aojse.com ISSN 3067-1140

AMERICAN ONLINE JOURNAL OF SCIENCE AND ENGINEERING (AOJSE)

OPEN ACCESS. PEER-REVIEWED. GLOBALLY FOCUSED.

The Wetlands as Natural Sewage Treatment Plants for cost-effective water management in peri-urban areas

Hina Alam[1*], Kainat Aziz[2], Misbah Bashir[3] and Shakeel Ahmed[3]

[1] School of Sciences, Maulana Azad National Urdu University, Hyderabad,
hinaqasim2005@gmail.com
[2] Indian Institute of Technology, Guwahati, Assam
geosara1@gmail.com
[3] Islamic University of Science and Technology, Awantipora, J&K
*hinaqasim2005@gmail.com

Abstract

The city of Hyderabad has a small river, a tributary of Krishna river viz., Musi river and due to huge and unplanned constructions and destruction of the catchment area, the flow in the river has been gradually reducing and at the same time huge sewage water flows in the river due to increasing population living in the peri-urban areas without any infrastructure. Thus, the river in the down-stream carries mostly the sewage water particularly in the non-rainy season.

Conveniently, there exist a number of natural wetlands on the bank of the river and they help in purifying the sewage under natural conditions. Therefore, to check the efficacy of this purification an experiment was carried out by allowing the swage water of the river to pass through a designated wetland and it was found that the nitrate was reduced to more than 90% after passing the sewage through the wetland for a time period of 48 hrs. In addition to Nitrate reduction, the phosphate and Sulphate too have been reduced considerably.

Based on this experiment, a few schemes of irrigation through the constructed wetlands have been suggested using wastewater.

Introduction

The demography of rural and urban India is quite complex and the mobility has increased with time. However, there is only one-way migration and this has put enormous burden on the urban infrastructure particularly on the natural resources. Due to economic factors such a population forms a large peri-urban area in most of the major cities particularly in developing counties. These migrants start staying there before any basic infrastructure is developed. Among others water and sanitation are essential requirement. For water supply still borewells could serve the purpose but generated sewage is left unattended and they are put in nearby water bodies.

Peri-urban Agriculture is definitely a new conception in India. A large number of population are either forced or opt to leave the rural region due to poor infrastructures and facilities there and they settled in the outskirt of the city to carry out jobs other than agriculture. Horticulture in urban and peri-urban areas is quite common but agriculture is undoubtedly an interesting and useful concept. It is therefore necessary to assess the impact of a very different type of irrigation, viz., using wastewater on the initial groundwater and surface water system, groundwater budgeting and groundwater quality and to recommend for farming with scientific findings using the treated water through wetlands.

Domestic and industrial wastewater from Hyderabad is discharged to the Musi River and to date only 21% of the water is treated. The river has dams every few kilometres downstream of the city and a grid of canals exit on both sides taking this water for irrigation. This network is used to irrigate approximately 10,000 ha of paddy rice (two crops annually) and paragrass (perennial and cultivated for buffalo fodder) along the Musi sub-basin in peri-urban and rural Hyderabad (Celio *et al*, 2009; Massuel *et al*, 2007; McCartney *et al*, 2008).

This wastewater has a profound impact on crop production, soil degradation and yield reduction of rice (i.e. reduction of 30% in the village of Peerzadiguda) (Biggs and Jiang, 2009; Grattan, 2002; McCartney *et al*, 2008; Pescod, 1992). For the Musi River, 94% of salt is from city and the EC of soil irrigated by wastewater sampled within 8 km of the city is 6.0 to 8.4 times more than soil EC irrigated by uncontaminated groundwater. The salinity values of the soil are very high following the waste water irrigation (1.9 $dS.m^{-1}$) the recommended salinity threshold of 0.7 $dS.m^{-1}$ (Biggs and Jiang, 2009; McCartney *et al*, 2008). Para-grass seems to be a more resistant crop for high salinity soils; it has a higher salt tolerance than rice. It may be one reason for farmers to switch from their rice crop to para-grass. This way, they will save money by using less fertilizers because of important quantity of nutrients in wastewater (Buechler and Mekala, 2005; Biggs and Jiang, 2009; Massuel *et al*, 2007).

A feasible solution for irrigation has been to mix groundwater with waste water to increase volume (Buechler and Mekala, 2005). The impact of this type of irrigation will be one of the objects of this study.

Wastewater management in Indian urban areas are mostly based on unplanned practices which are evidenced by the contamination of Indian Rivers with untreated wastewater. These practices lead to alteration in physical, chemical and biological characteristics of the natural resources and epidemics which is usually observed in India and other developing nations as well. Wastewater, if properly managed in sustainable mode is one of the largest resources of water for irrigation and industrial purposes and also it reduces the stress on groundwater resources and environmental degradation. In India the large amount of wastewater generation is from urbanized areas owing to the dense settlements. The demands for freshwater and generation of wastewater in urban areas are alarmingly increased and still increasing with time at significant pace. Hence, the wastewater generating at urban areas is an eternal source as long as the community exist. Literature study shows that the groundwater sources of India are getting exhausted at an alarming rate. An alternate or additional source is needed to reduce the scarcity. Wastewater generated in the urban areas of India, if treated in natural way, is the only existing alternate to meet the challenges such as the agriculture water demand. More than 38 MCM per day of sewage is generated from major cities with the limited treatment capacity of 12.00 MCM per day (CPCB, 2009). Hyderabad city generates about 12.000 MCM per day of wastewater with treatment capacity of 6.530 at various sewage treatment plants (STPs). This imbalance need to be addressed and solved in India.

The clinical studies in India shows more people die from malaria, diarrhea or respiratory diseases which are mostly water borne diseases. Hence, it is utmost important to safeguard the drinking water resources which can essentially be met by development of proper integrated management strategies. The integrated management strategies should be focused to meet the present need of safe water for drinking as well as agriculture aspects to every citizen and protect the water resources for future generation in sustainable way. The water pollution is much in urban areas of India where generation of wastewater is high in comparison with rural areas. Hence, urban wastewater management has to be dealt effectively to protect the health of the peri urban environ.

In India even, primary public health centers are sometimes lacking electricity, so the treating huge amount of wastewater at STPs is far away. Therefore, it is an urgent need to establish the natural treatment systems which is an ultimate alternate to the treatment of wastewater generating in India. Therefore, an integrated management plan integrating natural treatment systems in urbanized areas of India would certainly serve the purpose of enhancement of wastewater reuse in India.

The Study area and the experiment to test the Efficacy of treatment

Musi River is linked with an ancient irrigation system containing a series of wetlands and passing through the city of Hyderabad and Secunderabad. It initiates from Ananthagiri hills flowing 247kms through the city of Hyderabad and finally joins the Krishna River at Wazirabad as its tributary. It gets several million m3/day of wastewater from domestic and industrial sources of the city, which is a mixture of partially treated or untreated water, generated in the Hyderabad city.

The same is used for irrigation in the peri urban areas. As an economic profit to the local inhabitants in the area, the wastewater is main source of irrigation in the peri-urban situation where the cultivation of fodder grass, paddy and vegetables are practiced. Use of untreated wastewater for food production has health consequences; therefore, treatment of wastewater is important. There are many treatment options that can be utilized and here we propose constructed or engineered natural wetlands which are cost effective. The developed model will be used to optimize the performance of engineered treatment that will render the wastewater safe for crop production.

To assess the efficacy of natural treatment systems such as wetlands, lagoons, ponds, etc. for wastewater treatment and to enhance the surface water recharge in India, a pilot study has been carried out at Hyderabad for Wetlands. The dominating processes involved in enhancing the quality of wastewater have been determined by periodical monitoring of wastewater quality in the natural treatment systems for two years. The natural wetlands are functioning well for wastewater treatment. The functional parameters can be used to construct engineered mini wetlands for decentralized wastewater treatment. The main objective is to adapt the established natural treatment systems by developing appropriate integrated management plans for the long run.

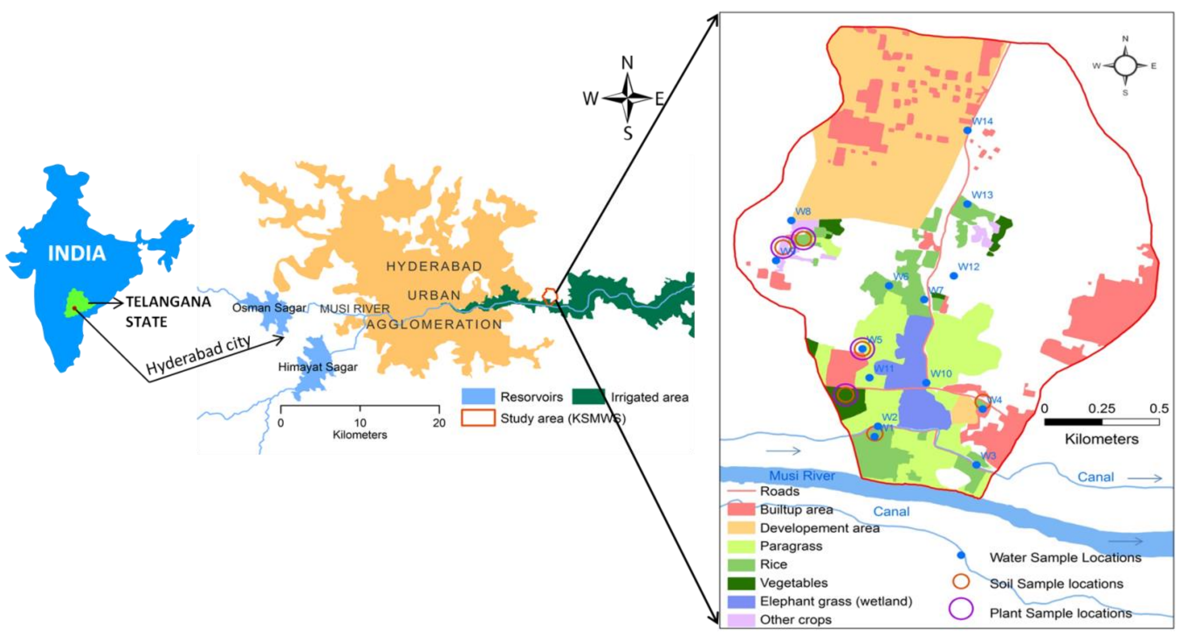

Fig. 1: Location map of Musi River catchment area around Hyderabad City, India

Scope of the integrated management plan for wastewater using NTS

Contemporarily in India, the centralized sewage treatment technologies are practiced which have proven to be expensive, complex and are failing to cater to the total wastewater generated. The untreated/partially treated wastewater makes its way to the water body causing immense degradation of the ecosystem and the environmental health. Need is for sustainable wastewater treatment technologies adapting natural treatment systems (NTS) which treat the sewage in natural way to reuse. Therefore, the demand for decentralized wastewater systems which is reliable, efficient and low-cost wastewater treatment systems is the primary concern especially in densely populated urban regions where adequate wastewater treatment systems do not exist. Hyderabad based case study indicates that NTSs such as wetlands are proven to be the best alternate for decentralized wastewater treatment systems which can remove the pollution load up to 90% in wastewater. Similarly, Chennai case study shows Managed Aquifer Recharge (MAR) is the only alternative for meeting the freshwater requirements at coastal areas. Therefore, this deliverable which deals with integrated management plan derived from the two pilot experiments at Chennai and Hyderabad on MAR and NTS, respectively will have great scope in resolving the urban water and wastewater challenges. The pilot studies can be replicated on large scale and the established management plans can be used as elements in preparing city sanitation plan (CSP) in Indian urban areas.

Water resources distribution in the peri urban area

The river Musi flows through the Hydrerabad city originates from around Vikarabad and joins Krishna River at Wazirabad town. Osman Sagar and Himayat Sagar (Fig. 1), the two natural reservoirs on the Musi River upstream from Hyderabad have supplied water to Hyderabad from centauries. However, since the 1950s the water from these reservoirs has been insufficient due to increasing population and the demand as well as reducing the catchment areas due to uncontrolled catchment reduction. The water pumped from reservoirs are shown in Table 1.

Table 1. Sources of water to the city of Hyderabad. (Source : Van Rooijen et al., 2005)

Source	Date commenced	Catchment	Estimated volume of water supplied 2004 (M m^3)
Osman Sagar	Early 1900s	Musi	12
Himayat Sagar	Early 1900s	Musa	12
Manjira River	1960	Godavari	61
Singur River	1991	Godavari	102
Krishna River	2004	Krishna	61
Groundwater	-	-	41
Total	289		
Osman Sagar	Early 1900s	Musi	12

There are no dry season releases from the Osman and Himayat dams and except for spillway overflow during heavy rainstorms in the monsoon months, the Musi River ceases to flow upstream of the city. Hence, for most of the year, the flow downstream of Hyderabad is primarily wastewater from the city. The average discharge of wastewater into the Musi River is estimated to be 1252 MLD, (i.e., 80% of the water supplied to the city). The wastewater comprises both domestic and industrial effluent. Although more wastewater treatment plants are planned, it is estimated that currently only 652 MLD (52% of the wastewater) has any form of treatment prior to disposal at 14 STPs (Table 2).

Musi wastewater circulation and quantification

The twin cities of Hyderabad and Secunderabad do not have a satisfactory system of collection, conveyance, treatment and disposal of/or utilization of sewage and industrial wastewaters discharged into the public sewage system. The sewage system for the city covered partially and the balance of sewage from unsewered areas find its way into Musi through storm water drains and nallahs leading to pollution of Musi River and surrounding areas. It is estimated that nearly 52% of untreated sewage is let out into the Musi River. The sewage and industrial wastewater collected through the sewerage system, on both sides of River is collected at Amberpet through an outfall and subjected to partial treatment through primary treatment system. The primary treatment plant is designed to handle only 48% of wastewater, consists of screens, grit chambers, primary; sediment tanks, sludge digesters and sludge drying beds. The partially treated sewage is let into an outlet channel running parallel to the Musi River and ultimately joins Nallacheruvu at Uppal. The details of the wastewater quantification at STPs and their capacities are provided in Table 2.

Table 2: Current wastewater treatment capacity of sewage treatment plants and systems associated with lakes

	Value (MLD)	Source of information
Sewage (80% of water supply to the city)	1252	Hyderabad Water Supply & Sewerage Board
Treatment capacity	652.8	
Amberpet	339	
Nagole	172	
Nallacheruvu	30	
Attapur	51	
Hussain Sagar	20	Greater Hyderabad Municipal Corporation
Patel Cheruvu	2.5	Hyderabad Metropolitan Development Authority
Pedda Cheruvu	10	
Durgam Cheruvu	5	
Mir Alam Cheruvu	10	
Saroor Nagar Lake	2.5	
Safil Guda Lake	0.6	
LangarHouz Lake	1.2	
Noor Mohammad Kunta	4	
Ranghadhamini Lake	5	

Untreated	599	

City Sanitation Practice of Hyderabad

The Ministry of Urban Development (MoUD) approved the 'National Urban Sanitation Policy (NUSP)' in October 2008. The MoUD has requested all major cities to develop their CSPs, and a large number of cities have started to do so. The Administrative Staff College of India has helped develop a number of CSPs. The objective of this policy is to transform urban India into community driven, totally sanitized, healthy and livable cities and towns. Cities and towns are requested to develop City Sanitation Plans (CSPs) as an overarching strategic approach to improve their sanitation conditions. However, CSP development is a challenging task which needs involvement of experts and public bodies such as urban planning, sanitation, technical infrastructure and financing. Improvements in the sanitation sector concern every urban citizen and, therefore, require a participatory approach. For implementing a CSP, capital investments, adjustments of by-laws, strengthened administrative structures and adequate expertise might be necessary.

The current practice of Hyderabad city sanitation plan is based on the conventional ones where the existing sewage treatment plants (STPs) are capable of treating only 52% of the sewage generated in the Hyderabad city. The existing sanitation practice includes underground sewerage systems in urban area, septic tanks in suburban and open release of sewage in general. Hyderabad Metropolitan Water Supply and Sewerage Board (HMWS & SB) looks after the water and wastewater management in Hyderabad city. According to the Shyamala Rao, IAS, Managing Director HMWS & SB ((2013) (http://www.icrier.org/pdf/hyd_short_presentation.pdf), the core city drainage network coverage is about 80%, most of which are 30-40 years old and is not sufficient to cater to current sewage flows. Peripheral city network coverage is about 30%. City needs about 1300 MLD sewage treatment capacity but existing treatment capacity is 700 MLD. The sewerage issues are inadequate finances to maintain because it is non revenue activity and depend on water cess to maintain these lines, and high cost of land in urban areas for construction of new STPs.

For strengthening and improvement of existing sewer network, refurbishment project taken up in the Old city area of core city and in two municipalities of peripheral areas. Certain remodeling sewer works are being taken up under the State Budget. For newly merged municipal areas, detailed project reports for creation of sewer network are posed for JICA loan assistance. For treatment of sewage generated in the core city and peripheral areas, steps are taken to formulate the DPR proposals under National River Conservation Plan of NRCD, of GoI, for creation of 610 Mld capacity of STPs at various locations Models being worked out to recycle the STPs water. The sanitation issues are 1) sweeping – forenoon / afternoon / night sanitation 19500 working, SWG units 2500 Nos, 2) Self Help Groups, 6800 km road length being swept. 3) Weekdays sweeping, safety measures to the personnel, provided road accident policies, radium jackets, quality implements, etc. 4) monitoring and evaluation by resident welfare associations and self-help groups, women groups, and 5) community-based sanitation involving local welfare associations & self-help groups. Collection of solid waste is by Tricycles provided at free of cost to rag pickers for collecting the household waste at minimal cost. Dumper bins provided at every 500 M distance intervals. Rag pickers are also permitted to segregate the waste at dumper bin locations. Pin point program prepared for lifting of dumber bins. Solid waste transported from dumper bin location through designated transfer station and then to major dumping yard at 40 Km away from the city. Initiatives have been taken for scientific disposal of solid waste through BOOT/PPP Modes (i.e. compost, RDF, landfill & leachate treatment). Reclamation and reuse of existing dump sites. Development of scientific landfills. Developed 137 public toilets with good facilities.

The wastewater generated in the city, by direct release into the underground sewerage systems and septic tanks has eventually been leading to the Musi River systems. The residual matter in the septic tanks has also been released into the Musi River at an interval of about 6 months. Thus the sanitation practice in the city is unhygienic and needs to be revised by adapting NTSs as a strategy. Wetlands as natural treatment systems can be applied to treat the entire wastewater generated in Hyderabad city which can address the present challenges such as economical, space availability, operational, etc. of the public body.

Present scenarios of water supply and sewerage management of the city

Hyderabad Metropolitan Water supply and Sewerage Board (HMWSSB) is a statutory body vested with the responsibility of providing and maintaining water supply and sewerage facilities within the Municipal Corporation of Hyderabad (MCH) limits. The water supply and sewerage in the adjoining municipalities are being maintained by the respective municipal authorities. Water is being supplied to Hyderabad and Secunderabad cities from four impounding reservoirs on three Rivers mentioned below:

a) Osmansagar on Musi River
b) Himayatsagar on Musa River
c) Manjira Barrage on Manjira River
d) Singur Dam on Manjira River
e) Krishna Water

The project wise quantity of drinking water supply and their sources since 1980s have been shown in Fig. 2 which indicates increased demand with time.

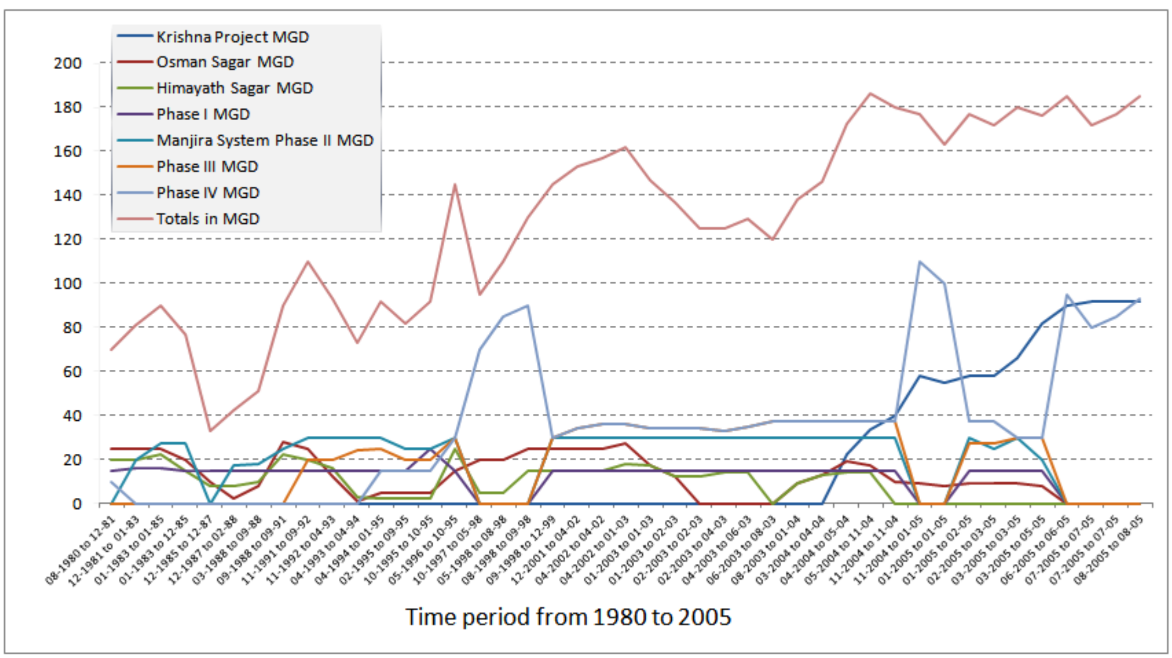

Fig. 2: The project wise quantity of drinking water supply and their sources since 1980s in Hyderabad city (Source: HMWS & SB, 2014)

Means of irrigation practices using wastewater

Wastewater is the major source of irrigation practices in the peri-urban environ of Hyderabad city. Downstream of the city, Musi water is retained in large and small reservoirs with the help of weirs and from there diverted into irrigation canals and village tanks to be used by farmers for crop production (Fig. 3). Due to increased demand for drinking water by the city, no controlled water releases from the Osman Sagar and Himayat Sagar reservoirs occur and the River downstream of the reservoir and upstream of Hyderabad is dry. The Musi River traditionally provided farmers downstream of Hyderabad with irrigation water for the cultivation of paddy during and after the monsoon rains. Through the construction of weirs, River water is retained in large and small reservoirs on the River from where it is diverted through irrigation canals to village tanks and agricultural fields. There is a total of 22 weirs situated on the Musi River irrigating an area of approximately 10,000 hectares (Katta 1997). In the rural areas the main crop is rice (*Oryza sativa*), while close to the city the main crop is paragrass (*Brachiaria mutica*).

Wastewater from wastewater canals and Musi Rivers have been lifted through various means like lift irrigation by high capacity pumps, gravity flow to storage wells through subsurface pipes and then pump from storage wells to upstream areas, and irrigation through direct gravity flow of wastewater to downstream of canals. In additions to these irrigation sources borewells and dug wells are also used as water source for irrigation (Fig. 4). Such wells in the proximity of Musi River (up to 700 m) are shown mixed water of wastewater and groundwater.

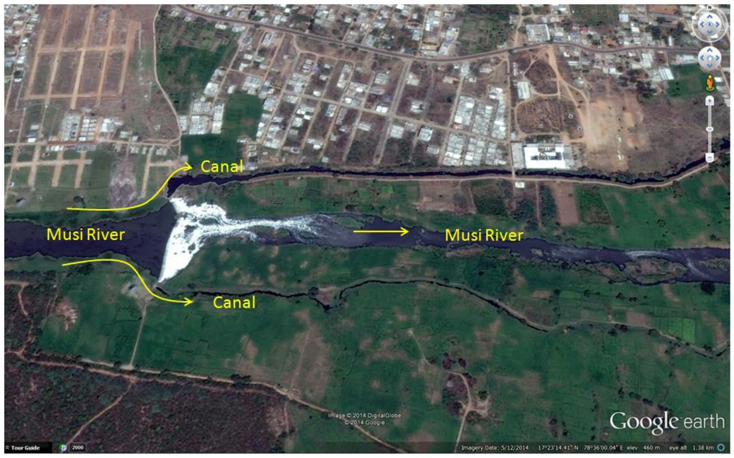

Fig. 3: Diversion of wastewater by weirs to either side of canal systems at Musi River study area, Hyderabad.

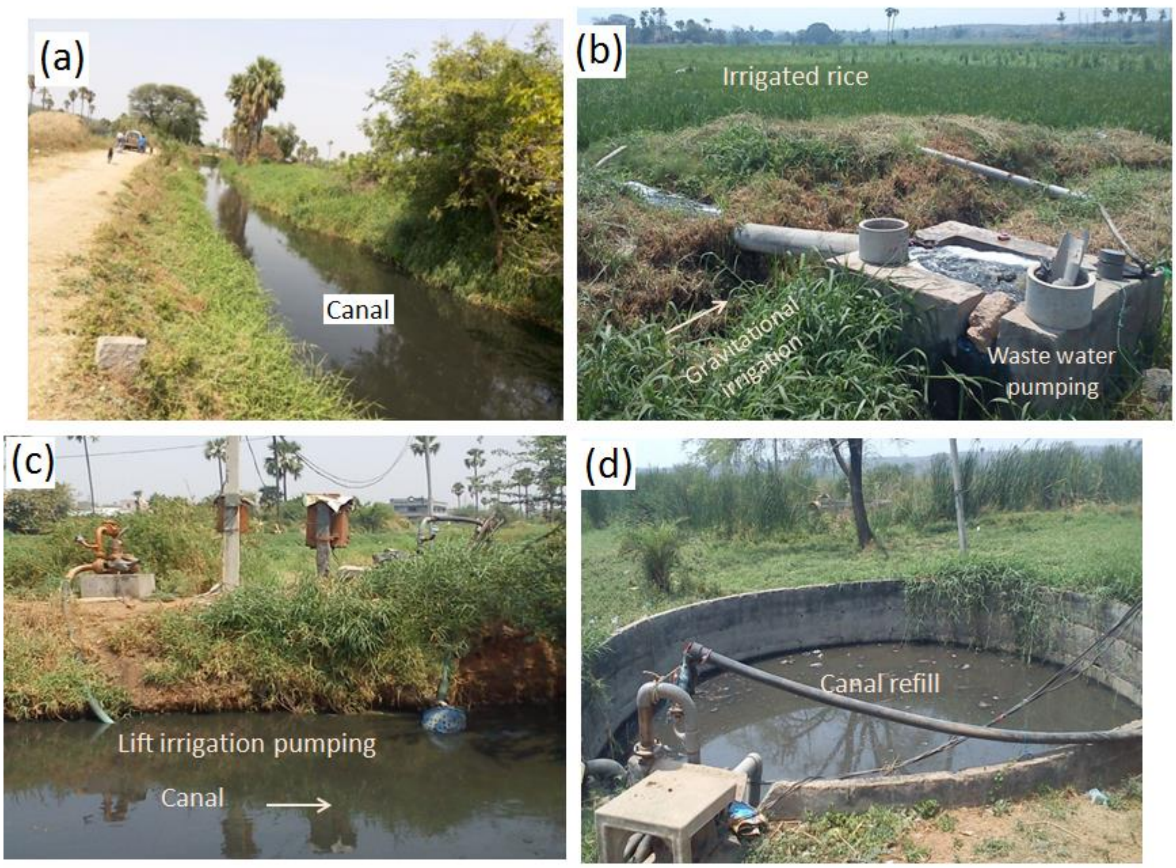

Fig. 4: Means of irrigation in the peri-urban environ of Hyderabad city. (a) northern canal of Musi River, (b) gravitational irrigation, (c) lift irrigation through pumps, and (d) wastewater storage well of gravitational discharge.

Areas of irrigation with wastewater and groundwater

Demarcation of areas under wastewater irrigation and fresh water irrigation has been significant in terms of agriculture economic assessment. The purpose could be solved by generating land use land cover (LULC) maps of the study area. The LULC map of the study area has been generated (Fig. 5) using high resolution satellite imagery (Google Earth) and existing interpretation from a former study (Amerasinghe *et al.*, 2009). To observe the micro-level spatial land use variability in the study watershed, the satellite images are validated with ground truth field observations and farmers interviews. The LULC map addresses the spatial variability in cropping pattern and other land cover classes. The datasets on cropping pattern, built-up area, topographical maps, ground truth data and farmers interviews were used as inputs for classification and accuracy assessment.

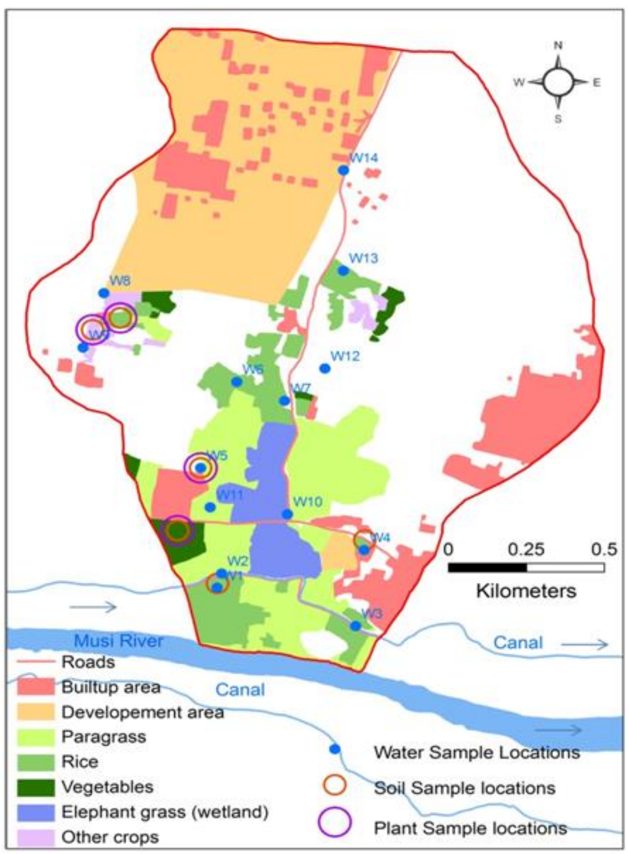

Fig. 5: Land use and land cover map of study area, Kachiwani Singaram, Hyderabad**.**

Table 3: Land use and land cover of the study area Kachiwani Singaram, Hyderabad

Land-use type	Type of crop	Area (ha)
Built-up area		29.6
Area under development		50.2
Total irrigated area		**48.5**
Crop wise total irrigated area	Paragrass	27.2
	Paddy rice	15.2
	Vegetables	3.8
	Other crops	2.3
Groundwater-irrigated area		**12.7**
	Paragrass	0.6
	Paddy rice	9.0
	Vegetables	0.8
	Other crops	2.3
Wastewater-irrigated area		**35.8**
	Paragrass	26.6
	Paddy rice	6.2
	Vegetables	3.0

The interpretation of LULC maps indicates that total irrigated area is 48.55 hectare (ha) and the area under development is 50.2 ha in the study area. The Table 3 shows that wastewater irrigated area is 35.8 % and groundwater irrigated area is 12.7 ha in the pilot area. Para-grass is the major crop of the study area accounting 27.2 ha in the pilot area. The wastewater irrigated area is noted mostly in the downstream, close to Musi River and the groundwater irrigated area is observed in the upstream of the study area.

Evaluation of wetland competence for removal of contamination from wastewater and wetland sustainability

Assessment of wetland efficacy for pollutants removal from wastewater along with economic viability is the prime concern of the natural treatment systems in developing countries of tropical zone. Hyderabad (India) located on the tropical zone of semi-arid climate which promotes the mesophilic and thermophilic bacterial activity to digest the organic contents and trace elements present in the wastewater. A regular monthly monitoring of static water level and in-situ pH, electrical conductivity and dissolved oxygen from the existing piezometers have been carried out during the hydrological years 2012-13. The wastewater from wetland showed a greater variation in its constituents compared to the canal water. The parameters such as BOD, COD, Na, Al, K, V, Cr, Fe, Cu, As, Rb, Ba, and Pb (mg/l) were found decreased in wastewater of wetlands systems indicating the efficiency of wetlands in enhancing the wastewater (Table 4). Thus, wetlands can be considered as an efficient natural treatment system for wastewater prior to its application for irrigation aspects.

Table 4: comparison of chemical parameters in wastewater of canal and wetland

mg/l	BOD	COD	Na	Al	K	V	Cr	Fe	Cu	As	Rb	Ba	Pb
Wastewater (from Canal)	60	184	49	0.1466	4.46	0.0046	0.0076	0.1552	0.0077	0.0013	0.0076	).0375	0.0031
Wastewater (from Wetland)	13	44	29	0.0143	0.8205	0.0033	0.0063	0.0736	0.0112	0.0006	0.0004	).0291	).0013

A significant reduction in the biological oxygen demand (BOD) and chemical oxygen demand (COD) has been observed in the wastewater of wetland outlet. Also, when compared the chemical constituents and microbial strength of raw wastewater and treated wastewater from wetland systems, the results show reduction of pollution load up to 80% in the wetland treated wastewater. It shows that the efficacy of wetlands for the wastewater is up to 80%. Significant reduction in the nutrient concentration (nitrates, phosphates and sulphates) were also noted in the wetland systems for three-year period (2012-2014). As per the local public information the existing wetland is since last 20 years. Further, a conceptual model of flow and mass transport, and the hydrogeochemical model would help to establish the strategies for enhancement of constructed wetlands and other natural treatment systems to determine the sustainability.

The detailed assessment of the physical environment using hydrogeological, geophysical and bio-geochemical investigations at the study site reveal the potential for removal of selected contaminants in the natural state. It can be further enhanced by using appropriate engineering designs.

The research findings of the experiment show reduction in the pollutants (nutrients) load of wastewater up to 97 % in the wetlands (Fig. 6). The detailed study of wetlands comprises calculation of wetland area, volume of standing water in wetland, volume/ biomass of *Typha capensis* grass and wetland outlet discharge measurements. The results show, wetland area is 8.8 ha, volume of standing water is 16295 m3, discharge of wetland is 1728 m3 and biomass occupied is 9 kg/m2.

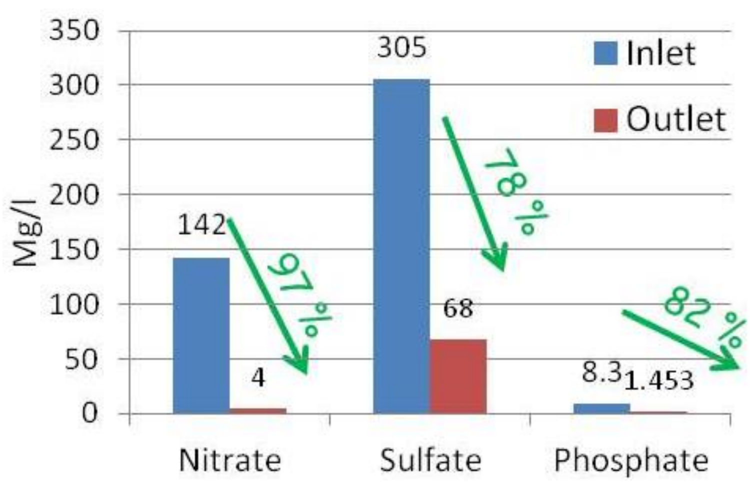

Fig. 6: Reduction of the pollutants load in wastewater at natural wetland

The eutrophic condition is the primary indication of climax stage of lentic water body. This resulted by enrichment of nutrients in the water body. The eutrophic condition enhances the biological oxygen demand (BOD) by reducing the dissolved oxygen (DO) concentration. So, reducing the nutrient concentration in water bodies is considered significant for the healthy ecosystem. Preliminary results at Musi case study show considerable reduction of nutrients such as nitrogen, sulphur and phosphorous concentration up to 97%, 78% and 82% respectively, in the wetland. The dominated process involved in the chemical transformation of nutrient has to be applied in engineered way. Based on the research findings of Musi River case study at Hyderabad few plans have been proposed to upscale the pilot study.

Proposed scenarios of NTSs

Scenario 1:

<u>Community driven wetlands - Its Management Plans and Feedback from the Stakeholder</u>

The existing wetland in the field site could be used as community/ group of former driven wetland. In the present scenario, the existing wetland is fed by return flow of wastewater through various channels (Fig. 7). The proposed idea is to pump the wastewater from wastewater refill well to wetland and allow for 48 hours retention time for biophysical and geochemical reaction, and then the treated wastewater from the outlet of wetland can be stored in proposed wastewater refill well and applied for horticulture purpose. The discharge of the treated wastewater from the wetland outlet is recorded about 1800 m^3/day. This can irrigate significant horticulture land. On this scenario the feedback from the stakeholder was not appreciable except two stakeholders.

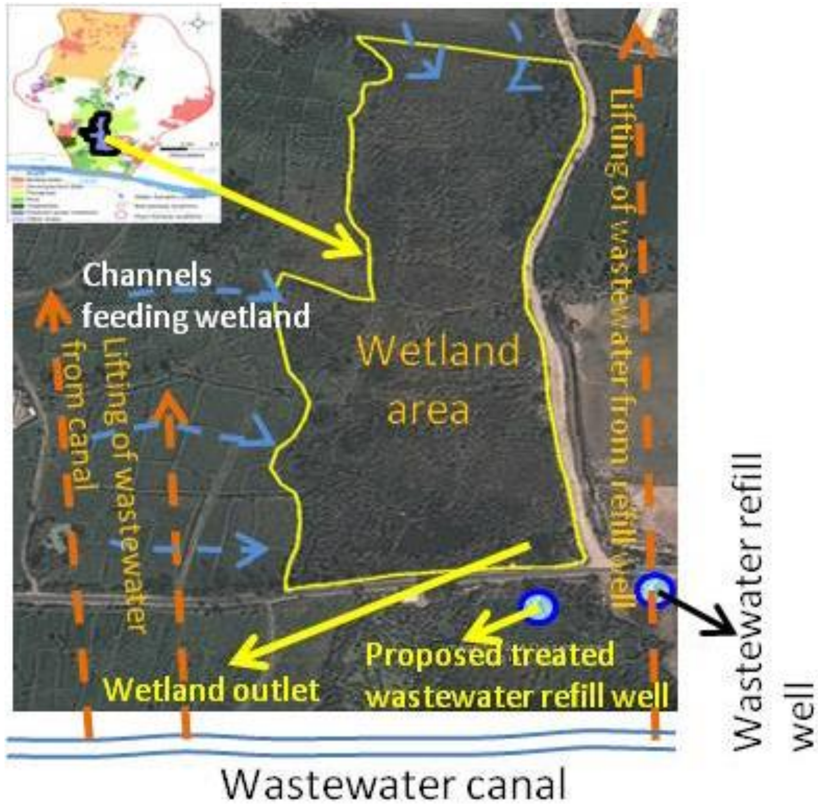

Fig: 7. Proposed community driven wetland at study area, Hyderabad

Scenario 2:

<u>Engineered wetland - Its Management Plans and Feedback from the Stakeholder.</u>

In the engineered/ constructed wetland, the wastewater flowing in the canal can be diverted to the topographic low-lying areas to create an engineered wetland similar to community driven wetland (Fig. 8). A series of naturally topographic low areas are existing along the Musi River which can be converted to engineered wetlands. Further, the treated wastewater from engineered wetland can be applied for the horticulture purposes. The views of the stakeholder on the diverting the wastewater to topographically low-lying areas to construct the engineered wetlands were found not encouraging. The reasons could be, the availability of the natural low areas is uncertain and the management strategies cannot be framed to implement practically.

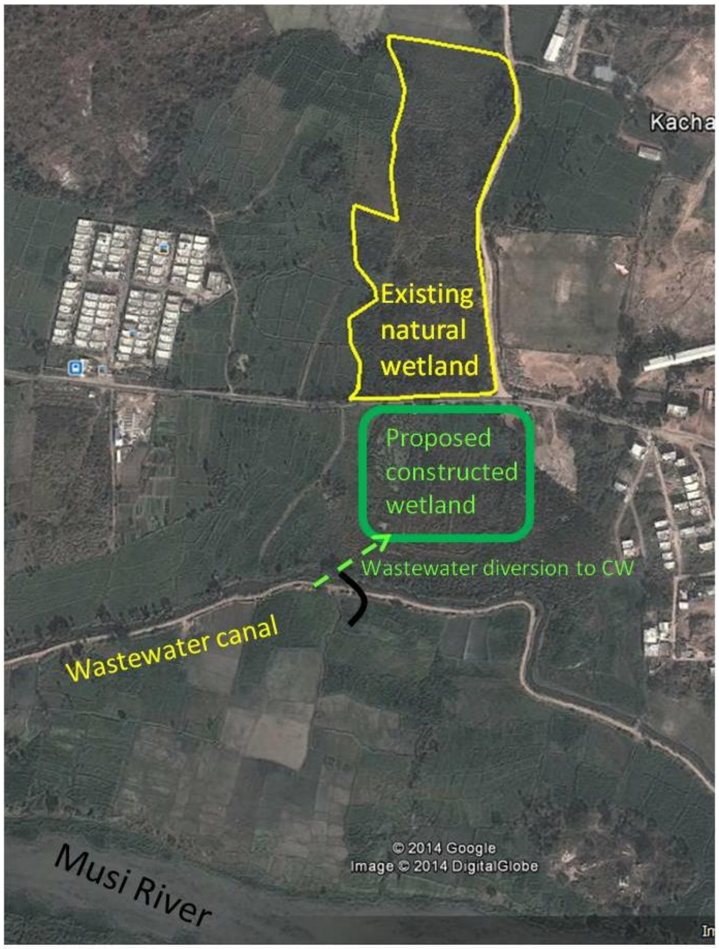

Fig 8. Proposed engineered wetland at study area, Hyderabad

Scenario 3:

Mini wetlands for individual formers - Its Management Plans and Feedback from the Stakeholder

The mini wetlands have been proposed for the individual formers to be established (Fig. 9). The ideal size of the mini wetland has been identified 0.05 acres. Formers can establish a mini wetland in the upstream of their form and let the wastewater to feed the mini wetland first before applying to form land. Allow the wastewater for about 48 hours as a retention time. The outlet wastewater which is naturally treated can be used for the irrigation purposes. This idea can also be used as decentralized wastewater treatment systems within the urban areas in place of centralized wastewater treatment systems at STPs. The decentralized wastewater treatment systems would be effective to prevent the pollution at source and to control the organic decay. The feedback of the stakeholders was very much positive about this scenario which is possible at individual level. The formers would be trained to maintain the mini wetland for the long run and also, he receives local government support in terms of policy guidelines. Once, this type of scenario gets successful, the formers will be self-motivated to learn the process. Majority of the stakeholder proposes the mini wetland concept.

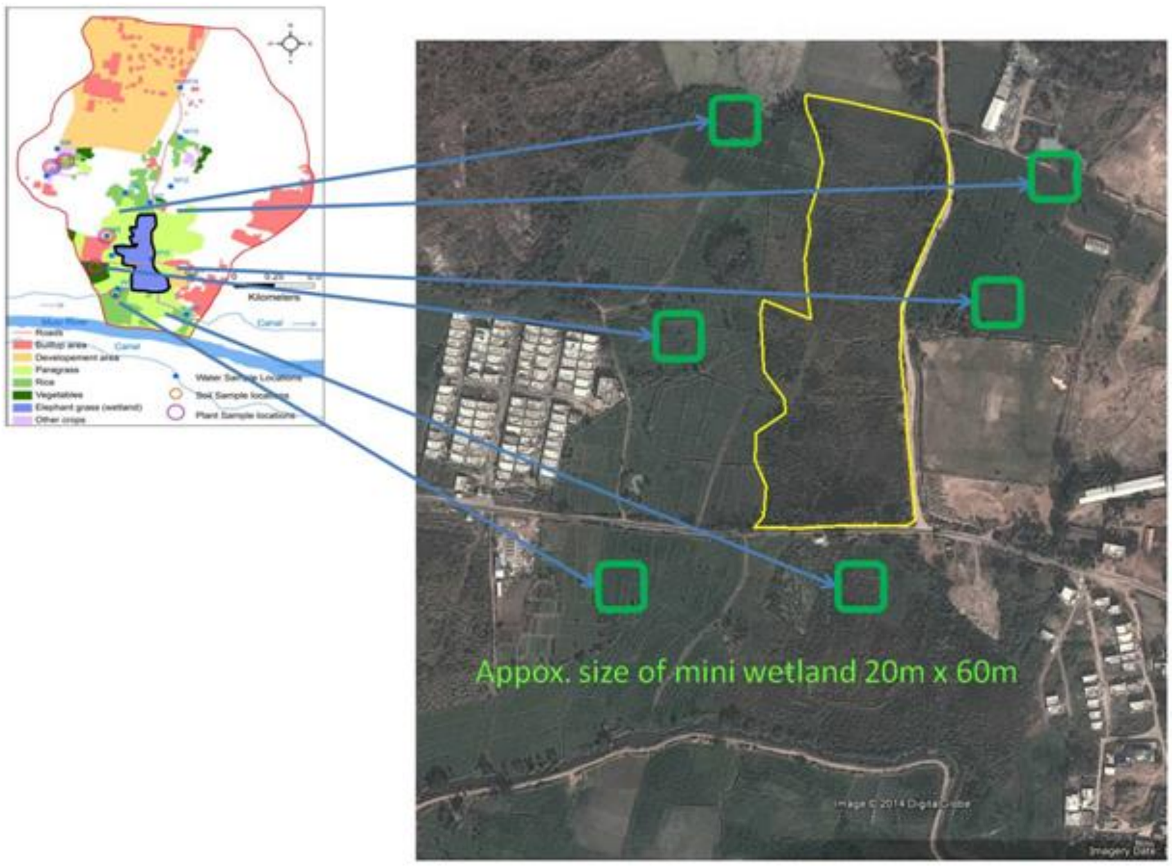

Fig. 9. Proposed mini wetlands for individual formers at study area, Hyderabad

Conclusions

With given set-up of infrastructures differences in rural and urban areas in developing countries, the migration continues to form the unorganized peri-urban areas. Thus the basic requirement of sanitation can be managed in a natural or semi-natural way using the naturally existing wetlands as well as constructed wetlands if required. The above studies have shown that almost the sewage water can be treated for nitrate and other associated contamination under natural condition by modifying a little the flow system such a way that the swage water is allowed to pass through wetlands for a specified period of time. A few scenarios too have been proposed to use the constructed wetlands if the natural wetlands are not available with specified plants such as para-grass or elephant grass. An irrigation mixed with treated sewage water and groundwater is the best and sustainable practice. Another useful ness is that the wetland treated water can be used to recharge groundwater for its sustainability in case irrigation is not taking place. Such a practice has no environmental consequences as well as the most economic ones compared to STPs.

Acknowledgements

The main study has been carried out using the funding of a couple of important projects funded by the EU and discussions with a number of experts for reinterpreting the findings are duly acknowledged. We gratefully acknowledge the discussion made with Dr. Masroor Fatima, Assistant Professor, at the School of Sciences, MANUU, Hyderabad.

References

Amerasinghe AP, Weckenbrock R, Simmons S, Acharya, Blummel M (2009) An atlas of water quality, health and agronomic risks and benefits associated with “wastewater” irrigated agriculture an atlas of water quality and agronomic risk and benefits associated with "wastewater" irrigated agriculture. A study from the banks of the Musi River, India. Published online: http://www.freidok.uni-freiburg.de/volltexte/6963.

Inala, R. (2025). A Unified Framework for Agentic AI and Data Products: Enhancing Cloud, Big Data, and Machine Learning in Supply Chain, Insurance, Retail, and Manufacturing. *EKSPLORIUM-BULETIN PUSAT TEKNOLOGI BAHAN GALIAN NUKLIR*, *46*(1), 1614-1628.

Biggs T.W and Jiang B. 2009. Soil Salinity and Exchangeable Cations in a Wastewater Irrigated Area, India. *Journal of Environmental Quality* Vol **38**

Biggs T.W., Gaur A., Scott C.A., Thenkabail P., Gangadhara Rao P., Krishna Gumma M., Acharya S. and Turral H. 2007. Closing of the Krishna Basin: Irrigation, Streamflow Depletion and Macroscale Hydrology. *IWMI Research report* 111 p.30.

Meda, R. (2025). AI-Driven Demand and Supply Forecasting Models for Enhanced Sales Performance Management: A Case Study of a Four-Zone Structure in the United States. *Metallurgical and Materials Engineering*, 1480-1500.

Buechler S, Devi G and Raschid L (2002) Livelihoods and wastewater irrigated agriculture along the Musi River in Hyderabad City, Andrha Pradesh India. RUAF Magazine 8: 12.

Buechler S, Devi, G, Devi R (2003) Making a living along the Musi River. Wastewater users in and around Hyderabad City, India. Video.

Sheelam, G. K. (2025). Agentic AI in 6G: Revolutionizing Intelligent Wireless Systems through Advanced Semiconductor Technologies. *Advances in Consumer Research*.

Buechler S, Mekala DG (2005) Local Responses to Water Resource Degradation in India: Groundwater Farmer Innovations and the Reversal of Knowledge Flows. Journal of Environment and Development 14 (4): 410-438.

Buechler S. and Mekala D. G. 2005. Local Responses to Water Resource Degradation in India: Groundwater Farmer Innovations and the Reversal of Knowledge Flows. *Journal of Environment and Development* **14** (4): 410-438.

Kummari, D. N., Challa, S. R., Pamisetty, V., Motamary, S., & Meda, R. (2025). Unifying Temporal Reasoning and Agentic Machine Learning: A Framework for Proactive Fault Detection in Dynamic, Data-Intensive Environments. *Metallurgical and Materials Engineering*, *31*(4), 552-568.

Celio M., Scott C. And Giordano M. 2009. Urban–agricultural water appropriation: the Hyderabad, India case. *The Geographical Journal,* Vol. **175**, No. 3

Coudrain-Ribstein A., Pratx B., Talbi A., and C. Jusserand. 1998. Is the evaporation from phreatic aquifers in arid zones independent of the soil characteristics ? *C.R. Acad. Sci. Paris, Sciences de la Terre et des Planètes* 326: 159-165.

Singireddy, S. (2025, May). AI-Driven Comprehensive Insurance and AAA Membership Benefits Overview. In *2025 2nd International Conference on Research Methodologies in*

Knowledge Management, Artificial Intelligence and Telecommunication Engineering (RMKMATE) (pp. 1-13). IEEE.

CPCB 2009. Status of water supply, wastewater generation and treatment in class-I cities and class-Ii towns of India. Control of urban pollution series: CUPS/70/2009-10.

Balaji Adusupalli. (2025). Integrated Financial Ecosystems: AI-Driven Innovations in Taxation, Insurance, Mortgage Analytics, and Community Investment Through Cloud, Big Data, and Advanced Data Engineering. Journal of Information Systems Engineering and Management, 10(36s), 1103–1117. https://doi.org/10.52783/jisem.v10i36s.6709

Deliverable D 6.2 (2014) Report on case study assessments and feasibility studies, Saph Pani

Dewandel B., Gandolfi J.M., Zaidi F.K., Ahmed S. and Subrahmanyam K. 2007. A decision support tool with variable agroclimatic scenarios for sustainable groundwater management in semi-arid hard-rock areas. *Current Science*, vol. **92**, no. 8

Koppolu, H. K. R., Munnangi, A. S. M., Nayeem, S. M., Ravulapalli, L. T., & Mukkamalla, B. R. (2025). AI-Aided Prioritisation with Physics-Based Validation: MD/MM-PBSA of Antiviral Binding in SARS-CoV-2 and Monkeypox. *Journal of Marketing & Social Research*, *2*, 223-235.

Dewandel, B., Gandolfi, JM., de Condappa, D., Ahmed, S. 2008. An efficient methodology for estimating irrigation return flow coefficients of irrigated crops at watershed and seasonal scales, *Hydrological Processes* 22: 1700–1712

Botlagunta Preethish Nandan. (2024). Semiconductor Process Innovation: Leveraging Big Data for Real-Time Decision-Making. Journal of Computational Analysis and Applications (JoCAAA), 33(08), 4038–4053. Retrieved from https://eudoxuspress.com/index.php/pub/article/view/2737Grattan S.R. 2002. Irrigation water salinity and crop production. *University of California*, Publication No. 8066. pp. 9.

HMWS & SB (2014) Hyderabad Metropolitan Water Supply & Sewerage Board. http://www.hyderabadwater.gov.in/wwo/UI/soruce_info.aspx.

Katta MR (1997) Predatory industrialisation and environmental degradation: a case study of the Musi River. Telangana: Dimensions of Underdevelopment, Centre for Telangana studies, Hyderabad, India. Pp. 203-212

Maréchal J.C., Dewandel B., Ahmed S., Galeazzi L., Zaidi F.K. 2006. Combined estimation of specific yield and natural recharge in a semi-arid groundwater basin with irrigated agriculture. *Journal of Hydrology* **329**, 281– 293.

Maréchal, J.C., Dewandel, B., Subrahmanyam, K., 2004. Use of hydraulic tests at different scales to characterize fracture network properties in the weathered-fractured layer of a hard rock aquifer, *Water Resources Research* 40, W11508: 1-17.

Mariappan Julie (2014) As population surges, Chennai's water needs to double in 3 years. The Times of India (Chennai: The Times Group). Retrieved 9 Aug 2014.http://en.wikipedia.org/wiki/Water_management_in_Chennai

Massuel S., George B., Gaur A., Nune R. 2007. Groundwater Modelling for Sustainable Resource Management in the Musi Catchment, India. Proceedings, *International Congress on Modelling and Simulation*, 10-13 December 2007, Christchurch, New Zealand, p. 1429-1435.

McCartney M., Scott C., Ensink J., Jiang B. and Biggs T. W., 2008. Salinity implications of wastewater irrigation in the Musi River catchment in India. *Cey. J. Sci. (Bio. Sci.)* **37** (1): 49-59.

Pescod M. D. 1992. Wastewater treatment and use in agriculture. *Food and Agricultural Organization*. Rome, Italy.

Praasma, T., Novakowski, K., Kyser, K, Hall, K. 2009. Using stable isotopes and hydraulic head data to investigate groundwater recharge and discharge in a fractured rock aquifer. *Journal of Hydrology* 366: 35-45.

Schmitt, R. 2010. Wastewater reuse in Indian peri-urban agriculture: Assessment of irrigation practices in a small, peri-urban catchment in Hyderabad, Andhra Pradesh, India. *MSc report ETHZ*, Zurich.

Shyamala Rao J (2013) The status of water & sanitation in Hyderabad metro city. ICRIER's Workshop on Water & Sanitation. February 6th, 2013. http://www.icrier.org/pdf/hyd_short_presentation.pdf

Van Roojen D, Turral H, Biggs TW (2005). Sponge city: water balance of mega-city water use and wastewater use in Hyderabad, India. Irrigation and Drainage 54: S81-S91.