Household Food Security and Wastewater-dependent Livelihood Activities Along the Musi River in Andhra Pradesh, India

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This study focuses on landless and smallholder households who use wastewater generated from the twin cities of Hyderabad and Secunderabad in the semi-arid tropics of Andhra Pradesh state for agriculture and the contribution of the wastewater to their food security. Three locations in the urban, peri-urban and rural areas were chosen to get a comprehensive view of wastewater use and users. The study revealed that in the research sites, about 920 hectares of land is irrigated with wastewater and about 48,000 people are directly or indirectly dependent on wastewater for their food security. In the peri-urban and urban areas, the income generated by labor on wastewater irrigated fields and by the sale of produce such as vegetables, para grass, coconut fronds and banana leaves from wastewater-irrigated fields contributes to the household food security of the wastewater users. All of the vegetable producers surveyed retain a part of their produce for their own consumption and the rest is sold. Many of the leafy vegetable producers engage in barter, exchanging part of their produce for other vegetables to add variety to their diet. Vegetable producers in the urban and peri-urban areas save about 20% of household expenditure which they would have had to spend on the purchase of vegetables. Most of the households in the urban and peri-urban area with livestock use wastewater irrigated para grass as fodder and earn income through the sale of the milk. Typically, 25% of the milk produced (assuming a household of 6 members owns one buffalo) is retained for household consumption and 75% is sold. Many of the farmers also grow certain fruits like lemon, mango, coconut and custard apple which they retain for household consumption. In the rural areas, 43% of the total food consumed by a household is wastewater-irrigated paddy. Many of the small farmers in the rural areas used part of their land for vegetable cultivation for household consumption. Migrants who come from drought hit areas work as laborers in the wastewater-irrigated paddy fields and are paid in rice which contributes to their food security. At the end of the harvest season, each laborer carries home about 2 bags or 140 kg of paddy.

Introduction

In a semi-arid area with frequent periods of drought, wastewater is a critical resource for landed and landless households along the Musi river in and around Hyderabad city, Andra Pradesh, India. This wastewater, which is generated daily by a rapidly growing megacity and which flows into the otherwise dry riverbed, supports a wide variety of livelihood activities that require water. The produce procured directly from these activities, the produce received by means of barter and the cash income stemming from the sale of this produce are all utilized to ensure household food security. Migrants also gain access to food and income in these wastewater-irrigated areas. If this water were to be diverted elsewhere, most of the adults living along the Musi river would have to migrate to other irrigated areas. However, with the drought and with overdraft, these ground and surface water irrigated areas have diminished in area in Andhra Pradesh. Therefore, the amount of labor employed in these areas has also been decreasing. This study[1] examined urban, peri-urban and rural areas along the river in order to discover the differences by location in the livelihood activities of the varied social groups utilizing the wastewater. These livelihood activities determined their direct access to food as well as their capacity to purchase food for their household members. Dryland farmers, as rainfed farmers are termed in India, were studied as a point of comparison in order to better assess the benefits for household food security derived from wastewater.

Food Security

How does wastewater aid in achieving household food security in the study area? This was the main question that this study sought to address. First, the question of what food security is must be addressed. Food security has been defined thus:

All people have, at all times, access to and control over sufficient quantities of good quality food for an active, healthy life. Food security is based on a combination of these factors: food availability, food access and food utilization (Oxfam and Novib, 2001:6-7).

Food security is integrally linked to livelihoods. The United Kingdom Government's Department for International Development's (DfID) livelihoods framework has identified five types of capital upon which sustainable livelihoods are based: social, physical, natural, financial, human and political (Moriarty, 2002:4). Unemployment and lack of access to assets such as land and water leads to poverty which in turn leads to food insecurity (N.P. Nawani, 1994:2). This is because poor households have less purchasing power to buy food and they often lack assets such as land and water; therefore they cannot produce their own food either. As stated by Oxfam International and Novib:

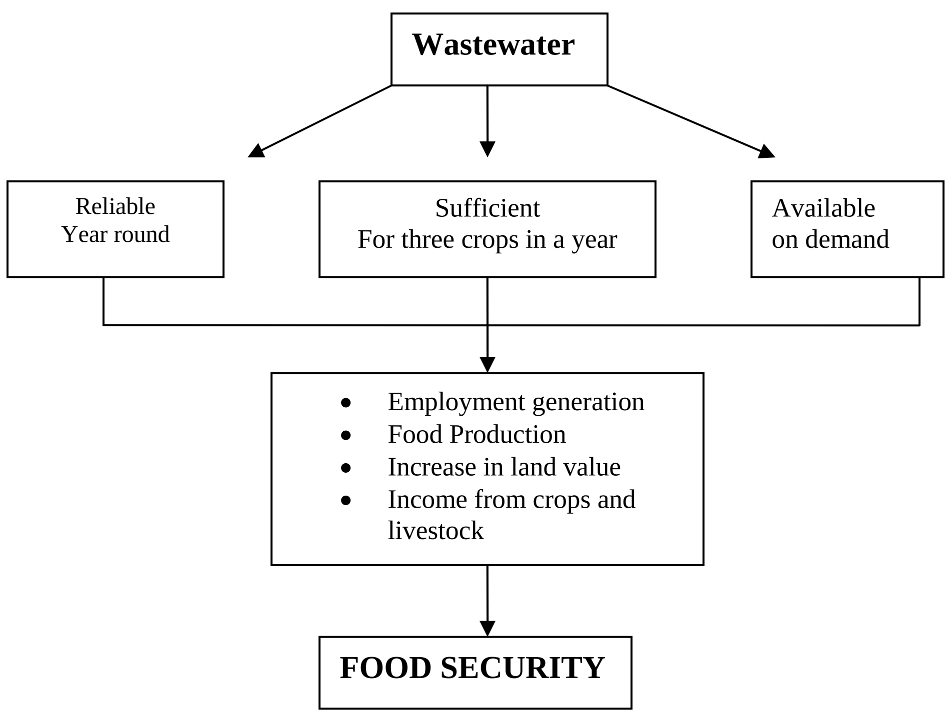
[1] Data collection for this study was undertaken by Stephanie Buechler, Gayathri Devi and Rama Devi of the International Water Management Institute's South Asia office and Umamaheshwar Reddy of Osmania University, Department of Environmental Geology.

The right to food is currently embedded in the right to a sustainable livelihood. A livelihood relates to the capabilities, assets and activities required for a means of living. Food and nutrition are inherent parts of a livelihood. People need not only have enough food all year round, but they need:

- To be healthy and well-nourished to work and care for each other;
- To be educated to participate actively in public life
- Access to natural resources
- Access to jobs and markets to make a living
- Enough support from family and community so that if there are problems, others can be called on for assistance; and
- The income or other resource to survive bad periods, caused by e.g. deaths in the family, unemployment, bad harvest, or collapsing markets (2001:2).

The majority of undernourished people live in Asia (526 million in 1999). FAO projects that by 2010, 70 percent of undernourished people will live in South Asia and Sub-saharan Africa (FAO, 1999). We argue here that wastewater contributes to food security by providing water for livelihood activities that is reliable, sufficient and available on demand. The flowchart in Figure 1 illustrates the manner in which wastewater contributes to food security.

Figure 1: Contribution of Wastewater to Food Security



Site selection, Sampling and Data Collection

The twin cities of Hyderabad and Secunderabad are located in the heart of the Deccan Plateau at 1760 ft. (536 meters) above sea level and receive approximately 700-800 mm of rain during the short monsoon and cyclone season from June-October. The urban area is 178 square km.; however, with the nine surrounding municipalities this area covers 500 square km. The twin cities of Hyderabad and Secunderabad had a population of 3.7 million in 2001, a 17.2 % increase over the population of 1991 making it one of the fastest growing urban areas in India (Handbook of Statistics of Ranga Reddy, 2001:157; www.geohive.com/cd2/in_28.php). With the surrounding nine municipalities, the population in 2001 was 6 million. The population projections for 2011 for the twin cities range from 9.5 to 11.3 million people. The research sites outside of the city were located partly in Rangareddy district, which forms the eastern part of the peri-urban area of Hyderabad. This district has seen phenomenal growth in the past two decades with a population growth rate of 60.32 in 1981-91 and 37.41 from 1991-2001. This reflects the fast-paced expansion of the city. The neighboring district of Nalgonda (where the rural research sites were located) experienced a lower population growth rate than the peri-urban area studied. However, the rural growth rates were similar to those of the urban area with 25.11 percent for 1981-1991 and 13.55 percent for 1991-2001. Currently, 145 million gallons of surface water from the Musi river and the Manjira river and 25 million gallons of groundwater is provided to the cities' inhabitants. More water will have to be delivered to this growing area, which will translate into growing volumes of wastewater produced.

The research sites were located along a 5 km stretch of the river in the urban area as well as in 2 peri-urban areas that were 3 and 5 km downstream of the city and 2 rural areas that were 50 and 60 km downstream of the city located on different sides of the river (see Figure 2). Primary and secondary data were collected for this study. Both quantitative and qualitative research methods were utilized to collect the primary data for this study. Household interviews were conducted to gather information on livelihood activities based on the use of the wastewater and income derived from these activities. A structured questionnaire with primarily open-ended questions was used. Portions of the interviews were taped in order to better reflect the opinions of the wastewater users and follow-up interviews were conducted with all of the respondents. For the larger study on livelihoods, a total of 105 questionnaires were applied to wastewater users (one male and one female member of a household) as well as vendors in urban, peri-urban and rural sites. For this study on household food security, a new questionnaire on income and food expenditure patterns were applied in the urban sites, in the Uppal area that is 5 km away from the city and in the village that is 50 km downstream of the city. We applied the new questionnaires to a sub sample of the respondents who had been interviewed previously, with the breakdown as follows:

12 households (22 respondents) for the urban sites
12 households (30 respondents) for the peri-urban sites
18 households (36 respondents) for the rural sites

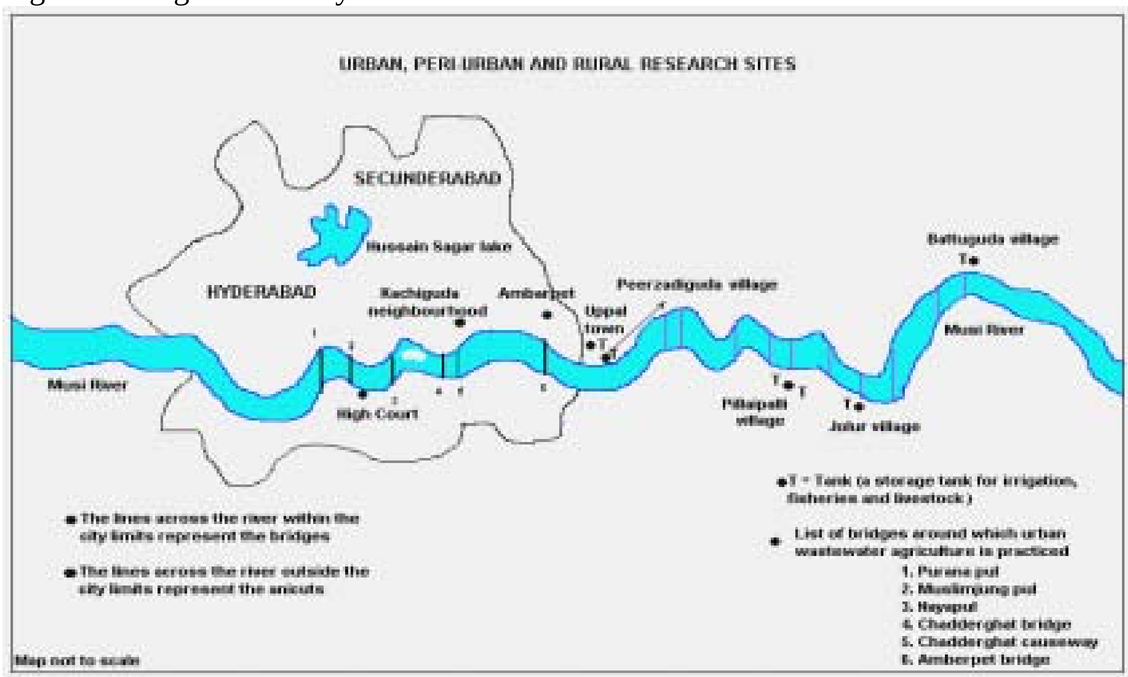
We also applied questionnaires on food security in 13 new households (26 respondents) in the rural site who only own dryland (rainfed land) to get a better sense of the importance of wastewater as a resource in a semi-arid area experiencing a prolonged period of drought.

In the urban locations surveyed, landowners, renters, casual laborers, permanent laborers, and caretakers were interviewed. In the peri-urban site, landowners whose main occupation was agriculture, renters, vegetable vendors and renters with livestock were interviewed. In the rural sites, landowners whose main occupation was agriculture, landless farmers who rent land, dairy producers/farmers, toddy tappers/farmers, fisher-folk/farmers and casual laborers were interviewed.

Water Quality

Pre-monsoon water quality samples from the Musi river were taken at five points in the urban, peri-urban and rural research sites. The samples were sent for physico-chemical analysis and were also tested for heavy metals. One Quality Assured pre-monsoon sample was tested for Bio-chemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Coliform (MPN/100ml), Total Nitrogen (TN), Electrical Conductivity (EC) Total Dissolved Solids (TDS), Chloride, Zinc (ZN), Copper (CU), Chromium (CR), and Lead (Pb). More frequent monitoring needs to be conducted to get a better indication of water quality in each season. Annex II provides the report on the water quality results obtained by IWMI in 2002. The BOD and COD values were quite low for wastewater in Hyderabad along the Musi river. MPN values indicated high levels of faecal contamination, which increased the health risks of the wastewater to farmers and agricultural laborers in direct contact with it. The risk to the consumer is expected to be lower since none of the vegetables grown are consumed raw. However, no quality-assurance tests were done on the vegetables. The EC and TDS values were higher than those recommended by the FAO guidelines. However, since the major crop is para grass which is able to withstand higher salinity conditions, this water may not have a detrimental effect. Total Nitrogen is higher than FAO guidelines but all heavy metals are within safe limits.

Figure 2: Diagram of study sites



Wastewater from Urban Areas

The twin cities have only one sewage treatment plant (STP) with primary and secondary treatment and one STP that only has primary treatment capabilities. In total, these two plants treat 133 mld's (113 mld's receive primary treatment only and 20 mld's receive secondary treatment) of water. The untreated sewage water is estimated at 327 mld's. This means that 23% of the wastewater produced by the city receives primary treatment while only 4% receives secondary treatment before it is disposed in the river Musi. For 2011, the sewage load is estimated to rise from the current 460 mld's to 2,560 mld's due to the population increase and concurrent increased inter-basin transfers of river water to Hyderabad to meet rising water demand (HUDA, Draft Master Plan for 2011). Plans for 3 new and 2 upgraded existing plants aim to treat 630 MLD's by 2006.

There are 12 industrial areas within 30 kms of Hyderabad city that include electro-plating, cooking oil mills, lead extraction/battery units, pharmaceutical, leather, textile, paper, soap and jewelry industries. Two of the industrial estates are located near Uppal, the peri-urban area studied. There are only two Common Effluent Treatment Plants (CETP's) and these are not able to treat the effluents adequately due to the many types of effluents received and to the lack of pre-treatment conducted in the industries. The individual industries that do not bring their effluents to the CETP's illegally discharge their waste into wells, into the Musi directly, or into other water bodies.

Wastewater in the Musi River

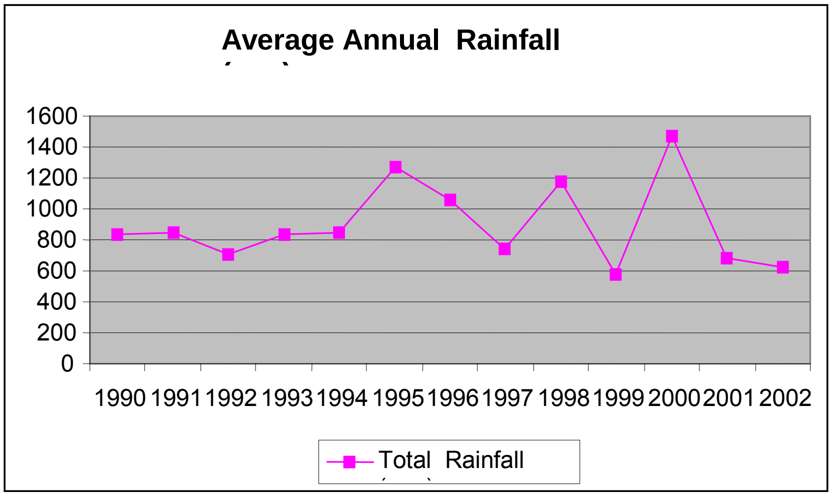
The entire Musi river is located in Andhra Pradesh state. This river originates in the Anantha Giri Hills and flows from West to East across this state. It is a tributary of the Krishna river, a large river that flows out to the Bay of Bengal. The Musi river is used upstream of the twin cities for paddy production and other crops. The remainder flows into a reservoir located upstream of Hyderabad and is used as a drinking water supply for the city. Water from a tributary of the Musi, the Easa river, is also diverted into a reservoir for drinking water, so that there are two reservoirs for the urban area. The Musi river only flows for three months per year during the monsoon season. At Hyderabad, however, the Musi river receives water from the sewage system as well as sewage water that is outside of the purvue of the sewage system. The sewage network only covers 62 per cent of the municipality of Hyderabad. The Musi is now a perennial river due to the year-round inflow of wastewater. The Musi joins the Krishna River in Nalgonda district, a major river that flows out to the Bay of Bengal. However, due to upstream wastewater use, the Musi is usually dry by the time it reaches the Krishna river except when rainfall exceeds normal rates. The area on either side of the Musi downstream of the city is called the Musi belt or 'green belt'.

Wastewater and Livelihood Activities

Urban and peri-urban agriculture is a significant economic activity, central to the lives of tens of millions of people throughout the world. There is ample evidence here and abroad, that the potential of urban agriculture for food security is very real. Only now is its full potential beginning to be tapped. The United Nations Development Program estimates that fifteen percent of food worldwide is grown in cities and this figure could be significantly expanded (Smit et al 1996). Initial estimates by the IWMI Hyderabad wastewater program calculated that approximately 40,600 ha of land are irrigated with this domestic and industrial wastewater that flows from the city and from several points downstream. Of these 40,600 ha, 40,500 ha is irrigated with indirect use of mixed treated and untreated wastewater and approximately 110 ha of land are under direct use of untreated wastewater in the urban area. These figures, of course, only give an indication of the extent of the agriculture that can be practiced because of the wastewater. They do not provide a good indication of the other types of economic activities that depend on the existence of this wastewater. The main reason that wastewater is used for all of the activities is that it is the only water source available except for rainwater during the short and unpredictable monsoon season. Drought conditions have prevailed since 2001 (see Figure 3), therefore dryland agriculture[2] has largely been abandoned in the rural area studied.

[2] The term dryland agriculture is used in India instead of rainfed agriculture. Since it better captures the conditions under which this agriculture is practiced (very little rainfall) we use this term.

Figure 3: Rainfall Pattern, 1990-2002 near Study Sites



Source: Weather Data recorded at ICRISAT, Patancheru, Andhra Pradesh, India

Groundwater levels have also been decreasing in the whole area (see Table 1) due to overdraft and lower rainfall (The Times of India, 18/11/5). There has been a 20-25% reduction in the area under irrigation due to the drought in the state of Andhra Pradesh in 2002 (government planning discussion, Jan. 22, 2002).

Table 1: Groundwater Levels for Andhra Pradesh State, 2001 and 2002

	2001	2002
Average depth of groundwater levels	7.52 meters	10.09 meters
Average rise in water levels during south-west monsoon	4.27 meters	0.96 meters
Number of wells	800,000	2,200,000
Area irrigated with groundwater	1,000,000 ha	2,600,000 ha
Percentage of groundwater exploited	16%	43%

Adapted from The Times of India, Nov. 18, 2002.

Table 1 shows clearly the deteriorating situation with respect to groundwater: low recharge rates, decreasing aquifer levels, with higher rates of groundwater extraction leading to a 27 per cent increase in groundwater exploited in the space of one year. Those who have wells must deepen them at great expense and risk since there is no guarantee that they will be able to actually access the groundwater. Wastewater is the only source of water available for agriculture and other livelihood activities that contribute to household food security in this context.

Livelihoods and Crops in relation to the Wastewater System

All along the Musi river there are men and women who depend on the wastewater for a variety of different activities. In the research sites along the Musi river, water for these activities is available because of the existence of wastewater that flows in the river and is channeled to the fields. This flow in the Musi is perennial due to urban domestic and industrial discharge. The study revealed that in the research sites, about 920 hectares of land is irrigated with wastewater. Livelihood activities based on the availability of water, which in this case is wastewater from the Musi river, vary according to the urban, peri-urban or rural location of the area cultivated. This is due mainly to three factors: 1) the land area available, with the least amount available in the urban areas in the narrow belts of land along the river, and the greatest expanses of land available in the rural areas which is conducive to the production of paddy; 2) the quality of the wastewater; and 3) the proximity to urban markets. Caste/class, gender and religious affiliations of the users also influence the type of wastewater-related activity they become involved in. About 48,000 people are directly or indirectly dependent on wastewater for their food security. Landowners and or/irrigators are only some of the actors who earn and/or save money from these activities. Other actors who derive a benefit from the sale, exchange, barter or retention for household use of various types of agricultural and tree crops as well as livestock, fish and fowl were also studied. These include the landless who rent land with access to wastewater for farming, livestock rearers (who often rent land for fodder production), casual, migrant and permanent laborers, toddy tappers, fishermen, vendors and autorickshaw and truck drivers. These activities contribute to household food security through the income earned, the products derived from and the products bartered for these wastewater related goods and services.

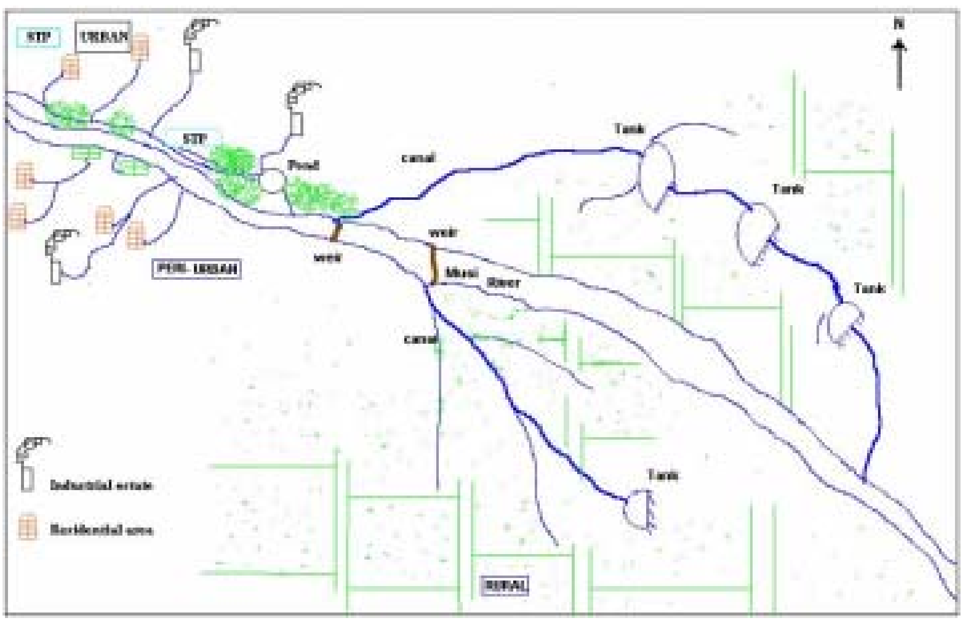
The wastewater channeling and storage methods vary according to location (see Figure 4). Two-thirds of the wastewater from the sewage system is channeled via the sewage system into open sewage drainage canals and into the river or it is discharged directly into the river. In the urban areas, water from the sewage drains empty from spouts in the walls along the city roads into the fields below along the Musi. This wastewater, which is from both domestic and industrial sources (and storm water during the short monsoon season), is channeled to several contiguous plots of land. It sometimes supplemented by water pumped from the river or, less commonly, from shallow wells along the riverbanks. The remaining third of the wastewater is channeled via the sewage system to either of the two treatment plants, depending on the location in the sewage network. Downstream of the primary treatment plant, the water is channeled via a canal and used for agriculture near the treatment plant and also further away to fields in the peri-urban area after it passes through a natural pond where untreated[3] and treated water mix. Most of the area is under fodder grass (para grass) production since fodder grass tolerates higher salinity levels in the water used for irrigation.

Some water reaches the river from the irrigated peri-urban area and some drains from the urban reaches of the river where the drainage canals flow into the river. Wastewater in

[3] There is a diversion canal that diverts much of the wastewater around the primary treatment plant since the capacity of the plant is only 113 mld.

the river is diverted via weirs (or anicuts as they are termed in India) on both sides of the river to main canals which feed branch canals. The water reaches the fields via different channeling methods. One method is direct irrigation from the branch canals or main canals to the fields. Another method, utilized for areas located at elevations that are higher than the river, is where the water is pumped from the branch canals into underground pipes and later directed to smaller channels that go to the fields. In other cases, the river water is directly pumped from the river to fields close to the riverbanks. In still other cases, the water from the weirs is channeled to tanks of varying sizes where it is stored for irrigation then channeled to fields near the tank. Some villages have only one tank and others have several. Some of the tanks are interconnected and are termed link tanks. These link tanks are commonly shared by two or more villages. Many tanks in this Musi belt have water year-round now due to this wastewater. See Figure 4 below on channeling methods.

Figure 4: Channeling methods in urban, peri-urban and rural areas along the Musi river



Urban Livelihoods and Food Security

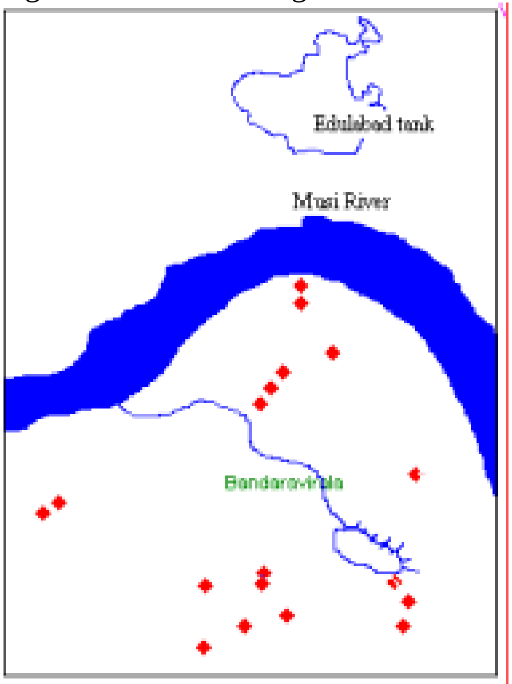
Wastewater in urban areas is used by approximately 250 households for agriculture on a total of about 100 ha of land in the urban area along the Musi river. Most of the urban agriculture is practiced along a 5 km-stretch of the river in the city from the Purana pul bridge to the Amberpet bridge (see Figure 2). Approximately 2500 people depend directly or indirectly on wastewater for their livelihoods and food security. It is a green area within a busy area of the Old City and helps to improve air quality.

Figure 2: Sampling wells (1S—33S), streams, tanks, and Musi River Source: Ludmilla

<<INSERT MAP HERE >>

Aristilde, Berkeley University, IWMI consultant

Figure 3: Locations of groundwater sampling in Bandiravirala, a peri-urban research site



IWMI, S. Asia office

Table 7: Summary of groundwater quality results

Parameters	Korremula (4S)
Electrical conductivity (ds/m)	2.1
Total dissolved solids (mg/l)	1406.00
Chloride (mg/l)	
Nitrate (mg/l)	87.00

Table 8: Heavy Metals and Groundwater Quality results of Bandaravirala Village:

ID No	Location of the field	A1	B	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
2	Next to wastewater canal	nil	0.083	nil	0.003	Nil	0.002	nil	0.143	0.003	nil	0.004
3	Next to wastewater canal	0.008	0.062	0.002	0.005	0.001	0.002	nil	.007	.002	nil	0.004
4	Adjacent to wastewater canal	0.229	0.138	0.004	0.004	Nil	0.006	0.162	0.035	0.009	nil	0.004
6	½ km away from ww canal	nil	0.004	0.001	0.001	Nil	0.002	nil	.001	nil	nil	0.003
20	1 km away from wastewater fed tank	nil	0.105	0.001	0.005	0.001	0.002	nil	0.077	0.008	0.010	nil
21	1 km from wastewater fed tank	0.009	0.038	nil	0.009	nil	0.001	nil	0.011	0.005	nil	0.322
22	Adjacent to wastewater fed tank	nil	0.028	nil	0.002	nil	0.004	0.001	0.001	nil	nil	.083
31	½ km from wastewater fed tank	nil	0.135	Nil	nil	0.001	0.002	0.010	0.170	nil	0.005	0.061

Note: ■ Indicates concentration levels higher than those prescribed by WHO for drinking water
■ Indicates concentration levels equal to those prescribed by WHO for drinking water

According to WHO standards for drinking water, Bandaravirala water sample results (see table 8) show that aluminium and boron levels are above the standards in one of the borewells making it unfit for drinking. The nickel and lead concentrations in two of the sites are just equal to the standards and any increase in their levels would make the water unfit for drinking. The concentrations of the other elements are within the limits prescribed by the WHO. Comparing the data with the standards prescribed by the FAO, it was found that the concentrations of all the elements are within the limits posing no threat to the quality or quantity of the crop yields.

Table 8a: Non-metal Results of Groundwater Quality results of Bandaravirala Village:

Parameter	ID No 2	ID No 3	ID No 4	ID No 6	IS:10500 Safety Requirements for Drinking water
1. pH	7.05	7.03	7.13	7.72	6.5 to 8.5
2. EC (micro mhos cm^{-1})	2190	1350	2180	1640	-
3. Total Dissolved Solid (mg L^{-1})	1460	890	1440	1082	upto 500
4. Alkalinity to Phenolphthalein as $CaCO_3$ (mg L^{-1})	NIL	NIL	NIL	NIL	-
5. Alkalinity to methyl orange as $CaCo_3$ (mg L^{-1})	380	320	325	382	-
6 Total Hardness as $CaCo_3$(mg L^{-1})	605	550	762	350	Up to 300
7. Chloride as CI (mg L^{-1})	401	206	440	256	Up to 250
8. Sulphate as SO_4 (mg L^{-1})	120	38	115	19	Up to 150
9. Nitrate as NO_3 (mg L^{-1})	33	13	13	59	Up to 45
10. Fluoride as F (mg L^{-1})	-	-	-	-	0.6 to 1.2
11. Total phosphate as P (mg L^{-1})	0.2	NIL	0.1	NIL	-
12. Calcium as Ca (mg L^{-1})	177	135	210	80	Up to 75
13. Magnesium as Mg (mg L^{-1})	39	51	57	36	Up to 30
14. Potassium as K (mg L^{-1})	1	1	1	15	-
15. Sodium as Na (mg L^{-1})	230	68	151	197	-

Note: ID No = Identification Number

Table 8b: Water Quality results of Bandaravirala Village:

Parameter	ID No 20	ID No 21	ID No 22	ID No 23	IS:10500 Safety Requirements for Drinking water
1. pH	7.02	7.26	7.27	7.10	6.5 to 8.5
2. EC (micro mhos cm^{-1})	2180	1450	780	2140	-
3. Total Dissolved Solid (mg L^{-1})	1435	955	515	1412	upto 500
4. Alkalinity to Phenolphthalein as $CaCO_3$ (mg L^{-1})	NIL	NIL	NIL	NIL	-
5. Alkalinity to methyl orange as $CaCo_3$ (mg L^{-1})	375	360	295	490	-
6 Total Hardness as $CaCo_3$(mg L^{-1})	602	591	306	514	Up to 300
7. Chloride as CI (mg L^{-1})	419	224	66	350	Up to 250
8. Sulphate as SO_4 (mg L^{-1})	115	38	NIL	91	Up to 150
9. Nitrate as NO_3 (mg L^{-1})	12	19	6	7	Up to 45
10. Fluoride as F (mg L^{-1})	-	-	-	-	0.6 to 1.2
11. Total phosphate as P (mg L^{-1})	0.2	0.1	NIL	0.2	-
12. Calcium as Ca (mg L^{-1})	465	400	210	310	Up to 75
13. Magnesium as Mg (mg L^{-1})	33	46	23	49	Up to 30
14. Potassium as K (mg L^{-1})	1	1	1	1	-
15. SODUM as Na (mg L^{-1})	228	62	44	265	

Note: ID No = Identification Number
IWMI S. Asia office: Jeroen Ensink

The EC and TDS levels in all the groundwater samples in Bandaravirala were found to be higher than the prescribed WHO levels thus making the water unfit for drinking. The nitrate and chloride levels were also found to be in higher concentrations than FAO guidelines would permit restricting its use in agriculture.

Impact on Cropping Patterns

More than 90 % of the farmers in the peri-urban areas irrigating with wastewater have shifted from growing paddy to para grass. Farmers using groundwater are still growing paddy but said that their paddy yields have fallen. The salinity level of the water indicated by the electrical conductivity and total dissolved salts shows that the water is not suitable for the cultivation of paddy; the electrical conductivity of 2.7 and 2.5 dS/m from the Musi water in Korremula could cause up to a 25 % reduction (Ayers, 1985) in the paddy yield. Farmers interviewed in Pirzadiguda have observed a 50% reduction in the yield of the paddy when they used the Musi River. However, most grasses and forage crops have higher tolerance to salinity than paddy (Aristilde, 2002). For instance, wheat-grass, Bermuda grass, barley, and ryegrass could still have 90% yield potential with irrigation water having an electrical conductivity up to 5.0 ds/m (Ayers, 1985). In the present research areas, 90% of the farmers were mainly growing para grass, which is used as a fodder grass.

The highest concentrations of total dissolved solids and chloride were found in wells situated along the Musi River where the Musi is extensively used for irrigation (see Figures 3 and 4). However the higher concentrations of nitrates correspond with wells located near wastewater-fed tanks (see Figure 5). Pirzadiguda had the highest concentration of chemicals among all the villages. Pirzadiguda village is located right next to Pirzadiguda Lake, which received urban sewage and domestic wastewater until 3 years ago. Currently, only sewage water from the village goes into the lake. Wastewater-irrigated fields surround the village, and there is a wastewater-fed canal, which flows about 500m west of the village. The Musi River also flows about 500m south of the village. As you move downstream, the river quality improves and the groundwater quality along the river also improves. Korremula located 4 km downstream of Pirzadiguda is about 3 times less salty than Pirzadiguda in terms of electrical conductivity (Aristilde, 2002).

The concentration of TDS suitable for drinking water is 500 mg/L. This level is exceeded across most of the Mandal with higher concentrations found along the Musi River (see Figure 3).

Figure 3: Concentration of total dissolved solids (TDS) across Ghatkesar Mandal.

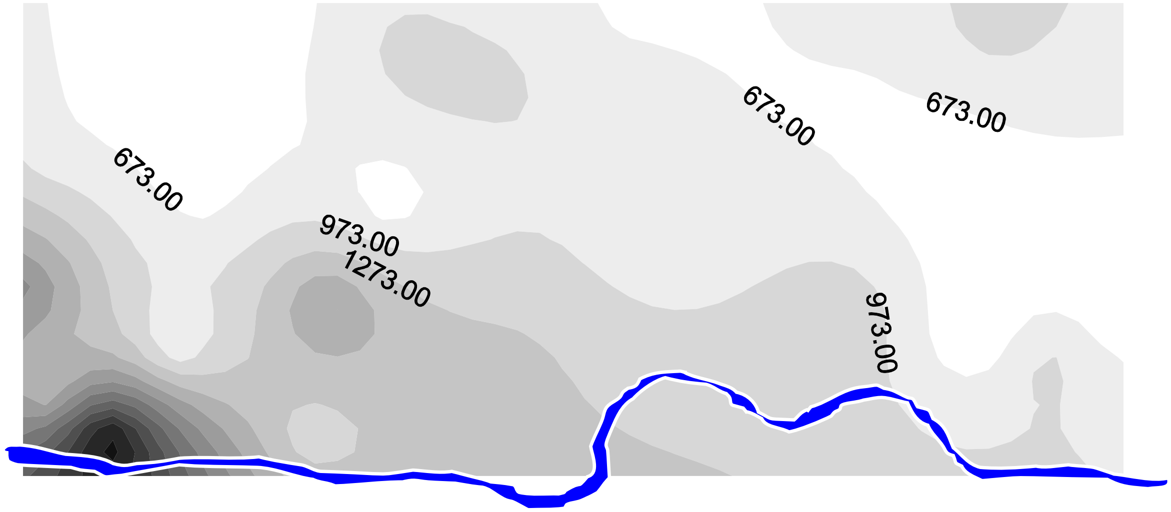


Figure 4 shows the concentration of Chloride in mg/l across Ghatkesar Mandal. Higher concentrations of Chloride are found along the Musi River. The safety requirement for drinking water is 250 mg/L. The well water of most of the villages along the river exceeds that concentration.

Figure 4: Concentration of Chloride in mg/l across Ghatkesar Mandal.

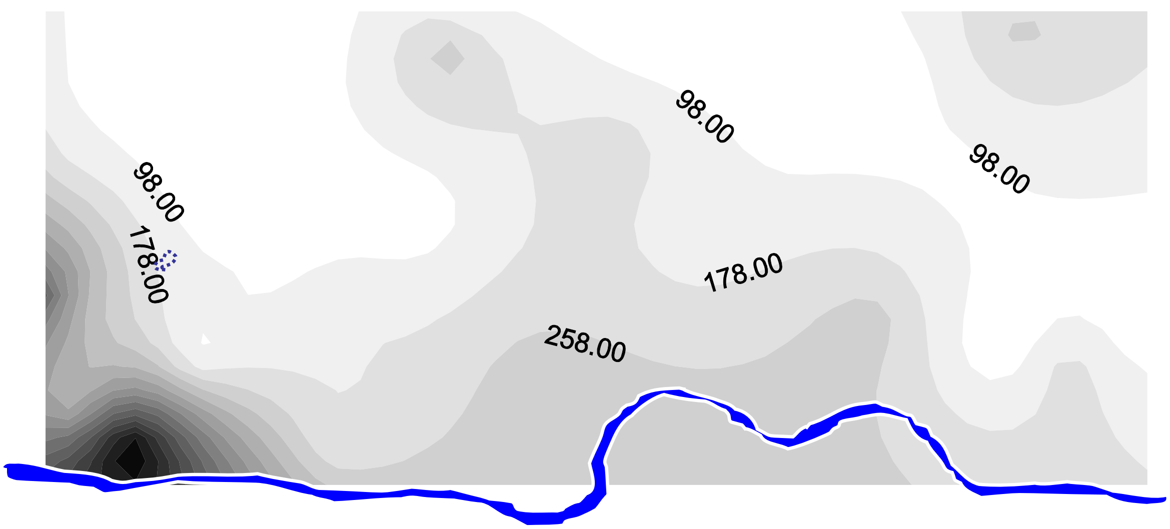
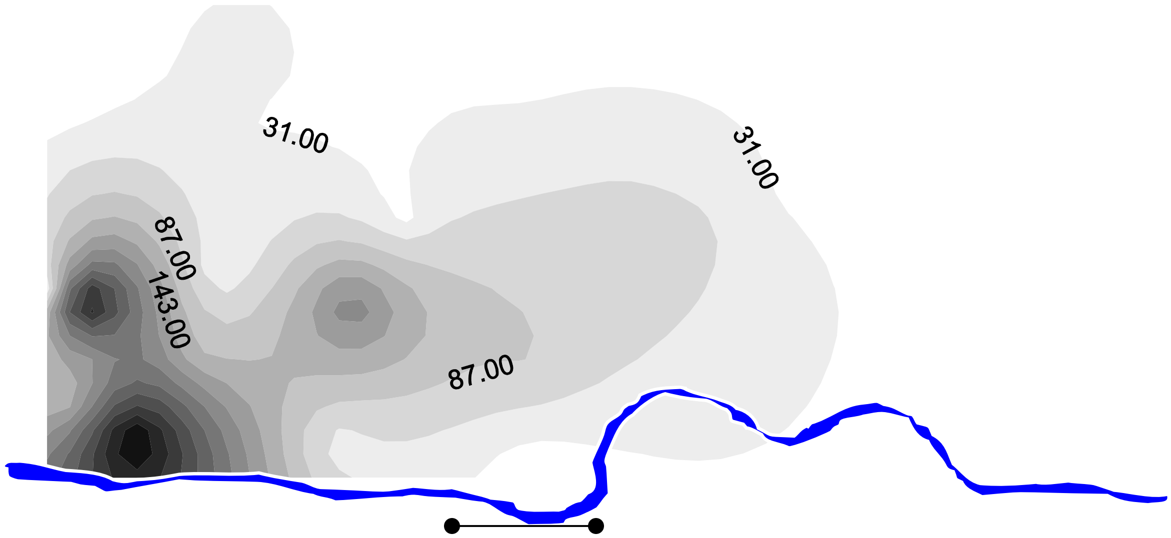


Figure 5 shows nitrate concentration across Ghatkesar Mandal. Higher concentrations were found near wastewater-fed tanks. The desirable limit for drinking water is 45 mg/L. The wells located closer to the urban areas and next to wastewater-fed tanks do not meet that limit (see figure 3 for location of tanks).

Figure 5: Nitrate concentration across Ghatkesar Mandal.



Figures 3,4,5: Aristilde, 2002.

Summary of water quality results

Aristilde has summarized the results of the groundwater quality tests and has made the following recommendations.

- Salinity levels in the irrigation water from the Musi River are not suitable for 100% yield potential of paddy. Fodder grasses are more tolerant to salinity levels but are worth much less than rice. Chloride toxicity was observed only in cases of direct-leaf absorption.
- Higher concentration of nitrates, total dissolved solids, and chloride in the groundwater were found near wastewater-irrigated fields (along Musi River) and wastewater-fed tanks.
- From interviews conducted in the villages, many villagers informed us that they get sick as a result of drinking the local well water. Some of the complaints were joint pains, stomachaches, and nausea. Further study needs to be done to determine the correlation between the quality of the water and health impacts.

Recommendations

- The wastewater could continue to be very beneficial to paddy farmers if the salinity levels do not increase too high. Implementation of policies that could regulate the effluent quality of the wastewater into the river and irrigation tanks would help improve and regulate the quality of the water.
- These policies should also include the use of the wastewater that contains high concentrations of salts for less water-intensive crops such as forage crops. This would decrease the amount of salt constituents that reach the groundwater.
- Where possible, farmers should be encouraged to cultivate crops that are more tolerant to salinity levels, nitrate, and chloride than paddy. Some of the crops that

could be recommended, in addition to the mentioned forage crops, are sorghum, cotton, and soybean.

- Adequate drinking water needs to be provided to the villages with contaminated groundwater where the water is no longer potable due the high concentration levels of chemicals (Aristilde, 2002).

Depths of Wells and Groundwater levels in the Research Sites and Effects of Wastewater on Levels and Livelihood Strategies

In all the study sites, the groundwater levels were measured and the average depths are indicated in table 9.

Table 9: Depth of the wells and the groundwater levels

Location	**Depth of wells (feet)**	**Depth at which groundwater is available (feet)**
Pirzadiguda	30	20-50
Korremula	102	20-50
Edulabad	153	50-80
Banda Ravirala	172	50-100
Pillaipalli	117	50-100

It can be seen that groundwater levels are lower in the wells further away from the city. However, groundwater levels depend on other factors like the distance from wastewater fed tank/river/canal, amount of rainfall received, topography of the land and hydro geological characteristics of the region.

Wastewater recharge of groundwater varies by elevation and location of the borewells or open wells with respect to the canals/tanks. The groundwater levels of farmers whose land is lower than the wastewater fed tank or canal are rising due to the constant recharge from wastewater. A farmer with 2 ha of land who uses groundwater explains:

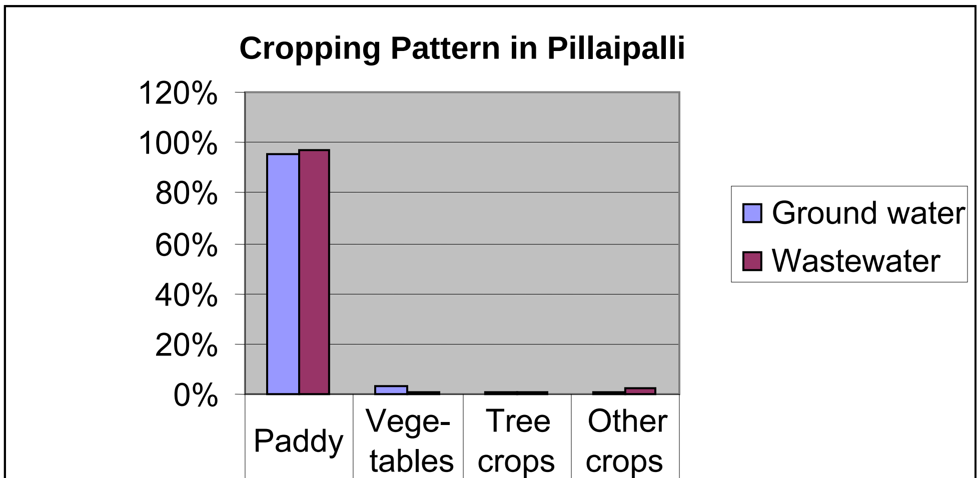
> Our borewell is next to the Musi fed tank. Wastewater is also available in more quantity as a result our borewells are also recharged. The quality of water has also changed due wastewater. As our borewell is next to the wastewater fed tank, the borewell is recharged and filtered to some extent. Hence the water levels in our borewells have increased. But if the water is stored for a day the color of the water changes to green.

The groundwater levels of farmers whose land is higher than the wastewater fed tank or canal have decreased with drought conditions in the state of Andhra Pradesh (see Annex A) although the drop in the water levels has not been as rapid as those in areas without wastewater irrigation. A farmer with 1.6 ha of land cultivating paddy and vegetables (50:50) using groundwater responded: “Our well is near the Musi tank, so water is recharged into our well but it is sufficient to cultivate only 1.6 ha of our land and 3.2 ha are barren”.

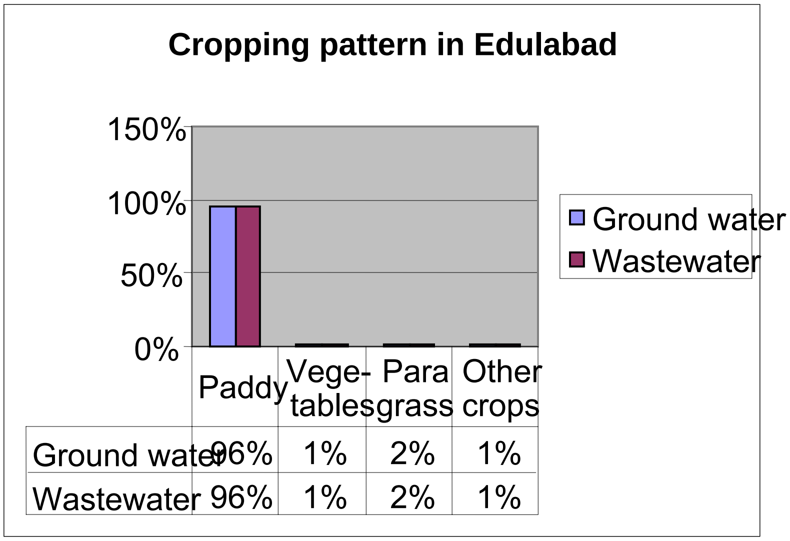
Wastewater irrigation has improved the situation for groundwater farmers but has not been able to fully compensate for the generalized falling water table levels in the area that are due mainly to drought and over-extraction.

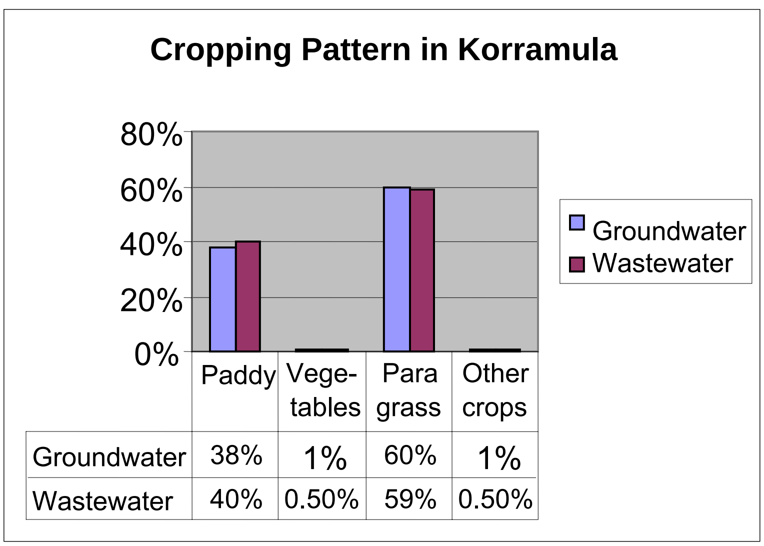
Cropping patterns across the users

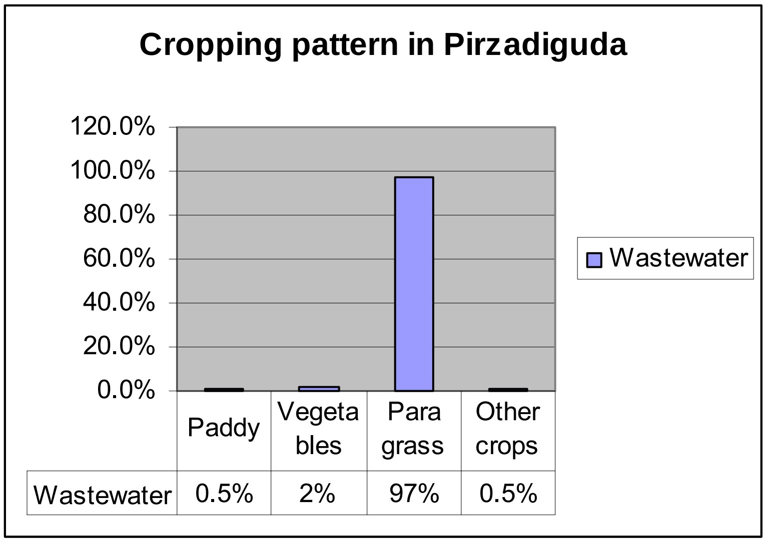
The study results show the following cropping patterns at the different research sites. The following charts show the percentage of available groundwater and wastewater use for various crops.



	Paddy	Vege-tables	Tree crops	Other crops
Ground water	95%	3%	1%	1%
Wastewater	97%	0.50%	0.50%	2%


Cropping pattern in Edulabad
150%
100%
50%
0%
Ground water
Wastewater
Paddy
Vege-tables
Para grass
Other crops
Ground water 96% 1% 2% 1%
Wastewater 96% 1% 2% 1%


Cropping Pattern in Korramula
80%
60%
40%
20%
0%
Groundwater
Wastewater
Paddy
Vege-tables
Para grass
Other crops
Groundwater 38% 1% 60% 1%
Wastewater 40% 0.50% 59% 0.50%



In Pirzadiguda, the groundwater was not being used for irrigation of any crop due to the abundance of wastewater. In this area groundwater was used by people mainly for household activities like washing clothes, cleaning house and utensils and for all livestock related activities like cleaning the buffalo sheds, bathing them and watering the buffaloes.

In Pillaipalli, which is 40 km downstream of the urban area, the wastewater quality was found to be suitable for economically viable paddy cultivation. In Pirzadiguda, which is 10 km from the city, the groundwater and wastewater quality is unfit for cultivation of paddy and hence farmers have started growing para grass instead of paddy. In all the research sites, vegetable cultivation is low as it is labor intensive and also requires more investment and has high risk in terms of shelf life of the produce and high elasticity of demand.

The major crop grown with wastewater and/or groundwater in all the research sites is paddy. Most of the farmers grow two crops of paddy [monsoon season and winter] per year. Even though the paddy yields have decreased over the years with the deteriorating water quality, farmers prefer paddy over other crops because of the following reasons:

- **Demand for rice and easy marketability:** Paddy has demand round the year since the staple food of people in this region is rice. Government announces farm gate prices for paddy. Farmers need not worry if they could not sell their produce in the open market, they could always sell it to the Government. Farmers need not worry about taking the produce to the market as rice mill owners and other contractors buy the produce right at the field level.
- **Labor requirement:** Labor required for paddy is much less compared to other crops like vegetables.
- **Contribution to food security:** About 43 % of the total household food consumption is wastewater and/or groundwater irrigated paddy
- **Only crop that can be grown:** In certain areas near the wastewater fed tanks / canal, where the soil never dries up completely, paddy is the only crop that can be grown properly.

Management practices of the paddy farmers

The study results showed some marked differences between the wastewater irrigated paddy and groundwater irrigated paddy. These differences are the result of the innovative management practices of the farmers to mitigate the ill effects of the wastewater on the crop yields and quality of the grain. The differences have been presented in Table 10.

Table 10: Differences in the wastewater irrigated and groundwater irrigated paddy

S. No	Attribute	Wastewater irrigated paddy	Groundwater irrigated Paddy
a	Spacing between two transplanted seedlings	60 x 60 cm	30 x 30 cm
b	Amount paid for transplanting (Rs 45 = 1$)	Rs 240 per ha	Rs 280 per ha
c	Yields (kg paddy per acre)	4,000-5,000 kg per ha (65 kg per bag)	4,500-7,000 kg per ha
d	Quality of grain	Poorer quality (lower grain weight due to improper grain filling and low shelf life of cooked rice)	Good grain formation and good shelf life
e	Varieties	BPT (Rs. 5 higher per kg), 1010, 1001, IR 64	BPT (Rs. 5 higher per kg), 1010, 1001, IR 64, Hamsa
f	Expenditure on fertilizer	None	Rs. 6,250 per ha
g	Problems	More pest attacks of stem borer, lower yields, deteriorating soil structure, skin irritation, gw contamination	Power fluctuations burn pumps, power supply limits, salinity of water, seedlings lost in nursery due to salinity, higher input cost
h	Benefits	Sufficient water so greater area brought under irrigation, ensures food security and provides employment to migrant laborers	Higher yields, better quality produce, more varieties could be grown, no skin problems, better price

a. In wastewater irrigated paddy, the seedlings are planted with at a wider spacing (60 x 60 cm) compared to the groundwater irrigated paddy (30 x 30 cm) as wastewater is very nutrient rich leading to more profuse tillering and vegetative growth. This extra space accommodates the extra growth triggered by high nutrient content of wastewater, increases aeration between plants and reduces disease/pest transmission from one plant to the other.

b. Transplanting of paddy is contracted out by the farmers to a group of laborers. The spacing between the plants is higher for the wastewater irrigated paddy than groundwater irrigated paddy so the time and effort required for planting is also lower. Hence, the amount of money paid for transplanting in case of wastewater irrigated paddy is lower (by Rs 100) than groundwater irrigated paddy.

c. The yields of paddy are lower (by 500 to 2000 kg per ha) in wastewater irrigated paddy than the groundwater irrigated paddy because of higher pest attacks and poor grain formation.

d. The quality of grain in the wastewater irrigated paddy is poorer and has lower shelf life compared to groundwater irrigated paddy. In the words of one of our respondents,

> The rice irrigated with wastewater when cooked in the morning, becomes mushy by evening and we can't eat it, whereas the rice irrigated with groundwater remains in tact and can still be consumed the next day morning

e. Except Hamsa variety of paddy, the varieties grown with wastewater and groundwater are common. Hamsa, which is a tall growing variety, cannot be cultivated with wastewater as it grows so tall when irrigated with the nutrient rich wastewater that it topples over and causes crop loss.

f. The wastewater farmers can grow paddy without applying any fertilizer as the nutrients in wastewater are considered to be sufficient for the crop. Therefore, they save up to Rs. 6,250 (1$ = Rs. 45 according to current rates) per ha.

g. There are a number of problems with wastewater irrigation. Most of the groundwater in and around the wastewater canal/river/tank/irrigated land is polluted rendering it unfit for human and animal consumption. The excess chemicals in the wastewater have over the years harmed the soil structure and cause skin irritations to the people who come in contact with it. The fish population in the wastewater fed tanks is nil or very low affecting the livelihood of the fishermen community. The yield and quality of wastewater irrigated paddy has also come down. The other long term impacts of this untreated wastewater use for irrigation are not yet clear. It has bee seen that the salinity of the groundwater in the wastewater irrigated areas has increased causing crop losses at the nursery stage. The other disadvantages of groundwater use compared to wastewater use are that, it involves higher costs – for digging the borewell, well maintenance, motor maintenance, and electricity. Power fluctuations burn out pumps and limited power supply (6 hrs. per day) causes, according to farmers, insufficient amount of time to pump and irrigateGreater volumes of wastewater are available now from the growing city and farmers are able to sometimes access it via gravity fed systems thus saving on power.

h. One important advantage of wastewater is that it is available round the year, highly reliable irrespective of delayed monsoons and droughts and also with increasing volumes more land could be brought under cultivation. It not only ensures food security for the farmers but also provides employment for many migrant laborers from drought prone districts. Our study on the nutrient uptake and household expenditure on food showed that wastewater irrigated paddy contributes 43% of the household expenditure on food. Groundwater farmers do not face any of the problems associated with wastewater and in addition get good paddy yields both quality and quantity wise. Groundwater irrigated paddy also fetches Rs 20-30 more per quintal compared to wastewater irrigated paddy.

Innovative management practices of groundwater paddy farmers in wastewater irrigated areas

- Pumping from a wastewater fed canal or tank into an open well: **In Korremula, 25 households have fields that are located on elevations that are higher than the canal is on a lower elevation and their fields are on a higher elevation and the well is on the higher elevation in the field. They installed underground pipes from the canal into their wells such that the well is gravity-fed with the wastewater and from that well they pump the water into their fields. Open well has some water in it from seepage and the quality is no better than that in the canal. Five years ago they began doing this because the amount of water in the canal increased. Also, it takes time for the open well to recharge often more than 2 days so its faster to recharge with wastewater. Twenty-five households do this on 1.2 ha of land or 30.35 ha total.**

A 65 year old widowed woman from Korremala owns 1.2 ha of land and diverts water from the wastewater canal to her open well via underground pipes and then pumps the water to her fields. These pipes were installed in 1997. For her five cows and four buffaloes and two bullocks for plowing their land, she uses a handpump to obtain groundwater. She retains one liter of milk for household consumption. Her income from selling the milk is Rs. 26,000 per year. Before 1997, she used to cultivate vegetables with the groundwater in the open well but then she found that the vegetables got many pest infestations, the roots were rotting, the leaves showed signs of burns and the leaves curled. She told us:

People whose fields are at a higher elevation than the wastewater-fed canal divert water from the canal into open wells through an underground pipe and from the well water is pumped into paddy fields for irrigation. Farmers adopted this practice five years ago when they saw that there was plenty of water flowing in the canal and all of the farmers on the lower elevations to the canal were happily tapping it and bringing more and more land under cultivation. So we also wanted to utilize this water and grow paddy in our fields. So we adopted this practice and are now able to grow two crops of paddy per year.

- **Mixing wastewater with groundwater for irrigation:** The farmers of Bandaravirala village observed the deteriorating water quality of both GW and WW for the past 5 years and their consequent negative impact on crop yields. Hence to avoid the risks and attain maximum benefits nearly 60 farmers in the village are irrigating paddy with a mix of wastewater and groundwater. As a result their paddy yields have increased by 25 to 30 percent. This has also improved the quality of grain by mitigating the ill effects of both wastewater (excess nutrients and other chemicals) and groundwater (high salinity). The only constraint in adopting this practice is the ability of the farmer to access both wastewater and groundwater.
- **Alternate use of wastewater and groundwater for paddy irrigation:** Some of the innovative farmers have experimented by using different water during different times of the crop stage. Five years ago farmers began engaging in this practice when wastewater quality started to become noticeably worse and yield reductions were substantial. Table 11 shows the water used for each stage of cultivation/crop.

Table 11: Water used during different crop growth stages

Stagewise	**Source of water used for irrigation**
Preparatory cultivation	Waste water
Sowing	Groundwater
Transplanting and weeding	Wastewater
Grain formation and milking stage	Groundwater

According to a farmer in Bandiravirala who owns 2 ha of land, alternating the use of wastewater and groundwater by stage for paddy has proven very beneficial. He says:

> Initially for ploughing we use wastewater. After ploughing, at 30 to 40 days, we use wastewater lifted from the Musi canal. After that, we use borewell water. Wastewater contains more nitrogen content which is most suitable for vegetative growth of the plant. There is a chance of pest attack on the crop (fire blast or *aggitegulu)* with wastewater irrigation but with borewell water the pest attacks are very minimal. Pest attack are controlled by alternating both sources of water. Groundwater is of good quality and there are no ill effects from using it.

This new practice has increased the yields of the farmers by 20% to 25%. Again, the main constraint in the adoption of this practice is the ability of the farmer to access both wastewater and groundwater. Approximately 8 farmers in Bandaravirala village have adopted this management practice.

In other cases, farmers use wastewater on some of the plots and groundwater on others. A farmer from Bandiravirala who is the owner of 2.4 ha of land cultivates paddy on separate plots of land with different sources of water: .8 ha with wastewater and .4 ha with groundwater and he also plants eggplant and tomatoes with groundwater on 1.2 ha.

> The paddy crop is very badly affected by the Musi wastewater. So we have gone for a borewell. But borewell water is not sufficient so we are using wastewater also to irrigate our fields. We are retaining the paddy grown with groundwater for ourselves and selling the paddy grown with wastewater. That is the reason why I am not mixing both of the sources.

In Pillaipalli, a 35 year old man grows paddy on .4 ha with tank wastewater and paddy on .4 ha with groundwater and tomatoes and mustard on .04 ha with groundwater for household consumption. He explains the benefits of both and also the benefits of having his borewell close to the tank:

> Tank water [wastewater fed] causes certain health problems in wastewater irrigated fields and the pest attacks are higher, but under well irrigation the grain quality and weight is higher also there is a price differential of Rs. 20 to Rs. 30 per quintal between wastewater and groundwater irrigated paddy with groundwater fetching a higher price. Since this year [July 2002-July 2003] there were less rains the inflow of water from the canal into the tank was less also the water in the wells is also lower. But otherwise we have water throughout the year both in the tank and the wells. Since six years ago we have water throughout the year, before six years whenever there were not enough rains the fields used to go dry. Fifteen years ago the tank would always go dry in the months of April and May so we dug a borewell. But since 15 years the tank has never gone dry. Now we feel that we have unnecessarily invested in a borewell. Since our borewell is next to a tank the water is reliable: both wastewater and groundwater. Our groundwater is sufficient for two crops per year and wastewater is sufficient for three crops but we grow only two paddy crops [6

months in monsoon and 4 months for the winter crop] since there is no time for a third crop.

In addition to paddy, the other crops grown with groundwater and/or wastewater are paragrass, guinea grass, mango orchards and vegetables like gourds, cucumbers, roselle, okra, chillies, tomatoes, egg plant, french beans, spinach, hibiscus, coriander, amaranthus and mint. Certain flowers like jasmines and crosandra are also grown with wastewater.

A farmer in Edulabad is the owner of 2 ha of groundwater irrigated land on which he grows .8 ha of vegetables and 1.2 ha of paddy.

> Our borewell is next to the Musi fed tank. Wastewater is available in more quantity and as a result our borewells are also recharged. The quality of water has also changed due to wastewater. Since our borewell is next to the tank, water is recharged and filtered to some extent. But if the water is stored for a day the color of the borewell water changes to green. Crop yields of the vegetables and paddy are also reduced due to the poor quality of the water.

Three mango orchards have also been seen in the research sites irrigated with groundwater in close proximity to the wastewater irrigated areas. The farmers of these orchards gave the following reasons for the preference of this crop:

- Demand and market availability: There is a good demand for this fruit and because these areas are close to the city, transportation is also very easy.
- The red soils in this area which drain very well are most suitable for growing mangoes.
- A bumper crop would give huge profits to the farmer

The trees are irrigated by a drip system throughout the year, except from the flowering to the end of the fruiting season when they are irrigated by round pit irrigation. However, only large farmers (owning land of more than 6 ha) can afford to have an orchard as the gestation period for the crop to come to fruiting is 5 years and any loss in yield which could be caused by hail storms, excess heat during the summer, disease or pest attack, would mean huge losses to the farmer. The risk-bearing capacity of the farmer needs to be very high in order to be able to engage in orchard production.

A 50 year old farmer in Edulabad village has a mango and guava orchard on 4.5 ha of land. He is also experimenting by growing grass for lawns on 1.2 ha of land. He uses groundwater for irrigation. The field and borewell is very close to the wastewater-fed tank. He feels that:

> The groundwater has become saline in the last 5 years due to the wastewater. We have not seen any difference in the guavas until now, whereas in mango, there is a dropping of the flowers and young fruit and rotting of the area around the stem. This is due to the pollution of the groundwater with the wastewater. But in the case of the lawn grass we saw that attacks by termites but when we used wastewater it was not affected by termites. But since the wastewater fed field is far away from our house, now I am growing grass in a field near my house and irrigating with groundwater. We have just started this lawn grass and it will take some time to see what the effects will be and we put gamoxin insecticide [a banned insecticide] on it.

Para grass (a kind of fodder grass) irrigated with groundwater is not economically viable and hence, it is grown normally only with wastewater. Para grass is still mainly cultivated in the urban and peri-urban areas, however its cultivation is now on the increase in the rural areas. With increasing demand for milk by the urban population (and for household consumption of the dairy producers), the demand for fodder grass is also increasing and many farmers are trying to tap wastewater to grow para grass as it grows extremely well with the nutrient rich wastewater and at the same time can tolerate the high salinity of the wastewater. With increasing wastewater irrigated areas, however, more and more groundwater is getting polluted.

A 37 year old farmer with .8 ha of land uses borewell water for irrigation in Bandiravirala. He cultivates paddy and fodder grass.

> The borewell water quality has changed and turned into a green color since three years ago and sometimes smells very bad. But still, we are drinking the same water because we do not have any other source due to lack of rain the water levels in the borewells have decreased.

Below are the average costs of production and income per harvest for the main crops grown in the Musi area.

Table 12: Average cost of production and Income from Various Crops Irrigated with Groundwater

Name of the crop	Average Expenditure per ha in (Rs.)	Average income per harvest per ha in (Rs.)
Paddy	12,585 per ha per crop	29,425 per ha per crop
Coconut	300 per tree	1000 per tree
Cheeku	250 per tree	800 per tree
Mango	120 per tree	500 per tree
Guava	70 per tree	400 per tree
Fodder Grass	2,500 per ha	6,000 per ha
Vegetables	12,500 per ha per crop	30,000 per ha per crop
Jasmine	11,250 per ha per crop	25,000/- per crop

Note: Vegetables include tomato, egg plant, okra, chillies, bottle gourd and bitter gourd and are harvested twice a year.

A broader range of crops of can be grown with groundwater than with wastewater such as tree crops and non-leafy vegetables. The costs of production are higher for groundwater-irrigated crops than for wastewater crops since groundwater users have costs that wastewater users tend not to have, such as for fertilizers, borewell and pump purchase costs and maintenance and electricity. However, income derived from the crops is higher since there is a 2-tiered pricing system for the paddy and since higher value crops such as mango grows best with groundwater. However, jasmine can be grown with a mix of water and is high value. By mixing the water, the negative characteristics of each type of water in terms of quality and or cost of production can be diminished. Risk is decreased and the quality of the crop increases.

WATER FOR DOMESTIC NEEDS AND DRINKING

In all of the research sites, groundwater was found to be used for all household needs (drinking, cooking, cleaning, bathing, washing clothes and for cattle rearing). However, in the peri-urban area, groundwater quality is particularly problematic for household needs. The groundwater is polluted and saline and is therefore not potable. In all the research sites it was seen that the groundwater is unfit for drinking and cooking purposes. Panchayat/village administration in these sites has dug borewells away from wastewater sources and pump the groundwater into an overhead tank from which water is supplied to all the villagers through a network of taps. The groundwater is used for other domestic purposes like washing utensils, clothes, house, cattle etc. people who can afford it buy Hyderabad Municipal water at Rs 10 per 15 liters from private vendors. Some people bring Hyderabad Municipal water from the city from public taps whenever they visit the city.

A resident of Pirzadiguda village explained:

> The quality of groundwater is not good now. Six years ago, it was still potable and good for domestic use. But now it is not suitable even for bathing. When we bathe, our hair becomes very rough. We get potable water from the Uppal cross roads (a suburb of the city 2 km away) from a municipal tap. In March 2002 two taps were laid by the Hyderabad Metro Board which supplies good potable water.

A 72 year old farmer from Bandiravirala who cultivates paddy is the owner of 2.4 ha of land next to the wastewater canal. He has an open well into which wastewater is lifted for irrigation. He speaks both about the quality of the wastewater and groundwater for domestic purposes and for agriculture.

> Water quality has changed since 10 years and the water has turned black and dirty. So we are not using it for domestic purposes. Ten years ago we used to drink this water. Groundwater has also changed. Now we are drinking tap water but before 4 years we used to drink borewell water in the village which has become salty. Crops yields have also been reduced since 10 years. We use this open well to just lift the water from the canal and irrigate our field. The wastewater canal is just beside our field.

Livestock water requirements

With the river and canal water quality deteriorating, residents in Pirzadiguda are depending on groundwater for all of their livestock's (buffaloes kept for milk) water requirements. However, it is tapped in different ways. The residents obtain it from the community/Panchayat tap, community tube well, own tap, own tube well and or shallow open wells. About 45% of our respondents use water from their own household taps for all livestock water needs.

A 35 year old man in Pirzadiguda has leased in .6 ha of land for their 10 buffaloes.

> The wastewater quality is bad and has a very bad smell. Its harmful to human beings and to our cattle so we are taking precautions to prevent the buffaloes from entering into the wastewater and drinking that water. If the buffaloes show any sign of ill health we immediately get them checked by a doctor. At present, our buffaloes drink the water at home from a borewell.

It is clear that residents in this peri-urban area are aware of the problems of using wastewater for their livestock and that they have found ways of mitigating these harmful effects by using borewell water.

Conclusions

This study focussed on the impact of wastewater irrigation on groundwater quality and quantity, the impact of groundwater quality on the livelihoods of the people dependent on this water, the advantages and disadvantages of using groundwater in wastewater irrigated areas and the innovative management practices of farmers to cope with the problems. Wastewater and groundwater quality tests were conducted in these areas in order to show some of the constraints that farmers face when using wastewater and groundwater in wastewater-irrigated areas. This study shows that farmers innovate when faced with adversity and when faced with changing water delivery rates. The adverse situation is the deteriorating quality of both the wastewater and the groundwater due to increased industrial pollution of the wastewater and increased areas under wastewater irrigation. Increased water supply to these villages has come in the form of wastewater. Under these conditions, farmers have adapted their strategies to gain access to more wastewater, to use both wastewater and groundwater either by mixing it, by using it at different stages of the plant growth, or by using both on different plots of land. Farming households utilize the resources at their disposal in a way that will provide maximum benefit to them in terms of income, food security and food safety. It is only through studies undertaken at the micro level of the farming household that grass roots, adaptive managerial practices are revealed. More studies need to be undertaken which focus on household members and livelihood strategies in wastewater irrigated areas. The study also reveals, however, that government authorities need to address the issue of deteriorating wastewater quality for the very valuable production that takes place downstream of major cities in India and around the world. Any treatment should be undertaken with a view towards improving water quality for the many producers who depend on it for various livelihood activities and who provide a service to the urban areas through the provision of agricultural produce and dairy products. New users should not be created with treated wastewater such as golf courses, gardens and public parks. Instead, existing users should receive priority. This will also help preserve the quality of large areas of land and of groundwater sources around the cities for future generations while continuing to generate employment for landowners, land renters, laborers and livestock rearers.

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