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RIVER POLLUTION & QUALITATIVE DILAPIDATION OF WATER RESOURCES IN GUJARAT

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ABSTRACT

Indian subcontinent has its own hydrological importance in the world as it is one of the most densely populated regions of the world, hosting ~23% of the global population within only ~3% of the world's land area. It encompasses one of the glob's largest river systems of world with many peculiar rivers. These rivers remain the prime sources not only for agrarian & industrial water demands but also to build up critically required groundwater reserves i.e. aquifers. From Indian context these rivers are endowed with rich water resources, encompassing about 45000 km long riverine systems criss-cross the length and breadth of the country with 20 major river basins, 46 medium river basins and 14 minor/desert river basins. This is one face of the coin, while the other face releases apprehensions towards factors like judicious utilization/conservation/management of river water at one end while assessing and mitigating various kinds of pollutions of river water bodies on other end. Rapidly increasing population, intensive agricultural operations, rising standards of living, exponential growth of industrialization and urbanisation have exposed water resources, in general, and rivers, in particular, to greater degrees of pollution. Under such scenario looking into the recent threats of climate change, the rivers flowing in and around industrial areas/commercial agricultural interventions, demands pressing evaluations in regards to quantitative as well as qualitative pollution of river water bodies. Present paper describe an updated status of river pollution in regards to Gujarat, the most leading industrial state of country by incorporating probable influences , causes and effects of surface water as well ground water resources in the region. It is evident from the findings of various researchers that the conjunctive consequences of over exploitation/ deterioration of surface & ground water resources tends to pollute not only the rivers but the underground water bodies too. Considering this point of view, the theme of this write up is set as "river water pollution" where an attempt is made to overview the issue with its causes , effects and probable solutions and food for thought . A thin volume of stuff towards national scenario is opted , followed by an in depth updated statue of water resources of Gujarat state being more inclined towards pollution of major rivers of Gujarat and also the adjacent bodies of surface and groundwater resources. It could be of some utilities for water resources manager, engineers, environmental experts, field officers, planners and policy makers.

INTRODUCTION

The Indian Sub-Continent (ISC) is one of the most densely populated regions of the world, hosting ~23% of the global population within only ~3% of the world's land area. It encompasses one of the glob's largest fluvial systems in present world with many peculiar rivers India's water future as

described by some researchers (Mukherjee et al. 2015; Verma and Phansalkar, 2007;Arora and Boer, 2001) very precisely intimating that at the beginning of every hydrologic year, >4000 billion cubic meters (BCM) water enters the ISC hydrological systems, of which almost half is lost by poorly understood and un-quantified processes (e.g. overland flow, surface discharge through rivers to oceans, submarine ground water discharge, evaporation and evapo-transpiration, etc.) . Annual groundwater withdrawals in the ISC are estimated to exceed a 340 bcm and represent the most voluminous use of groundwater in the world (FAO, 2013). The picture is extremely grim in Indian part where in many urban and rural areas , surface waters have been historically used as receptacles of sewage and industrial waste rendering them unfit for domestic use, prom ting a switch to groundwater and rainwater sources to meet drinking and agricultural water needs (Mukherjee et al., 2015). Indian rivers host some of the highest yield in aquifers even at global scale, but the actual distribution of usable ground water from these aquifers varies drastically causing so many constraints towards continued shortage of safe water from many of these aquifers. Presence of varieties of contaminants is adding up in the river water bodies and in turn to ground water bodies too. Story does not ends here, rather the prevailing "Climate Change" aspects adds on another threats (Gosain et al, 2006; Modi, 2009) to these water bodies (rivers as well as aquifers). No country in the world is as vulnerable, on so many dimensions, to climate change as India. Whether it is our long coastline of 7000 kms, our Himalayas with their vast glaciers, our almost 70 million hectares of forests (which incidentally house almost all of our key mineral reserves) – we are exposed to climate change on multiple fronts. Gosain et al (2006) revealed certain important finding, showing the turbulent water future of nation, as its mainland is drained by basins of varying sizes, viz. 15 major rivers (catchments > 20000 km^2), 45 medium rivers (catchments 2000 - 20000 km^2) and over 120 minor rivers (catchment < 2,000 km^2), besides numerous ephemeral streams in western arid region. Climate change has played a part in recent reductions in rainfall and water resources, however its specific contribution remains extremely complex & difficult to quantify.

When the state like Gujarat is considered the situation becomes highly complicated, because the state has its unique settings in regards to physiographic, geology, hydrology, climate, aquifers, land use patterns, socio economic patterns and advanced agricultural as well as industrial interventions. It is likely to have adverse influences on quantity & quality of river waters and reserve ground water bodies. If we see the probable quantitative influences, the expected reductions in average river flows in some of the regions of Gujarat is going to be reduced at least by an magnitude of 10 to 25 % even by the year 2030. The enormous peculiar reasons for this includes, the consistent qualitative degradation of aquifers with ever increased intensity over the years, adverse influences of longest coastline offering highest sea water intrusion, excessive levels of salinity & Fluoride and many other large pollutants load that are regularly being released owing to intensive industrial as well as agricultural interventions with high volumes of point sourced or non point sourced pollutants in flowing or non flowing water bodies. This all together has threatened the life of common people, animals and even the vegetation and eco-system in the region with multiple socio-economical consequences which are difficult to get revamped if sound scientific principles on assessment, monitoring, and integrated management of surface and ground water resources are not adhered with active people's participation. Qualitative as well as quantitative status in regards to pollution of rivers and groundwater bodies in Gujarat is categorically analysed and discussed. This write up is a sincere effort to read, review, realize and reflect some of the critical results of researchers for assessing and presenting an updated status of types and extents of river water potentials & threats in regards to their quantitative & qualitative concerns and conjunctive influence towards ground water bodies.

Face of Water Resources at National Level

Water resources of any nation or region play a governing role to deal and effectively tackle the undesired scenarios in such areas, as water scarcity remains a well-established context for development in arid and semi-arid countries. This is truer for India and in particular Gujarat where in many parts there is an expected precipitation decrease over the next century of 20% or more. It is expected that overall water stress will further increase and projected temperature increase will imply higher evaporation and drier conditions. Rain is also expected not only to reduce in frequency but increase in intensity, yielding frequent droughts and floods. A pictorial view of such categorised variations across different states of India is illustrated in Figure-1, which depicts an abstract view of relative water availability in western states like Gujarat.

Quantitative Estimates: Proper assessment of the availability of water resources is the cornerstone for proper planning, development and management. Different commissions, agencies, researchers have estimated water resources of the country using different approaches (CWC, 2011; CWC, 2014a). The 329 million hectare (Mha) geographical area of the country with mean annual rainfall of of 1170 mm, offers annual precipitation to the tune of about 4000 Billion Cubic Meter (BCM), a part of which enters the ground water, which sometimes again returns back to streams/rivers. Thus the surface and the ground water resources are inter-linked, continuously inter-active and therefore remains an integrated single entity, whose quantitative proportions varies in accordance to conjunctive applications/withdrawals for varied purposes at varied times. India is gifted with many surface water bodies (static as well as dynamic) and out of this plethora of rivers remains the most vital ones and in true sense the life lines for agrarians and non agrarians both. Table 1 illustrates a broad spectrum in regards to major rivers, among which about 12 are classified as major rivers, encompassing total catchment area of 252.8 Mha and average annual river water potential to the tune of 1571 BCM (about 85% of total natural run-off). Another 50 rivers are classified as medium rivers, which covers additional catchment area to the tune of 25 Mha. If we go for a rough approximation of volume of water in Indian rivers based upon average ranges of discharge rates across various parts of the country, it comes to the tune of about 1870 km^3. Many of these rivers are perennial, though few are seasonal. This is because precipitation over a large part of India is strongly concentrated in the summer monsoon season during June to September/October and the tropical storm season from May to October. It is only a spell of heavy rains, which may last for a period of several hours to few days that generates large run-off in the catchments and consequently mega volumes of river water bodies. Among these rivers couple of specific rivers like Narmada, Tapi, Mahi are peculiar in their directions of flows, patterns of flows, and other morphological settings. It is the Gujarat state which incorporates these specific west flowing rivers of the country, whose relative annual water potential is reflected in Table 1, which remains about 4 to 5 % of total national potential.

According to another exercise (CGWB, 2014a), the major parts of the country receive precipitation between 750 and1500 mm/year, with extremely low precipitation in the western parts (<150 mm/year) and some of the world's highest rainfall in the north- eastern parts (>2500 mm/year). Most of the total precipitation occurs during the south-west monsoon season from June to September. The major aquifers are related to the major river basins that drain the country. More recently the total Indian land can be divided into 20 major river basins (CWC, 2010), which may be further separated into four groups according to their origin and flow pattern: (i) the Himalayan rivers (Ganges, Brahmaputra, Indus) that originate from the melted high- altitude glacier sands now, and are perennial throughout the hydrological year (ii) rivers of Indian craton (Mahanadi, Godavari, Krishna, Pennar, Cauvery, Narmada and Tapi) are mostly rain-fed and strive on base flow;(iii) the coastal rivers, mostly non-

perennial; and (iv) rivers of the western dessert originate within small fluvioaeolian basins, and are rain-fed ephemeral and disconnected from the ground water systems (FAO, 2013). Similarly, the renewable ground water resources of country have been estimated to be 433 BCM, with annual ground water draft of 245 BCM in 2011. Of these, 223 BCM groundwater was used for irrigation, and the rest 23 BCM were used for domestic and industrial purposes (CGWB, 2011, 2014c).

Table 1. Major Indian River Basins and their Probable Water Potentials

River	Origin	Catchment area (km^2)	Average annual potential in river (BCM/year)
Indus	Mansarovar (Tibet)	321289	+ 73.31
Ganga	Gangotri (Uttar Kashi)	861452	+ 525.02
Brahmaputra	Kailash Range (Tibet)	194413	+ 585.60
Barak and other rivers	flowing into Meghna like Gomti, Muhari,Fenny, etc	41723	+10
Sabarmati	Aravalli Hills (Rajasthan)	21674	3.81
Mahi	Dhar (Madhya Pradesh; MP)	34842	11.02
Narmada	Amarkantak (MP)	98796	45.64
Tapi	Betul (MP)	65145	14.88
Brahmani	Ranchi (Bihar)	39033	28.48
Mahanadi	Nazri Town (MP)	141589	66.88
Godavari	Nasik (Maharashtra)	312812	110.54
Krishna	Mahabaleshwar (Maharashtra)	258948	78.12
Pennar	Kolar (Karnataka)	55213	6.32
Cauvery	Coorg (Karnataka)	81155	21.36
Total		2528084	1570.98
Other river/ basins of India		248505	298.02
Total		2776589	1869.00

Source: Central Water Commission (1999, 2014)

Water Pollution*:* If we look into the prevailing global facts , it becomes quite evident that as on today fresh water in the world is hardly 2.5 % of total available water quantity on planet. This meagre quantity of fresh water is further getting deteriorated on spatial and temporal dimensions. Rivers are getting polluted in intensive manner, making health hazards a chronic issue at global, national, regional and even at local levels. As Earth's population continues to grow, people are putting ever-increasing pressure on the planet's water resources. According to the WHO (World Health Organization) and United Nations Children Fund (UNICEF), Poorer water quality means water pollution. Around 2.5 billion people do not have access to good quality water and proper sanitation even. About 700 million people worldwide drink contaminated water. Surprisingly India has maximum numbers of polluted rivers than anywhere else in the world, and most of it contains bacteria created from human waste. WHO speculated at least 2 million tons of human waste being disposed in water every day. This established the fact that river pollution needs to be given top priority, for which a concise estimation followed by prevention steps are need of hour. River water pollution further believed to have aggravated due to extensive ground water abstraction (Mukherjee etal.,2011). High concentrations of ground water fluoride have also been observed, mostly in the crystalline aquifers in parts of 19 states (Meenakshi and Maheshwari, 2006; CGWB,2015). Elevated levels of ground water iron(Fe) and nitrate ($NO3^-$) have also been reported from several aquifers of the country (CGWB,

2015). Seawater intrusion resulting in aquifer salinization has been observed in many of the coastal aquifers adjoining the Bay of Bengal and Arabian Sea, however, highly brackish ground water are also prevalent in the inland aquifers of several states(CGWB, 2015). Such inland salination may be linked with mineral dissolution and /or agricultural pollution. Frequent ,wide spread floods, caused by intense precipitation and rejected recharge are common in parts of eastern India.

CHALLENGES OF WATER RESOURCES IN GUJARAT

Present Status

Gujarat has four distinct regions namely (1) South & Central Gujarat i.e. South of the Sabarmati River, (2) North Gujarat (3) Saurashtra (4) Kachchh. About 95 % of total annual rainfall occurs during few days of monsoon period (June to September) due to Seasonal winds from the South-West direction. There is a wide variation in availability & distribution of rainfall across the State and number of rainy days is also very limited. With total 185 river basins in the State, the available quantum of water resources varies widely from region to region. The total available water resources (surface and ground water) of Gujarat are estimated to be about 55.6 BCM (38.1 BCM surface water and 17.5 BCM ground water). About 88 % water is supplied for irrigation, 10% for domestic uses and 2 % for industries. There is a wide gap between irrigation potential created and utilized. Growing pollution of water sources, especially through industrial effluents, is affecting the availability of safe water besides causing environmental and health hazards. In many parts of the state, certain stretches of rivers are both heavily polluted and devoid of flows to support aquatic ecology, cultural needs and aesthetics. Most of Ground water resources of the State are limited to only 1/3 area of the State (alluvial area inclusive of sand stones) i.e. Central Gujarat, North Gujarat, Surendranagar District and some parts of the Kachchh. The State has to suffer from frequent droughts due to scanty and erratic rainfall. During previous century, the State had to suffer from droughts for every third year. As a result, groundwater is utilized as the main source for agriculture, industries and domestic purposes, with 3 to 5 meter per year depletion in ground water table; just because of simple reason that amount of water withdrawal is always manifold in comparison to groundwater recharge. As a result, quantity of groundwater resources goes on decreasing and quality also goes on deteriorating in some areas along with coastal areas. Access to water for sanitation and hygiene is an even more serious problem. Natural water bodies and drainage channels are being encroached upon, and diverted for other purposes. Groundwater recharge zones are often blocked; inadequate sanitation and lack of sewage treatment are polluting river water boides to an alarming rates and extent. Gujarat has about 2125 km long coast line in the Western side that is about 1/3 of the total coast line of the nation. In the coastal areas of the Saurashtra and Kachchh, sea water is intruded in the aquifers and salinity gets increased and ground water gets polluted. In contrary to this, more water is utilized through canals for irrigation. Hence, water logging and salinity is increased in soils of these areas and culturable land is converted into non-fertile areas.

Types and Extent

Prevailing water resources in Gujarat has high degree of uncertainties as well as heterogeneities over space as well as time. The total geographical area of Gujarat is 196 lakh hector, out of which, 124.5 lakh hector is cultivable land. Before independence, only 51000 hector area of the State was having a facility of irrigation. Later when Gujarat gave priority to the programme of irrigation potential creation, irrigated area of state hiked to more than 50 lakh hector. Still there exists a vast disparity among the regions within Gujarat. North Gujarat, Saurashtra and Kutch regions of the State are water

scarcity-prone areas having a famine condition almost every two to three years, whereas the South Gujarat faces a heavy damage of human life and property due to flood situation almost every year. Valuable quota of surface water often drains out in ocean, so state has always been vigilant & sensitive towards conjunctive utilities of surface & ground water resources to avoid/mitigate such natural calamities. The recent efforts by state in the shape of developments and policy updating (Bala, 2015; Govt of Gujarat, 2007; Gupta, 2014) are:

- Maximum water resources/water base through check-dams & irrigation schemes
- Economical irrigation utilizations with alternative shift system of water usages via reservoirs.
- Bringing awareness for conservation and discrete use of underground/surface water.
- Preventing loss of water through evaporation in reservoirs in the areas facing famine.
- Setting up Khet Talavadis and deepening existing lakes/ponds.
- Setting up Water harvesting Structures, especially check dams for saving every drop of water.
- Taking up care at planning stage itself regarding drinking water even in irrigation schemes
- Planning for lining canals and implementation for inter-basin transfer of water.
- Implementing specific schemes like, Sujalam-Sufalam to prevent water being drained from reservoir during monsoon rather divert it to spreading canals for groundwater recharge .
- Saving electricity used in farming, promoting agro-industries
- Making available the irrigation and drinking water facility through underground water

Spatial & Temporal Variability

Overcoming a challenging situation where State's 20% area had 71% water resource and State's 80% areas had 29% water resource, Gujarat speeded up rainwater harvesting replenishing the rapidly depleting ground water levels which led to water security and sustainability. Stream flow constitutes the principal source of fresh water in Gujarat. River flows are concentrated in the relatively short monsoon season. There are 17 rivers in Gujarat mainland, 71 in Saurashtra and 97 in Kutch region. Narmada, Tapi and Purna are perennial rivers. Gujarat has just 2.28% of India's water resources and 6.39% of country's geographical area. This is again constrained by imbalances in intra-state distribution. The State has an average annual rainfall of 80 cm with a high coefficient of variance over time and space and as a result droughts have been frequent. Out of 185 rivers, the State has only eight perennial rivers and all of them are located in southern part. Around 80% of the State's surface water resources are concentrated in central and southern Gujarat, whereas the remaining three-quarters of the State have only 20%. on average, three years in a cycle of 10 years have been drought years. Recent spectrums of variations in spatial distributions over the Gujarat state are illustrated in Table 2, which is self explanatory.

Table 2 Spatial Distribution of Rainfall & Estimated Available Water Resources in India

Region	Average Annual rainfall	Rainy days		
South Gujarat	> 1100 mm	120		
Central Gujarat	800 – 1000 mm	30 – 70		
Saurashtra	400 – 800 mm	20 – 30		
Kutchh	< 400 mm	10 - 20		
Region	Estimated Available Water Resources , MCM			%
	Total	Surface Water	Ground Water	
South Gujarat Region (South of Sabarmati River)	35700	31750	3950	71.40
North Gujarat (North of Sabarmati river)	5300	2000	3300	10.60
Saurashtra	7900	3600	4300	15.80
Kutchh	1100	650	450	2.20
Total	50000	38000	12000	100

WATER POLLUTION IN GUJARAT RIVERS

Most of the rivers in Gujarat have significant extent of pollution, in n number of forms and from equal numbers of sources. A brief description in this regards is framed as follows,

Types and Extent

Existence of Earth's water resources can never be thought of without rivers, which use to be the sole actor to govern surface and ground water. Two distinct ways in which pollution can occur in such water resources includes, point source pollution (pollution comes from a single location e.g. discharge pipe attached to a factory), and Non point source pollution where pollution comes from many different scattered sources, even non visible. In study region, the intensity of this pollution remains high with alarming limits. Owing to physiographic & climatic settings, most of the rivers in the state of Gujarat, passes through a course where majority of river reaches are touching industrial, municipal, intensively cultivated agricultural catchments with intensive chemicals/fertilizers. Among predominant causes of river water pollution, there emerge varieties of agents, processes, and managerial actions. Most pollution doesn't begin in river water itself (Chakrapani, 2005; Ujjainia and Mistry, 2012), but it has many visible or invisible routes. The predominant agents for giving river water pollution includes backwater pollutant fluxes from seas, adverse human activities, fertilizer/chemical applications in agrarian fields, which have enormous ways/routes to not only pollute river water but the nearby ground water too. Sometimes the causes of water pollution are quite surprising. Chemicals released by smoke stacks can enter the atmosphere and then fall back to earth as rain, entering rivers and causing severe river water pollution. Categorised pollution agents in Gujarat Rivers are as follows:

- Heavy volumes of disposed sewage wastes which badly affect people's immediate environments and leads to many water-related illnesses.
- Chemical fertilizers/pesticides as used by farmers drains into rivers adding up pollution.
- Higher scale problems of waste water owing to chemicals washed down drains/discharges pumped untreated into rivers from factories. It includes detergents/ toxic chemicals e.g. polychlorinated biphenyls are discharged into the river environment

- Toxic pollution as received from heavy metals (lead, cadmium, mercury).
- Power plants located nearby rivers releases harmful substances like radioactive waste..
- Most plastics are not biodegradable, as a plastic bottle can survive an estimated 450 years in the river/ocean water. Huge plastics dumped inside the flowing or stagnated rivers are another alarming noxious means as it can strangle or choke fishes by eaten plastic residues.

End Effects

River water pollution has enormous end effects on humans, animals and even the overall ground water reserve in the region. The state of Gujarat takes pride as the flag bearer of India's industrial strength. A 400 kilometer stretch between Vapi in south Gujarat and Mehsana in the north is dotted densely by hotspots where, 'rivers' is a misnomer for industrial gutters, hand pumps spew coloured water and open lands, both government and private, are good enough for dumping all manners of toxic wastes. Being industrial state, majority of people believes that pollution is an inescapable result of human activity, with inherent argument that if we want to have factories, cities, ships, cars, oil, and coastal resorts, some degree of pollution is almost certain to result. In other words, pollution is some time taken as granted as a necessary evil that people here must put up with if they want to make progress. It brings costs of its own that undermine any economic benefits that come about by polluted rivers/river water bodies. Moreover, end influences of river water pollution could be dampened,

- Making people aware of the problem and relevant laws to caring river water bodies.
- Understanding and caring trans-boundary nature of river water, where rivers/drains usually crosses several regions/reaches of variable set of pollution settings, unlike the sea which span continents. Pollution discharged by factories in one region with poor environmental standards can cause problems in neighbouring river water bodies, even when they have tougher environmental laws.
- Adopting the best way to tackle river pollution on standard “Polluter Pays Principle”, which means that whoever causes pollution, should have to pay to clean it up, one way or another?
- Avoiding misuse, improving proper understanding, well managing of ground water resources could be another way as rivers have direct/impactful connectivity with ground water bodies.

River Water Quality Concerns

Central pollution Control Board (CPCB) often sets the yard sticks to monitors the river water quality in India, where standard water quality parameters are analysed and monitoring locations exceeding the water quality criteria are identified as polluted locations with respect to risk. Priority levels of polluted stretch or reaches of major rivers is usually based on this risk indicator, which is defined as, “Risk = Frequency of Violation of Criteria X Consequences (i.e. Magnitude)”. There has been a vast variability in predominant river water quality indicators as evident from observations by large number of researchers and institutions. Moreover, an abstract details of certain common indicators of river water quality in majority of rivers located inside the Gujarat, are illustrated in Table 3, which are self explanatory to depict the ranges of pH, Dissolved Oxygen (DO), Biological Oxygen demand (BOD) and Chemical Oxygen Demand (COD) at specified limited river locations.

Table 3 Prevailing Status of Water Quality in Major Rivers of Gujarat

River	*Location*	*River Water Quality Parameters **				*River*	*Location*	*River Water Quality Parameters **			
		pH	*DO*	*BOD*	*COD*			*pH*	*DO*	*BOD*	*COD*
Sabarmati	Hansol	8.5	6.5	7	30	Mahi	Sevalia	8.1	7.3	0.25	4
Sabarmati	Ahmedabad	8	4.8	2.53	18.4	Mahi	Vasad	8.1	7.2	0.4	8
Sabarmati	Vasna Narol	8.2	3.4	51.33	211.7	Mahi	Mujpur	7.8	7.1	1.49	16
Sabarmati	Vautha	8	Nil	49	202	Mahi	Umeta	8.1	7.7	0.38	8
Sabarmati	Miroli	7.9	0	67	213	Tapi	Kathor	8.3	6.8	3.01	7
Sabarmati	Kheroj	8.4	6.9	4	37	Tapi	Mandvi	8.1	7.1	2.4	10
Narmada	Chandod	8.1	7.5	0.61	4	Tapi	Sherulla	8.2	6.9	2.24	6
Narmada	Garudeshwar	7.9	7.6	0.77	7.94	Tapi	Varachcha	8.3	6.6	3	17
Narmada	Panetha	8.2	7.4	1.24	8	Ambica	Amalsad	8.2	6.1	2.67	27
Narmada	Zadeshwar	8.2	6.9	1.14	7.94	Damanganga	Kachigaon	7.6	5.9	17.68	85
Narmada	NTPC, Zanor	8.1	6.7	1.11	7.84	Damanganga	Vapi	7.3	7.3	0.74	10.3
Narmada	Jageshwar	7.9	5.8	4.28	32 .00	Auranga	Valsad	7.7	6.9	4.56	19
Purna	Suart Navsari	8.3	5.4	3.23	24	Hiran, Kapila & Sarswati	Triveni sangm	7.7	4.5	2.12	17

(Source : Gujarat Pollution Control Board (2010); Units : Except for pH all values are in mg/L)

SET UP OF GRONDWATER & AQUIFERS IN GUJARAT

Major Aquifers

River water pollution has intimate connectivity with hydrogeology and water quality of aquifers located in an around the river reaches. The aquifers in Gujarat comprise of Trappean Basalts, Precambrian Crystallines, Alluvial and Limestone and clay aquifers (Phadtare, 1988). Much of central Saurashtra is underlain by Deccan Trappean Basalts, Coastal parts of Saurashtra are mostly Limestone & Clay aquifers and so are some regions in North Saurashtra close to Surendranagar. The North- South running Alluvial aquifers are of varied quality stretch from the Northern most parts of Gujarat to the Central and South parts. These aquifers have a deeper depth in the Northern parts and shallow towards the Southern regions. The Southern parts of the State again possess aquifers of Deccan Basalts which are spatially contiguous with the rest of the massive Basalt terrain comprising Maharashtra and some parts of Madhya Pradesh. Crystalline Aravalli aquifers comprise the North-East parts of the State. Kutch shows a wide variety of aquifers ranging from Alluvial, Limestone, Clay and Laterites. Figure 1 provides a generalized illustration of aquifers in India, with relative variability in Gujarat. Recharge processes in the aquifers varies from spatially and temporally concentrated contribution from ephemeral streams to diffuse recharge from canal networks. The arid and semi-arid climate flat terrain of Saurashtra and Kutch are characterized by recharge occurring from the monsoon streams. Recharge is primarily limited to a few humid pockets in hilly areas and the periphery of streams and rivers. The hilly regions of North Gujarat have little recharge from the ephemeral streams, while some recharge happens in the plain Alluvial terrain too from these streams. Due to a high variability of rainfall, the inter-annual recharge is also highly variable (Kumar, 2004). The rivers of Central and South Gujarat contribute in vast amounts to groundwater recharge and in some dry times. The canal networks of the Mahi, Sabarmati and Narmada too contribute wide & diffuse recharge across the year in the plains of south and Central Gujarat.

Ground Water Pollution

Groundwater pollution is usually defined as the artificially induced degradation of natural groundwater quality. Pollution can impair the use of water and can create hazards to public health through toxicity or the spread of disease. Most pollution originates from the disposal of waste water which is being used for variety of purposes. Thus, the large number of sources and causes can modify groundwater quality, ranging from septic tanks to irrigated agriculture. In contrast with surface water pollution, subsurface water pollution is difficult to detect and is even more difficult to control, and may persist for decades. With the growing recognition of the importance of underground water resources, efforts are needed to increase to prevent, reduce, and eliminate groundwater pollution. Generalized findings by visualizing pooled sets of reported results revealed the fact that nearly 70% of the districts in Gujarat have fluoride contents beyond the permissible limit in ground water. Data available from the ministry of water resources, concerning ground water quality scenario, expose that more recently, 18 of Gujarat's 26 districts (before add up of 9 new districts) have fluoride content above the permissible limit, and Gujarat ranks 5th among the 19 states categorised for high fluoride content in ground water. Data available from ministry of water resources shows fluoride content is above permissible limit in districts like Ahmedabad, Amreli, Anand, Banaskantha, Bharuch, Bhavnagar, Dahod, Junagadh, Kutch, Mehsana, Narmada, Panchmahals, Patan, Rajkot, Sabarkantha, Surat, Surendranagar and Vadodara. The nitrate content in ground water is also quite high in various districts of the state, like Ahmedabad, Anand, Banaskantha, Gandhinagar, Jamnagar, Junagadh, Mehsanan, Narmada, Rajkot, Sabarkantha, Surendranagar and Vadodara. Some specific groundwater characterization (CGWB, 2014b; Soni et al, 2010; Dubey and Ujjainia, 2013) in Gujarat is:

- Longest coastline in the country, hence sea water intrusion into aquifers is a common problem all across Gujarat right from Kutch and Saurashtra to Vadodara and Valsad.
- Numerous quality problems in Aquifers, which are increasing in intensity over the years.
- High industrial activity with large amounts of released effluents, even directly into wells.
- High amounts of toxic waste as detected in aquifers of South and Central Gujarat.

Prevailing Ground Water Development & Quality

Groundwater quality is being increasing threatened by agricultural, urban & industrial wastes. In many cases, the abstraction of excessive quantities of groundwater has resulted in the drying up of wells, salt-water intrusion & drying up of rivers that receives their flows in dry seasons from groundwater. The groundwater quality problems in Gujarat, are mainly due to i) contamination by geogenic and man-made sources; and ii) sea water intrusion due to over-abstraction of groundwater along the coasts. The fast industrial growth has resulted into generation of large quantity of wastes (solid, liquid and gaseous), which many times do not get collected, treated and disposed. Same is the fate as domestic wastes in the city. A large number of industrial activities are taking place in urban areas (Varghese et al, 2011), especially in congested, populated areas. The wastes generated by industrial activities in urban areas get mixed with domestic wastes and pollute the ground water. As groundwater is the only source of drinking in majority of areas, a large population is at risk of consuming polluted water. Thakkar gave a detailed account of the rainfall variation and the water availability in the rivers of Gujarat. The rainfall in Gujarat varies from less than 400 mm in Kutch to above 1100 mm in South Gujarat. Most of the rivers of Saurashtra and Kutch dry up in the summer. The available water resource is marked with inequitable distribution say about 71 % in South Gujarat, 11 % in North Gujarat, 16 % in Saurashtra and 2 % in Kutch. Ground water quality or groundwater development happens to be a wider subject and author has deep exposures and insights on it, but because of paucity

of space only a surface touch is offered in this discussion, which is appropriately depicted in Figure 2 & 3, showing the relative status of ground water contamination & ground water development.

CONCLUSION

Gujarat state has its own physiographic location and peculiar settings, where rivers and river network plays an important and decisive role for overall environmental concerns for people as well as region itself. Being a rrapidly developing State, here both the river water as well as ground water are scarce water source and they are ever depleting in a time when there is ever increasing demand of water resources. It all together is creating conflicting interests in water management policies. It is also seen that for the last few decades, wide ranging interests of agriculture, industry and domestic sector along with natural environment are emerging as new challenges which needs to be fulfilled. Quantitative and qualitative analysis of prevailing conditions of river water bodies and also the underlying ground water bodies clearly demands certain sustainable solutions for preventing water pollution at one hand while enhancing water use efficiencies on other hand. This could be only achieved by realistic estimations, tailor made solutions for local management of water resources ensuring conjunctive utilities of surface and ground water with good governance and active participation of peoples. The situation demands for deeper insights on the policy interventions (direct and indirect tools) too where certain innovative efforts needs to be conceived /implemented on real grounds at grass root level with ensured quantified benefits. The large mismatch of demands and supply, the large deviations/disparities in ground water extractions in agrarian v/s non-agrarian sector, river water- ground water interactions, pollution control measures and above all an awareness generation is need of hour. Other adverse situations like climate changing, large dams, reservoirs and river degradations are adding fuel to the fire, hence needs to be given sincere and serious thoughts to evolve solutions for local problems adopting global yard sticks and better integration of communities involving scientists, academicians, students, rural and urban youths, field functionaries, policy planners and many other segments of the human society to work towards well set target where there shall be enough quantity of qualitative water inside the rivers as well as aquifers.

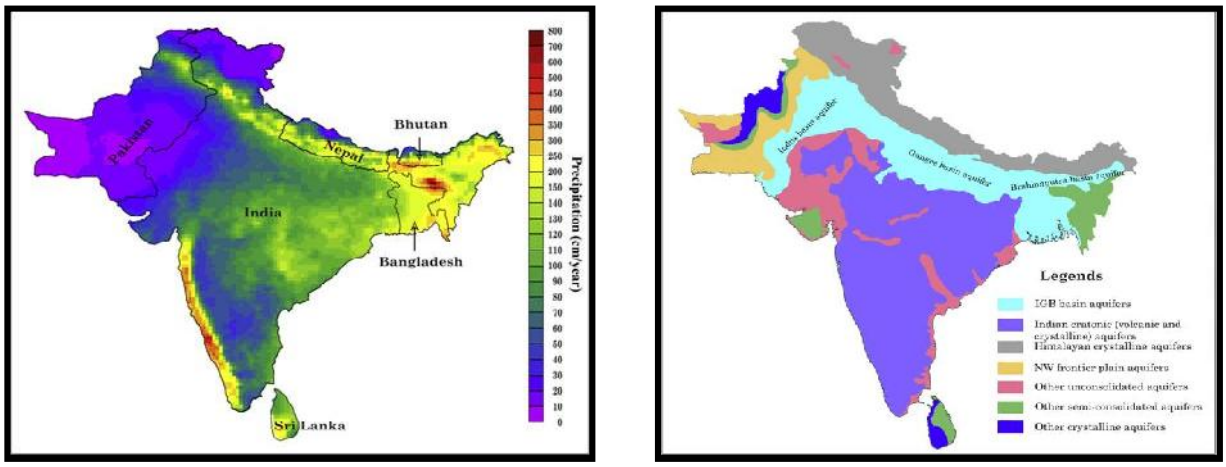

Figure 1 Regional Variability in Regards to Precipitation and Major Aquifers in India

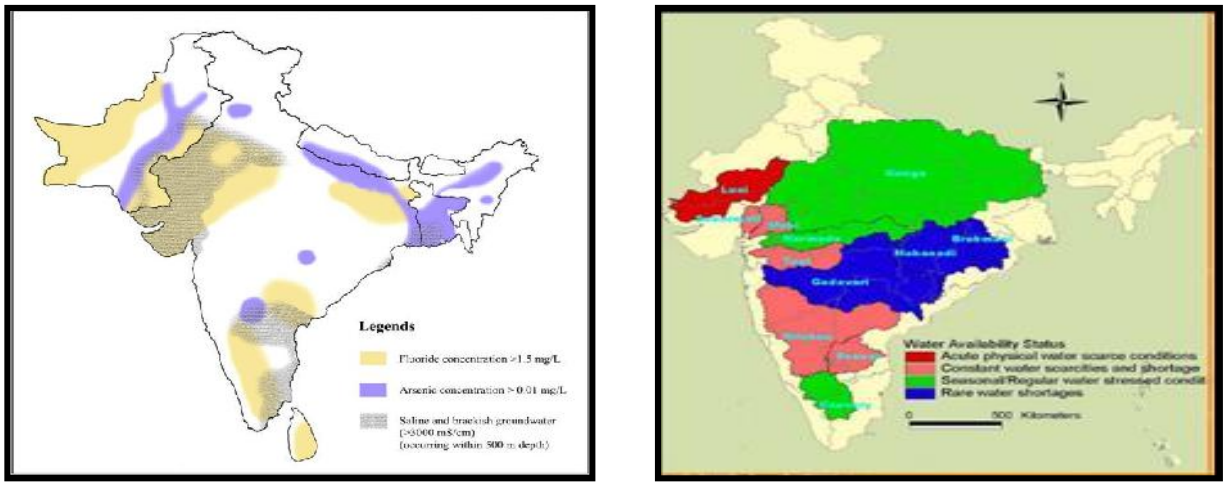

Figure 2 Regional Variability on Groundwater Contamination & its Development in India

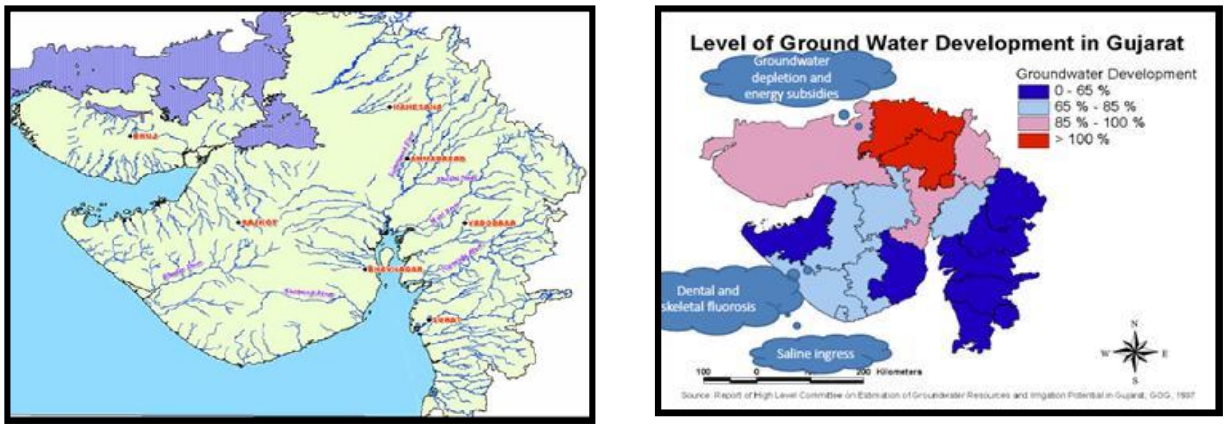

Figure 3 Status of Major Rivers & Corresponding Groundwater Development in Gujarat
(Source : CWC, 2010 and Mukherjee *et al ,2015)*

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