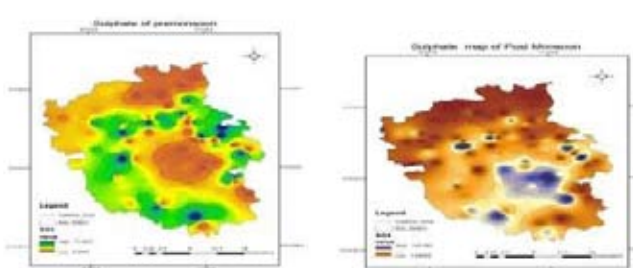

Pre monsoon   **Post monsoon**

Fig. 6 (i) : Iso Contours map of Nitrate

Nitrate is found north side of kunigal taluk during premonsoon season ranges from 4.0 to 93.84 mg/l. But comparatively less in post monsoon season due to dilution of the water and it ranges from 3.0 to 89.8 mg/l.

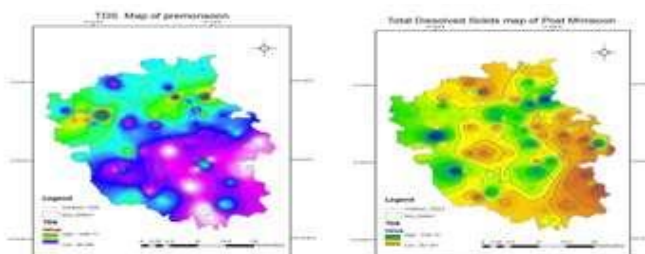**Pre monsoon**   **Post monsoon**

Fig. 6 (j) : Iso Contours map of Sulphate

Sulphate content is ranges from 8.06 to 73.46 mg/l and less in pre monsoon and more in post- monsoon season ranges from 1.08 to 139.38 mg/l help full for agricultural development.

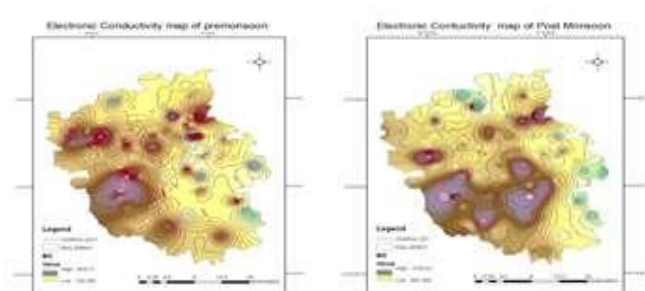**Pre monsoon**   **Post monsoon**

Fig. 6(l) : Iso Contours map of TDS

The TDS is spread in premonsoon season is ranges from 84.02 to 1565.71 mg/l in post monsoon season it is ranges from 257.40 to 1124.14 mg/l all around the area.
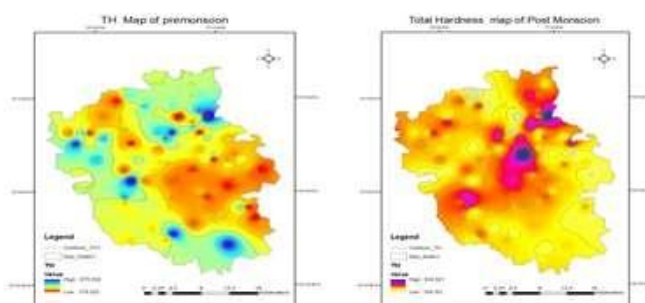
Pre monsoon   **Post monsoon**

Fig. 6(m) : Iso Contours map of Electrical Conductivity

Since the TDS is spread equally due to this EC is also spread accordingly which consisting in premonsoon ranges from 124.5 to 2457.5 mg/l and post monsoon is ranges from 402.18 to 1756.52 mg/l .

Pre monsoon   **Post monsoon**

Fig. 6(n) : Iso Contours map of Total Hardness

The Total Hardness in pre monsoon season ranges from 176.5 to 679.3 mg/l and post monsoon season ranges from 128.32 to 834.92 mg/l. Water in the north side of Kunigal taluk to be hard compared to south side in the pre monsoon season and less in post monsoon season.
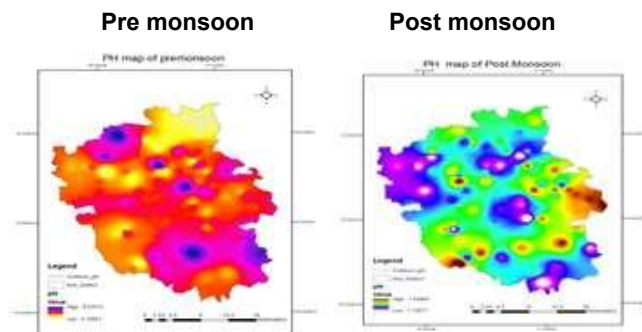
Pre monsoon   **Post monsoon**

Fig. 6(o) : Iso Contours map of pH

pH of all the samples are within the permissible range which can be observed that premonsoon season ranges from 6.16 to6.97 scale, having slightly acidic in nature and less in the post monsoon season ranges from 7.10 to 7.82 scale, slightly basic in nature which indicates the dilution of the water.
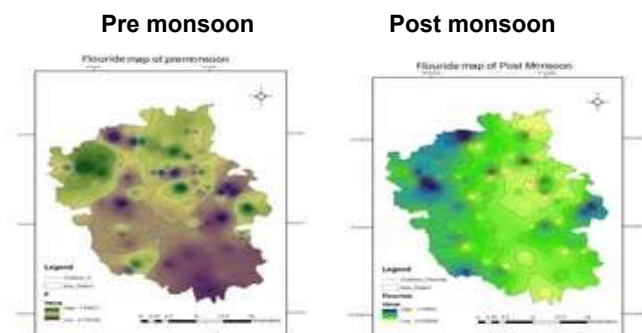
Pre monsoon   **Post monsoon**

Fig. 6(p) : Iso Contours map of Fluoride

Fluoride concentration is found very low in central part of Kunigal Taluk and south side of the kunigal taluk in premonsoon season and post monsoon is more in the concentration. In the premonsoon season the fluoride concentration is ranges from 0.15 to 1.09 mg/l and post monsoon season fluoride concentration is ranges from 0.02 to 1.49 mg/l. which indicates fluoride content is within the permissible limit.

CONCLUSIONS

GIS is a software source of spatial analysis combined with laboratory analysis to assess and mapping of groundwater quality. The spatial distribution map of based on contamination of the water Calcium, Magnesium, Sodium, Potassium, Bicarbonate, Carbonate, Chloride, Nitrate, Sulphate, Total dissolved solids, Electrical Conductivity, Total hardness, pH, Fluorides shows that, these parameters are within the permissible limit in many of the locations.which gives the information water is less contaminated. The variation in the ground water characteristics which are violating the permissible limits can be explained by following points. Agricultural Practice Industrialisation Lithological characteristics. Drainage parameters The following are the regions where the Drinking water parameters are exceeding the

permissible limit. Johnson industrial area – Ca:185.92 mg/l, Cl:475.85 mg/l , Nilathalli –Ca:123.45mg/l, Cl:81.97 mg/l,Bukksagara –Ca:160.32mg/l, Cl:211.97 mg/l and Kundur – Ca:110.62mg/l, Cl:149.95 mg/l

There are many number of industries using chemicals which explains the high concentrations of Chlorides, Calcium, Magnesium and Total Hardness in this area. The following are the regions where the parameters like Iron, Total Hardness and TDS are exceeding the permissible limit.

T.Hosahalli – Fe: 0.1, TH: 836, TDS: 659.20, Jaladhigere – Fe: 0.1, TH: 812, TDS: 1126.40

Dhoddamadre – Fe: 0.1, TH: 612, TDS: 634.24, Chikkmadre – Fe: 0.2, TH: 500, TDS: 660.00

And Bhalyadakere – Fe: 0.2, TH: 480, TDS: 557.44 The variation in the concentration of the chemical parameters in this region can be explained by the property of soil present in those areas which is represented in the Litho logical map. Fluoride content is found less in Gavimatta – F^-: 0.16mg/l Shettigere – F^-: 0.15mg/l Kothhigere – F^-:0.15mg/l The Fluoride content is less than 0.5mg/L, which will cause Dental Cirrhosis. Proper treatment must be given to the Drinking water before it is supplied. This study has demonstrated the utility of GIS combined with laboratory analysis to assess and mapping of groundwater quality. The spatial distribution map of Calcium, Magnesium, Sodium, Potassium, Bicarbonate, Carbonate, Chloride, Nitrate, Sulphate, Total Dissolved solids, Electrical Conductivity, Total hardness, pH, Fluorides shows that, these parameters are within the permissible limit in many parts of kunigal taluk locations.

REFERENCES

1. Standard Methods for the Examination of Water and Wastewater, 21st Edition, 2005. APHA, AWWA, WEF. 2005.

2. Bureau of Indian Standards (BIS) IS:10500:2012, Drinking Water Specification. 2012.

3. World Health Organization (WHO), Guidelines for Drinking-water Quality 4th Edition, 2011.

4. Uniform drinking water quality monitoring protocol- Draft by Ministry of Drinking Water and Sanitation, 2005.

5. BIS IS 3025-50:2001 Methods Of Sampling And Test (physical And Chemical) For Water and Wastewater, 2012

6. BIS IS: 1622 -1981 (Reaffirmed 1996) Methods of Sampling and Microbiological Examination of Water, 2009

7. Guidance manual for drinking water quality monitoring and assessment. 2nd Edition, 2010, NEERI, Nagpur.

8. National Rural Drinking Water Programme (NRDWP), 2009, Govt. of India.

9. American Society for Testing and Materials (ASTM)

10. U.S. Environmental Protection Agency (USEPA) (2000) Science Policy Council Handbook: Peer Review, 2nd Edition, EPA 100-B00-001, Washington, DC: U.S. Environmental Protection Agency, December 2000.)

Community Micro Irrigation - Why We Need New Way to Grow?

Ramdas Battalwan, *Head – Business Development – CI, Projects & Exports, Netafim Irrigation India Pvt. Ltd.*

The world's need for food & water is growing very fast and our resources are limited and already stressed. We are not efficient in use of available resources. We need to find a way to grow more with less. By 2050 there will be 10 billion of us. We will need 60% more food, and our resources are running out. By 2050, we may have 25% less water than we need, 20% less arable land per person and 4 Billion of us will be living under severe water stress. Currently around 69% worlds water goes into Agriculture to irrigate only 20% land under cultivation. Out of irrigated area, around 23% area uses advanced micro irrigation systems which has Overall Water Use Efficiency (WUE) of 80-90% while remaining 77% is irrigated with inefficient flood irrigation method where overall WUE is as low as 40%. So, it's clear that we need to make better use of the planet's resources. To make it in right way, we need to grow more with less, on the limited land we've got. Without an improvement in crop yield & quality, the demand for food will far away from production. We need a solution that increases farm productivity with efficient use of resource. To satiate the increasing food & water demand, effective water management and use of advanced irrigation technologies is becoming need of time. Drip irrigation is proven irrigation method for most efficient use of resources like water, energy, fertilizers, labor etc and application of drip technology in Community Irrigation Systems has potential to bring social transformation by addressing serious global issues of Food & Water scarcity.

Government of Karnataka (GoK) has not only understood the complexity & foreseen the critical issues but took right steps in form of execution of Community Micro Irrigation (CMI) Projects. Karnataka state is the pioneer & leader in CMI projects which is implementing complete integrated micro irrigation projects (lift + conveyance + infield water application by Drip + automation + O&M + associated services) in more than 4.5 Lakh acres' and many more are in pipeline. Ramthal (Marol) Drip Irrigation Project for 59,280 Ac is one of the project executed by GoK & KBJNL. Neighboring states of Karnataka are observing results of Ramthal and implementing similar projects in their respective regions.

Netafim along with MEIL is proudly part of Ramthal Drip Irrigation Project to irrigate 28,899 Ac previously rainfed area which covers 28 villages benefiting more than 6700 farming families in draught prone Hungund taluk of Bagalkot Dist in Northern Karnataka. The project execution is completed & most of the project beneficiaries are reaping benefits of CMI by cultivation of various crops like Maize, Cotton, Baby Corn, Red gram, Chilies', Soybean, Sunflower, Hybrid Jawar etc. Ramthal is first of its kind, CMI project of this extent which has potential to reap bumper yields with reduced farm input costs. Netafim-MEIL JV has already taken care of project for survey, design & construction, commissioning, capacity building, formation of WUA; s, marketing linkages etc and currently taking care of O&M from past 4 years. Netafim is committed to support project beneficiaries with over 55 years of Agronomic & Engineering knowledge and expertise throughout the O&M period & beyond.

Uniqueness of the Ramthal Community Drip Irrigation project–

1. With increase in WUE, doubled area under irrigation as compared to conventional flood irrigation method
2. Equitable distribution of water – bridging gap between IPC & IPU
3. Least land acquisition
4. Higher fertilizer & labor efficiency and improved crop quality & productivity
5. Lower input costs and higher returns on investment
6. Apart from construction of engineering infrastructure, social engineering aspects like formation of Water User Associations (WUA), training & capacity building, agronomic support, live demo's etc including 5 years O&M post project commissioning is part of project.

Basavaraj P.
Chilli
Net profit - 1,14,615 / Ha

Neelanagouda G.
Chili + Sorghum
Net profit - 1,27,083 / Ha

Basappa H.
Bengal gram
Net profit - 1,07,294 /Ha

Mallappa H.
Bengal gram
Net profit - 1,01,250 / Ha

Training Course on

Integrated Piped Irrigation and Micro Irrigation

12-14 February 2020, Jaipur (Rajasthan)

BRIEF REPORT

Mr. Naveen Mahajan, IAS, Secretary, Water Resources Department, Government of Rajasthan, Chairing the Special Session during the Training Course. Sitting on the Dais (L to R) Mr. T.K. Sivarajan, Chief Engineer, CWC, Mr. Naveen Mahajan, Mr. Amarjeet Singh, Chief Engineer, WRD Rajasthan and Mr. Uday Chander, Chief Manager, CBIP

As part of the proposed series of door step training programmes, CBIP conducted a Training Course on "Integrated Piped Irrigation and Micro Irrigation", exclusively for the engineers of Water Resources Department, Government of Rajasthan, at Malviya National Institute of Technology, Jaipur.

40 engineers participated in the programme.

The Course was inaugurated by Dr. M. Dinesh Kumar, Executive Director, Institute for Resource Analysis and Policy. In his inaugural address, Dr. Dinesh Kumar stressed the need for optimum utilization of water and mentioned that the present course was very much relevant in view of limited availability of water resources and rising demand for water, which has acquired critical importance for sustainable management of water resources.

Mr. Naveen Mahajan, addressing the participants during the Special Session

Mr. Uday Chander, Chief Manager, CBIP, delivered the Welcome Address and Mr. Dinesh Kumar, Superintending Engineer, Water Resources Department, Government of Rajasthan, proposed Vote of Thanks, during the Inaugural Session.

The experienced professionals/scientists, namely Dr. M. Dinesh Kumar, Executive Director, Institute for Resource Analysis and Policy; Dr. Sangita Ladha, Vice President – Marketing & Business Development, Jain Irrigation Systems Ltd.; Dr. Viraj Loliyana, Hydrology Expert, Mechatronics Systems Pvt. Ltd.; Dr. K.V. Ramana Rao, Principal Scientist, CSIR-Central Institute of Agricultural Engineering, Bhopal; Mr. Sabarna Roy, Senior Vice President (Business Development), Electrosteel Castings Limited; Mr. T.K. Sivarajan, Chief Engineer (Designs, E&NE), Central Water Commission and Mr. Dilip Yewalekar, Vice President - Projects, Jain Irrigation Systems Ltd. shared their experiences on the following topics:

* Micro Irrigation Adoption in India: Current Status and Future Prospects

* Prospects and Status of Micro Irrigation and Fertigation Systems in Improving Crop Production in India

* Use of Micro Irrigation in Surface Irrigation: Case Studies

* Modelling and Automation in Micro Irrigation

Dr. M. Dinesh Kumar, Executive Director, Institute for Resource Analysis and Policy, addressing the participants during Inaugural Session

Welcome Address by Mr. Uday Chander, Chief Manager, CBIP

Mr. Dinesh Kumar, Superintending Engineer, Water Resources Department, Government of Rajasthan, proposing Vote of Thanks during the Inaugural Session

Mr. Ravi Solanki, Additional Chief Engineer, WRD Rajasthan, addressing the participants

- Use of Software and DSS in Micro Irrigation

- Micro Irrigation System Concept, Design and Components

- Operation and Maintenance of the Irrigation Systems

- Piped Irrigation Network Planning and Design

- Emerging Challenges in Pipe Distribution Network for Irrigation Purpose and Ways and Means to Overcome Them

- A Case Study on Conversion of Canal Based Irrigation Network System to Pressurized Pipe Based Network System Integrated with Solar Plant in the State of Uttar Pradesh, India

- Integrated Water Resources Management

Participants with Faculty Members and CBIP Representative

IWRA News

POSTPONEMENT OF IWRA'S XVII WORLD WATER CONGRESS

New dates announced: 21-25 September 2020

As many of you have heard or read, the organisers of the XVII World Water Congress have been closely monitoring the development and implications of the COVID-19 outbreak during the past weeks. Due to serious health concerns and newly imposed regional and international travel restrictions, IWRA and the Korean co-hosts have decided to postpone the XVII World Water Congress, previously scheduled for May 11-15 at EXCO in Daegu, South Korea, to the new dates of 21 – 25 September 2020, at the same venue.

Over the past 50 years, IWRA's World Water Congresses have been held 16 times in different locations around the world. These congresses represent the world's largest event linking water researchers and policy practitioners. They provide a unique meeting place to address key water challenges and priorities, identify major global themes concerning the water agenda, and bridge the science and policy arenas for the development and implementation of well-informed decisions in the field of water. For its 17th edition, the organisers are also pleased to announce that this major international water event will now be held jointly with the Korea International Water Week (KIWW).

While we deeply regret any inconvenience this necessary change in dates may cause, the organisers strongly believe that postponing the joint events until September will ensure an excellent programme, while continuing to allow attendance by major water organisations, distinguished participants and delegates from around the world. If you have already registered for the XVII Congress, your registration will be automatically transferred to the new dates. If you are unable to attend the revised event in Korea in September, your registration fee will be fully refunded by contacting wwc2020@exco.co.kr.

Should you require any further information regarding these new dates, prior registrations to these events, or any other related matters, please do not hesitate to email us at congress@iwra.org.

MEET THE SELECTED WORLD WATER ENVOYS FOR IWRA'S XVII WORLD WATER CONGRESS!

IWRA is pleased to announce that the World Water Envoys have now been selected to participate in our Congress as the representatives of the next generations. They will showcase the multiple water challenges they face when it comes to water security during the XVII World Water Congress.

World Water Envoys will take part in the:

• Opening Ceremony, showcasing particular water security challenges in their communities on their everyday life.
• Sessions, discussing their issues with experts, colleagues, and international water community.
• Closing Ceremony, summarizing what they learned over the week and take back to their local communities help provide real solutions to their water security challenges.

Maria Almonte, Dominican Rep.   *Deepesh Jain, India*   *Bayan Khalaf, Palestine*

Georgina Mukwirimba,   *Pallavi Pokharel,*
Zimbabwe   *Nepal*

IWRA'S LATEST ACTIVITIES

OECD's 13th Water Governance Initiative Meeting, 9th-10th January, Paris, France

On the 9th and 10th of January 2020, the OECD Water Governance Initiative (WGI), held its 13th meeting at the OECD Headquarters in Paris, France. The meeting gathered more than 80 practitioners, policymakers and representatives from major stakeholder groups, including IWRA's Executive Director, Callum Clench, and the Association's Communications Officer, Ignacio Deregibus.

Some of the most prominent moments and topics discussed during this two-day event touched upon the

Group photo of OECD's 13th WGI meeting participants in January in Paris.

official release of OECD's Report on Water Governance in Argentina; updates on the implementation of the OECD Council Recommendation on Water; OECD Contributions to the G20 and OECD Action Plan on SDGs with practical examples of how countries are measuring progress towards SDG 6; the road to the 9th World Water Forum and other water governance projects and activities (e.g. studies in Mali and Niger, the 2021 Water Integrity Outlook, the Brasilia Declaration of Judges on Water Justice). Productive exchanges also addressed the Programme on Water Security for Sustainable Development in Africa, Water Governance in Asia, OECD draft Report on "Water Governance in Peru" with the presence of Peru's Vice Minister for Environment, Mr. Gabriel Quijandría Acosta, and the Third Phase of the National Water Policy Dialogue with Brazil.

Additionally, this important meeting provided an opportunity to inform about the latest updates and news for the upcoming XVII World Water Congress, to take place in Daegu, South Korea. Callum Clench, informed the participants with detailed insights of this major event for water researchers and policy practitioners, also within the framework of the road to Dakar and 9th World Water Forum. He thanked co-hosts from K-water, which were also present in the room for their work and support on this major water event in 2020. Together with Ignacio Deregibus, Callum joined the two back-to-back sessions to advancing the work of the Working Groups on Indicators and Capacity Development.

32nd UN WATER MEETING, 28TH-29TH JANUARY, ROME, ITALY

IWRA's Communications Officer, Ignacio Deregibus, represented the Association at the 32th UN Water meeting held at the headquarters of the International Fund for Agricultural Development (IFAD) in Rome on January 28th and 29th, 2020. He presented the latest updates on the XVII World Water Congress to the more than 50 UN Water members and partners being present, and thanked Korean co-hosts from K-water also participating in this event for their support and collaboration.

Participants discussed various high-level UN meetings to take place between 2021 and 2023, and the importance of the Decade for Action on SDG 6 implementation. On the latter, the SDG6 Global Acceleration Framework was highlighted as a good opportunity to strengthen cross-sectorial approaches, and better coordination and delivery at country and regional levels. This platform is intended to be launched at the High- Level Political Forum in July 2020.

The 32nd UN-Water Meeting also reviewed UN-Water's Strategy through a consultation process that was undertaken before and during this meeting. The draft was circulated for more inputs after this meeting for feedback of members and partners.

Moreover, an innovative open space was introduced to engage on interactive and fruitful discussions on topics suggested by participants. These topics included engineering achieving SDG6, the use of disruptive technologies, a water resilience pledge, and UN's 75th Anniversary celebration consultation. As a result, there was an agreement for a white-paper proposal and setting up a task force.

71st WORLD WATER COUNCIL BOARD OF GOVERNORS MEETING, 5TH-6TH FEBRUARY, LIÈGE AND BRUSSELS, BELGIUM

Group photo of the World Water Council's 71st Board of Governors meeting in Liège in 5 February

IWRA Executive Director, Callum Clench, visiting the European Parliament in Brussels on February 6th with WWC.

The World Water Council held its 71st Board of Governors meeting in Liège, Belgium in February. IWRA Executive Director, Callum Clench, represented IWRA at this meeting as an Alternate Governor to Yuanyuan Li (IWRA Vice President) who was unable to attend due to travel restrictions at the time from China.

The meeting on the 5th in Liège was opened with an address by the Walloon Minister for the Environment, Nature, Forests, Rurality and Animal Welfare, Céline Tellier. An address was also given by Alain Palmans, Managing Director of the Compagnie Intercommunale Liégeoise des Eaux (CILE). At a reception in the evening, the Mayor of Liège, Willy Demeyer announced the entry of his city into the World Water Council's members network.

On the 6th of February, the Board went to Brussels to visit the European Parliament where it was welcomed by MEP Soraya Rodriguez from the Committee on the Environment, Public Health and Food Safety. This was followed by a visit to the Water Europe HQ, also in Brussels. Presentations were given there by Tomas Michel, President of Water Europe, and Veronica Manfredi, Director for Quality of Life (Air, Water, Marine Environment, Industrial Emissions & Safety), Directorate-General for Environment at the European Commission, 6 February 2020.

This meeting provided the opportunity to not only learn more about what is happening in the World Water Council, but also more broadly across the European Union. It was also an opportunity to share more information on the XVII World Water Congress, and other IWRA activities.

The measures for better management of water resources developed by were also at the heart of the discussions, in order to offer technological responses against pollution and water scarcity.

IWRA'S PRESIDENT LECTURES IN DELFT, THE NETHERLANDS, AND TEXAS, UNITED STATES

IWRA's President, Gabriel Eckstein, lecture in Delft in February.

IWRA President, Professor Gabriel Eckstein, was invited to give an informal lecture on "The Status of International Water Law – Research and Practice" at the IHE Delft Institute for Water Education, Delft, The Netherlands, 14th February 2020. He was also invited to give a presentation on "Drugs on Tap: Managing Pharmaceutical Pollutants in Our Nation's Waters" at the Symposium: Pharmaceutical Innovation, Patent Protection and Regulatory Exclusivities in Fort Worth, TX, 25th October 2019.

International Water Resources Association (IWRA)

Introduction

International Water Resources Association (IWRA) is a non-profit, non-governmental, educational organisation established in 1971. It provides a global, knowledge based, forum for bridging disciplines and geographies by connecting professionals, students, individuals, corporations and institutions who are concerned with the sustainable use of the world's water resources.

The goal of IWRA is to improve and expand the understanding of water issues through education, research and information exchange among countries and across disciplines.

IWRA seeks to continually improve water resource decision-making by improving our collective understanding of the physical, ecological, chemical, institutional, social, and economic aspects of water.

Objectives

- Lead and influence water policy and governance
- Develop and publicize methodological tools for assessment, improvement and conjunctive use of water
- Advance water resources planning, management, development, technology, research and education at international, regional, and national levels
- Provide a multi-disciplinary forum to address and discuss water issues
- Generate, synthesize, and disseminate knowledge and information in the area of water and related resources and the environment
- Encourage, promote and participate in international, regional, national and local programs and activities related to water resources for common benefit of humankind and biosphere

IWRA Geographic Committees

IWRA actively promotes the exchange of knowledge and experiences across countries and regions. The critical importance of local-base knowledge and experiences is strongly emphasised in our information exchange activities. The belief that sustainability requires interdisciplinary action and international cooperation is a driving force behind the Association.

IWRA has developed national or geographical committees in China, **India**, Japan and Ocenia to further implement its mission and focus its activities. These committees allow for extensive regional networking among IWRA members.

IWRA World Water Congress

Since 1973, IWRA has held a World Water Congress every three years in various locations around the world.

The objective of the World Water Congress is to provide a meeting place to share experiences, promote discussion, and to present new knowledge, research results and new developments in the field of water sciences around the world. For almost four decades the World Water Congresses have been excellent events for the identification of major global themes concerning the water agenda; and for the bringing together of a large cross-section of stakeholders for the development and implementation of decisions in the field of water.

Following is the list of IWRA World Water Congresses held so far:

XVIth World Water Congress in Cancun, Mexico
Dates: 29 May - 03 June, 2017
Theme: "Bridging Science and Policy"

XVth World Water Congress in Edinburgh, Scotland, UK
Dates: 25-29 May, 2015
Theme: "Global Water, a resource for development : Opportunities, Challenges and Constraints"

XIVth **World Water Congress in Porto de Galinhas, Brazil**
Dates: 25-29 September, 2011
Theme: "Adaptive Water Management: Looking to the future"

XIIIth **World Water Congress in Montpellier, France**
Dates: 1-4 September, 2008
Theme: "Global Changes and Water Resources"

XIIth **World Water Congress in New Delhi, India**
Dates: 22-25 November, 2005
Theme: "Water for Sustainable Development, Towards Innovative Solutions"

XIth **World Water Congress in Madrid, Spain**
Dates: 5 – 9 October, 2003
Theme: "Water Resources Management in the 21st Century"

Xth **World Water Congress in Melbourne, Australia**
Dates: 12 – 16 Mars, 2000
Theme: "Sharing and Caring for Water"

IXth **World Water Congress in Montreal, Canada**
Dates: 1 – 6 September, 1997
Theme: "Water Resources Outlook for the 21 st Century: Conflicts and Opportunities"

VIIIth **World Water Congress in El Cairo, Egypt**
Dates: 13 – 18 May, 1994
Theme: "Satisfying Future National and Global Water Demands"

VIIth **World Water Congress in Rabat, Morocco**
Date: 13 – 18 May, 1991
Theme: "Water for Sustainable Development in the 21st Century"

VIth **World Water Congress in Ottawa, Canada**
Date: 29 May – 3 June, 1988
Theme: "Water for World Development"

Vth **World Water Congress in Brussels, Belgium**
Date: 9 – 15 June, 1985
Theme: "Water Resources for Rural Areas and their Communities"

IVth **World Water Congress in Buenos Aires, Argentina**
Date: 5 – 9 September, 1982
Theme: "Water for Human Consumption: Man and his Environment"

IIIrd **World Water Congress in Mexico City, Mexico**
Date: 23 April, 1979
Theme: "Water for Human Survival"

IInd **World Water Congress in New Delhi, India**
Date: 12 – 16 December, 1975
Theme: "Water for Human Needs"

Ist **World Water Congress in Chicago, U.S.A.**
Date: 24 – 28 September, 1973
Theme: "Importance and Problems of Water in the Human Environment in Modern Times"

Publications

- **Water International** (WI) is the official peer reviewed journal of the IWRA. Published by a major international publisher, Taylor & Francis, on behalf of IWRA, it is a leading source of information on international water resources research and policy.

- **IWRA Update** is a quarterly newsletter that contains news briefs about IWRA members, regional committee activities, calls for papers, and global water news.

IWRA also publishes **books, conference proceedings** and partners with various organisations to produce **special publications** and **affiliated journals** on water resources issues.

Awards

Since its creation, IWRA recognises the contributions towards water management and the excellence of water researchers, professionals and organisations. IWRA presents 5 main awards:

- **Crystal Drop Award** for individuals or organisations in recognition of their laudable contribution to the improvement of the world's water situation.

- **Ven Te Chow Memorial Award and Lecture** - IWRA has established a Chow Memorial Lecture program to honor its first president, as well as provide for an outstanding lecture at its Congresses.

- **IWRA Distinguished Lecture Award** - Every year, one distinguished member is invited to give this lecture at an IWRA sponsored conference.

- **Water International Best Paper Award** (Annual) is awarded to author(s) based on originality, innovation, technical quality, and contribution to water resources management.

- **Award for Excellence in Water Resources Management** seeks to recognise regional, national and local institutions that have exhibited sustained excellence in water resources management.

- **Young IWRA Member Scholarship Award** recognises a member under the age of 33 for an outstanding contribution to the management of water resources.

Membership

IWRA Offers following categories of membership

- Corporate
- Institution
- Individual-Fellow
- Individual-Regular
- Individual-Retiree
- Individual-Young Professional (35 years and younger)
- Individual-Full Time Student

Benefits to Members

- IWRA Publications in electronic format
- Access articles, posters and abstracts from the series of World Water Congresses
- Special rates for IWRA Events
- Latest updates on upcoming water events
- Make announcements on the activities on IWRA Website and Newsletter at no charge
- Opportunity to engage in professional networking and information exchange activities through participation in National and Regional Committees, mail lists server and IWRA News updates
- Opportunity to participate in international programmes and processes as representatives of IWRA

Better Water.
Better Life.

A leader in water management, we aim to make a visible difference to millions in India, and across the world, on the strength of our philosophy - the principles we believe in and the values we live by.

Care for the environment
Integrity
Respect for people
Customer focus
Leadership & teamwork
Enhanced shareholder value

ELECTROSTEEL

AN INTERNATIONAL WATER INFRASTRUCTURE COMPANY
(ISO 14001-2015, ISO 9001-2015 ACCREDITED & SA 8000-2014 AFFILIATED)

RA/ECL/CORP-16

P I P E L I N E S   F O R   A   L I F E T I M E