



## ANALYSIS

## Impact of irrigation water quality on human health: A case study in India

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## ABSTRACT

Untreated or partially treated wastewater, which is a negative externality of urban water use, is widely used for irrigation in water scarce regions in several countries including India. While the nutrients contained in the wastewater is considered as beneficial to agriculture, the contaminants present in it pose environmental and health risks. This paper examines the morbidity status, its determinants as well as the cost of illness for households living in the areas irrigated with wastewater in comparison with those using normal quality water. Primary data collected from six villages irrigated with wastewater along Musi River which is fed with wastewater and one control village where normal quality water is used for irrigation has been used for the analysis.

It is seen that higher rates of morbidity exist in the wastewater irrigated villages when compared to the control village. Specifically, adult and female morbidity rates are significantly higher than child and male morbidity rates. From the logit analysis it is seen that exposure to wastewater and engagement in activities based on it places the households in higher risk groups to report morbidity. Small and marginal farmers incur higher economic cost of illness. However, it has been difficult to ascertain the cause and effect relationship as most of the households have reported more common illnesses like fever, head ache, skin itching, stomach ailments, etc. The study points out the need for a comprehensive risk assessment and adoption of risk management measures including setting standards for treatment and discharge of wastewater and regulations on the type of uses etc. to prevent unplanned use of untreated or partially treated wastewater while taking into account local conditions.

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## 1. Introduction

Increasing scarcity of freshwater resources is driving many countries in the arid and semi arid regions to use marginal quality water for agriculture and related activities. Marginal quality water or water whose quality might pose a threat to sustainable agriculture and/or human health if used for irrigation without taking certain precautions is of two types. They are wastewater from urban and peri-urban areas and saline and sodic agricultural drainage water and groundwater (Cornish et al., 1999 quoted in van der Hoek et al., 2002; Qadir et al., 2007). Unlike saline and sodic water which contains salts that impair plant growth, wastewater comprises of both domestic sewage and industrial effluents. It therefore contains a variety of pollutants including pathogens and heavy metals which can potentially harm environment as well as human and animal health. The wastewater is, however, used for irrigation in water scarce regions in different parts of the world including countries from Asia, Europe, South America and the United States of America (van der Hoek, 2004). Globally around 20 million ha land is reported to be irrigated with

wastewater and at least 10% of the world's population is thought to consume foods produced by irrigation with wastewater (Hamilton et al., 2007; WHO, 2006a,b).

The supply of water to the city ensures the supply of wastewater because the depleted fraction of domestic and residential water use is typically only 15–25% with the remainder returning as wastewater (Scott et al., 2004). In a semi-arid area, a city of 1 million people would produce enough water to irrigate approximately 1500–3500 ha (WHO, 2006a). Irrigation with wastewater is said to have both beneficial and harmful effects (Chen et al., 2005; Singh et al., 2004). WHO (2006a) reports that at an irrigation rate of 1.5 m<sup>3</sup> of irrigation water per m<sup>2</sup> of field area per year in a typical semi arid climate, treated municipal wastewater can supply 225 kg of nitrogen and 45 kg of phosphorus per hectare per year which reduces or eliminates the need for supplementary fertilization needs. However, excessive accumulation of contaminants like heavy metals in soils lead to elevated heavy metal uptake by crops and thus affect food quality and safety (Muchuweti et al., 2006). Consumption of food crops contaminated with heavy metals is one of the important pathways for intake of toxic substances into the human body of which some become apparent only after several years of exposure (Bahemuka and Mubofu, 1999; Ikeda et al., 2000). This apart, the microbial quality of wastewater also poses a major threat to the health of those who are

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directly as well as indirectly exposed to it, of which, the greatest concern are pathogenic viruses, bacteria, protozoa, and helminths. As is evident from Section 2, a study on the health effects of wastewater irrigation on the workers and others is complex, as a whole lot of socio economic as well as hygienic and behavioural aspects also influence their health conditions. This is especially true in developing countries like India where wastewater use is mostly unplanned and unregulated. Over all, the health impacts of poor water quality translate into high morbidity and mortality rates, malnutrition, reduced life expectancy, etc followed by high economic cost of illness.

Against this background, the major objective of the paper is to assess the morbidity status of the households living in the wastewater irrigated villages in the peri urban areas of Hyderabad city in India in comparison with those who use normal quality water for irrigation. The study further identifies the determinants of morbidity and as well estimates the economic cost of illness for the households in the study area. Primary data at the household levels have been collected from six villages irrigating with wastewater in the peri urban areas of Hyderabad and one village using normal quality water for irrigation. Overall, the study points out to the prevalence of higher morbidity rates among the households in wastewater irrigated villages. It is identified that the type and extent of exposure to wastewater either directly or indirectly are important determinants of morbidity. Therefore, the study highlights the need for further research to explore the dose response relationships so that appropriate risk management strategies to prevent exposures to pathogens and toxic chemicals by a combination of measures such as wastewater treatment, produce restriction, methods of application and other exposure control methods etc can be adopted to minimise the health risks of wastewater irrigation while utilising its benefits, especially in the dry water scarce regions.

## 2. Wastewater irrigation and health risks: an overview

In this section, we present a brief overview of types of wastewater irrigation and health risks. Asano (1998) identifies three types of irrigation use of wastewater. They are (1) direct use of untreated water (2) direct use of treated wastewater and (3) indirect use of wastewater. The application of wastewater to land directly from a sewerage system or other purpose-built wastewater conveyance is generally referred to as the direct use of untreated wastewater. This type of use exists in countries like Pakistan and Kenya. On the other hand, the direct use of treated wastewater is where control exists over the conveyance of the wastewater from the point of discharge to a treatment plant and to a controlled area where it is used for irrigation. Many countries in Middle East, which makes use of wastewater stabilization ponds to remove pathogens, widely adopt this method. Indirect use happens when municipal and industrial wastewater is discharged without treatment or monitoring into the watercourses draining an urban area from where farmers draw water for irrigation like in the case of Musi River in Hyderabad in India which has become a *de facto* sewer.

Contamination of soils and crops due to wastewater irrigation are widely reported from different parts of the world. It has been reported that 45% of wastewater irrigated areas in China are contaminated with heavy metals at the most serious level. Not only in China, this has been a problem in several other countries like Germany, France and India as well (Ingwersen and Streck, 2006; Dere et al., 2006; Singh and Kumar, 2006). The chemical contaminants like cadmium and lead are sequestered in the soils and its uptake by crops serve as the transmission route in the human chain (Jeyabaskaran and Sree Ramulu, 1996; Mendoza et al 1996; Mitra and Gupta 1999). Evidence of heavy metal transmission through milk produced by cattle fed with wastewater irrigated fodder is reported in South Asia where per capita milk consumption is the highest in the developing world (Delgado et al 1999; Swarup et al 1997). The consumption of heavy metal contaminated food

can deplete some essential nutrients in the body that are further responsible for decreasing immunological defences, intrauterine growth retardation, impaired psycho-social faculties, disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates (Iyengar and Nair 2000; Türkdogan et al., 2003).

The presence of pathogenic micro and macro organisms is a source of threat, especially to those who are directly or indirectly exposed to wastewater. Key evidence for health risks associated with wastewater use include hazards from bacteria, helminths, trematodes, protozoa, viruses which are mainly through contact and consumption and other vector borne pathogens through vector contact. There are also hazards due to skin irritants through contact (WHO, 2006b; van der Hoek et al., 2005). Some of these infections are communicable in nature and the diseases of relevance differ from area to area, depending on the general status of sanitation and hygiene in the area (WHO, 2006b). Workers, their families and consumers face the risk of these infections. The health risks can also differ according to age and gender as well. For example, an epidemiological study by Habbari et al. (2000) undertaken to determine possible risk associated with raw wastewater use for agricultural purposes in Beni-Mellal Morocco found *ascaris* infection is approximately five times higher especially among children in wastewater-impacted regions compared to control regions. The study had taken into account possible demographic, hygiene and behavioural risk contact factors. In the present study, we have tried to control some of the above mentioned factors in the analysis.

## 3. Study area: Musi River in Hyderabad, India

Musi River is one among the several rivers in India which flows through such rapidly growing cities like Delhi, Kolkotta, Coimbatore, Indore, Kanpur, Patna, Vadodara, Varanasi, Dharward and Hyderabad carrying wastewater generated by them. It is one of the smaller tributaries of the Krishna River in the Deccan Plateau. Here the annual rainfall is 680 mm per year. It flows across the city of Hyderabad in Southern India which according to the Census of India 2001 has a population of 3.83 million. With only 60% of the area covered by the sewerage system in the city, the domestic and industrial discharges finally end up in the water bodies, particularly in the Musi River. As per the City Development Plan, the city's wastewater flows of about 850 million litres per day (MLD) are discharged into the Musi River through 64 sewage outlets making the river, the city's main sewer line. A primary sewage treatment plant (STP) with a capacity of 113 MLD is in operation at Amberpet since 1985 and another STP at Hussain Sagar with a capacity of 20 MLD. Even with the recently constructed treatment plant at Nagole which has a capacity of 172 MLD, only about 35% of the wastewater generated is getting at least primary treatment. Among other things, the water contains dissolved solids which are inorganic, bio accumulative and toxic in nature which can have serious health consequences. The adverse impact of industrial water pollution on rural communities in the Patancheru industrial belt near Hyderabad has been brought out earlier by Behera and Reddy (2002); Reddy and Behera (2006).

As is the case with other rivers, the Musi River has served as a source of irrigation water for downstream rural areas for centuries through a system of *anicuts* (weirs) and *ayacuts* (irrigation canal). According to van der Hoek (2004) approximately 40,500 ha is irrigated with wastewater in Hyderabad along Musi River. There are approximately 22 villages with a population of about 28,000 in this basin. Most of the households in these villages depend upon wastewater based activities either directly or indirectly for their livelihood. Agriculture and livestock rearing are amongst the most important livelihoods of the villagers. Here livelihood includes not only money income from wage labour and crop production but also food security and nutrition, etc. Vegetables and paragrass are cultivated mostly in the peri urban zones whereas paddy is the major crop in the rural zone. The crops cultivated here are mostly

marketed in the city markets. There are also other subsidiary activities linked to wastewater like transport and sale of wastewater produce, sale of other crop inputs etc undertaken by the households in the study area.

#### 4. Methods and techniques

##### 4.1. Analytical framework

Wastewater return is considered as an externality of urban water use, the magnitude of which is expected to vary from location to location (Young, 2000). It is an externality because it influences the welfare of individuals or communities through a non-market process and that there is no market feedback from those who experience the loss or gain to those who generates it. The benchmark for defining what is negative and what is positive depends upon definitions of individual rights to use the environment and natural resources (Young, 2000). In the case of unplanned use of wastewater discharged into a river system, urban water users are inflicting harm on downstream water users who seem to have a right to clean water. However, the problem at hand is more complex than what it appears to be. In water scarce regions wastewater also serves as an important input into agricultural production processes benefitting both rural and urban consumers which give it the characteristics of a positive externality. For example, a chain of economic beneficiaries from wastewater dependent activities is formed by those who benefit directly or indirectly from the production, use and/or sale of wastewater irrigated products (Buechler, 2004). Then the question is whether the positive externalities outweigh negative externalities, if so by how much? In addition to this, there is another dimension to this problem. Crops cultivated with wastewater which are likely to be contaminated are sold in the urban markets thereby posing threats to the health of the consumers. This in turn is a negative externality to the urban dwellers because they too have a right to safe food. On the other hand supply of perishable vegetables to urban dwellers depends significantly on this kind of agriculture (Nugent, 2000; Smith, 2002). In some places like Dakar, Senegal about 60% of the vegetables consumed are produced mostly with wastewater (Niang et al., 2002). This is obviously a positive externality for the urban area. Thus there exist a complex relationship between urban return of wastewater and its irrigation use in peri urban areas. A proper evaluation of various types of externalities is required to take policy measures which would maximise positive externalities. In other words evaluation of various externalities is very important to determine the economically and

**Table 1**

Distribution of sample households.

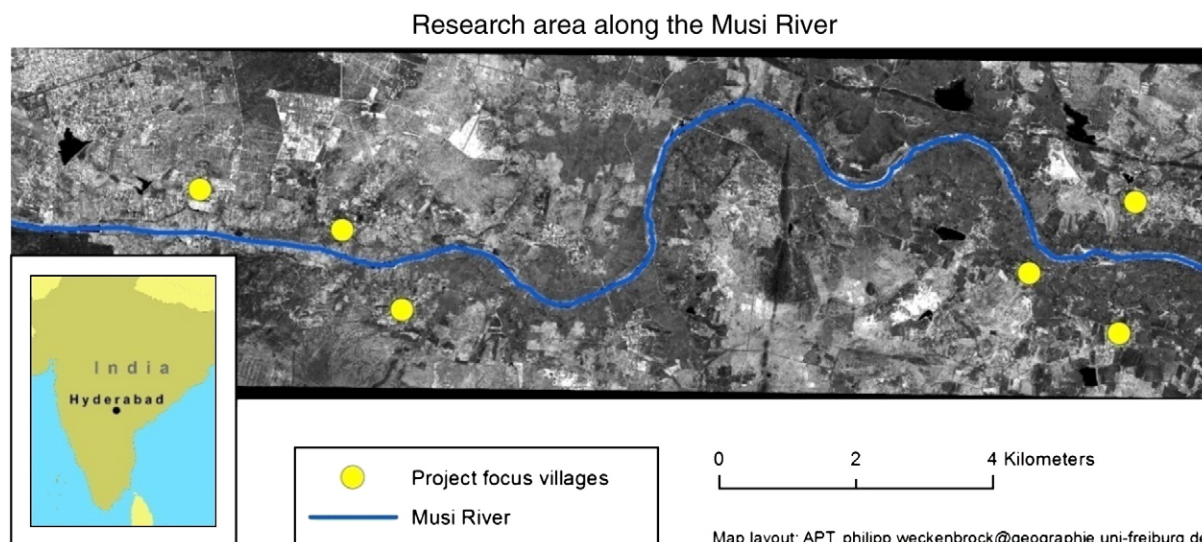
Village name	Zone	District	Total number of households	Sample households
Pillaipally	Rural	Nalgonda	552	84
Chinna Ravirala	Rural	Ranga Reddy	246	39
Makta	Rural	Nalgonda	265	41
Anantaram				
Qutbullapur	Peri urban	Ranga Reddy	492	73
Kachivani	Periurban	Ranga Reddy	465	70
Singaram				
Parvatapur	Periurban	Ranga Reddy	291	54
Vallala	Rural (Control village)	Nalgonda	728	110
All Villages			3039	471

socially optimum level of wastewater discharge and treatment, and also the types of uses to which it can be put into safely. Within this broader framework, this paper analyses the health impact of wastewater irrigation, a negative externality inflicted by urban discharge of wastewater on the households living and working in the peri urban and rural areas in terms of their morbidity levels.

##### 4.2. Data and techniques

In this study, by wastewater irrigated villages we mean those villages that draw water either directly through the canal system from Musi River which is contaminated with sewage flows or indirectly from groundwater sources which are also likely to be contaminated. Wastewater irrigated areas along a 40 km stretch of Musi River, comprising six villages grouped into peri urban (three) and rural zones (three) were purposively selected for detailed study (Fig. 1). The peri urban zone borders the Greater Hyderabad Municipal Corporation (GHMC) area of Uppal and the rural zone is 15 km downstream from the peri-urban zone. These villages belonged to Nalgonda and Ranga Reddy districts of Andhra Pradesh, India and differed in wastewater quality as it get improved further downstream. A control village was also selected after carrying out water quality analysis of random sample of irrigation water. The chemical characteristic of water was within the normal range as given by Ayers and Westcot (1994) and was therefore considered suitable for irrigation.

In each of the seven villages, at first, a survey was conducted to list out all the households and collect baseline information on their demographic and socio economic characteristics. This was followed by a detailed survey of sample households selected on the basis of



**Fig. 1.** Location Map of Musi River and Study Villages.



stratified random sampling procedure based on ownership of land. About 15% of the households from each stratum have been selected for detailed household survey using structured interview schedules. The surveys have been conducted during 2006 and 2007. The following Table 1 gives the details of the number of sampled households across villages.

#### 4.2.1. Estimation of morbidity rates

The definition of morbidity used in this study refers to episodes of illnesses during a specific set of three reference periods that is (1) during last one month, (2) before 2 to 6 months, and (3) before 7 to 12 months thus covering a period of 1 year prior to survey. Detailed information on illnesses and related aspects of each member in the household has been collected. Finally, to account for seasonality biases we clubbed the information from these reference periods to one in order to arrive at figures for a 1 year period. Information on major illnesses like cancer, heart problems, kidney failures etc has been excluded from the present morbidity analysis. We have calculated the morbidity rates following the methodology given by Sundar et al. (2002) which is based on detailed information of illnesses among the current living members of households actually sampled. Let

- $T_k$  and  $S_k$  are respectively the total number of sample household and number of households reporting a sick member in village  $k$ ;  $NS_k$  is the number of households reporting no sickness.
- $S_{fk}$  and  $S_{mk}$  are respectively the total number of female and male members among all households that reported at least one sick member.  $NS_{fk}$  and  $NS_{mk}$  denote the corresponding numbers for all households not reporting any sickness.
- $s_{sfk}$  and  $s_{smk}$  are respectively the number of sick female and male members among all households that reported at least one sick member

The morbidity rates among the households reporting at least one sick member has been estimated as follows:

$$\text{Total morbidity} = (s_{sfk} + s_{smk}) / (S_{fk} + S_{mk})$$

$$\text{Male morbidity} = s_{smk} / S_{mk}$$

$$\text{Female morbidity} = s_{sfk} / S_{fk}$$

The following formulae has been used to estimate the morbidity rate for the all the households surveyed in village  $k$

$$\text{Female morbidity, } M_{fek} = (s_{sfk} / S_{fk}) * (S_{fk} / (S_{fk} + NS_{fk}));$$

$$\text{Male morbidity, } M_{mek} = (s_{smk} / S_{mk}) * (S_{mk} / (S_{mk} + NS_{mk})).$$

The morbidity rates  $M_{fe}$  and  $M_{me}$  for the total population is a weighted average of their gender specific morbidity rates, with the weights being the listed population by gender in all households whether reporting sickness or not.

#### 4.2.2. Determinants of morbidity: specification of the econometric model

A logit analysis has been carried out to know the determinants of morbidity reported by the households. A dummy dependent variable assuming value 1 if the estimated household morbidity was greater than 0, that is the households report at least one sick member during the reference period and otherwise zero has been generated. Explanatory variables were selected based on the assumption that the following attributes influence whether households belong to high or low risk categories.

- (1) Location (proximity to wastewater) of households places them in high or low risk groups;
- (2) extent as well as type of exposure to (waste) water based livelihoods;
- (3) general hygienic and living conditions make some households more vulnerable to diseases than others;
- (4) socio-economic conditions of the households can influence the health status of the households and thereby morbidity.

The estimable logit model has been specified below (see Gujarati, 1988; Green, 1993) and the results are discussed in Section 5.

$$L_i = \ln(P_i / 1 - P_i) = \beta_1 + \beta_2 \text{ow\_land} + \beta_3 \text{treat} + \beta_4 \text{ow\_livestock} + \beta_5 \text{agri\_lab} + \beta_6 \text{family\_size} + \beta_7 \text{ru\_urban} + \beta_8 \text{caste} + \beta_9 \text{avg\_age} + \beta_{10} \text{edu\_head} + \beta_{11} \text{fuel} + \beta_{12} \text{mig\_lab} + \beta_{13} \text{pvt\_toilet} + \beta_{14} \text{vil\_c} + u_i. \quad (1)$$

The rationale for including the above given independent variables and the signs expected are given in Table 2.

#### 4.2.3. Cost of illness

In this study, we have tried to establish values for illnesses reported by the households by identifying the cost-generating components. This in fact can be termed as an 'opportunity cost' or the value of the forgone opportunity to use money and other resources that are lost due to illness in a different way. Here cost of illness includes both direct and indirect costs. The direct costs include mainly mitigating expenditures incurred to relieve illness, like the cost of treatment including costs of doctor visits, medication, lab tests and other clinical diagnostics, transportation costs etc. Given the low levels of literacy and awareness of the households and memory lapse disaggregated information on various components of cost was difficult to obtain. Some of the direct costs included but not separately reflected upon in the study include costs of medical care including doctor visits, medication, lab tests, transportation to health providers or hospitals. Indirect costs are those mainly resulting from the loss of workdays because of illness or morbidity as well as averting expenditures incurred by the households to limit their direct exposure to wastewater or to protect themselves from the adverse effects of it. It

**Table 2**

Description of variables included in the logit model with their expected signs.

Variable	Explanation	Expected sign	Attribute represented
Vil_c	Whether the households belong to wastewater or control villages 1 = wastewater irrigated village; 0 = otherwise	Positive	Exposure
Ow_land (dummy)	Ownership of land 1 = those owning land 0 = otherwise	Negative/Positive	Socio economic and exposure
Treat (dummy)	Whether drinking water is treated 1 = Yes, 0 = otherwise	Negative	Vulnerability to diseases
Ow-Livestock (dummy)	Ownership of livestock 1 = Yes; 0 = otherwise	Positive/Negative	Exposure
Edu_head	Education of the head of the household	Negative	Socioeconomic
Agri_lab (dummy)	Hired agricultural labour 1 = Yes; 0 = otherwise	Positive	Exposure
Family_size	Total number of members in the family	Positive	Socioeconomic
Ru_urban (dummy)	Whether periurban or rural villages 1 = Periurban; 0 = otherwise	Positive	Proximity and exposure
Avg_age	Average age of the members in the household	Positive	Vulnerability to diseases
Fuel (dummy)	Fuel used for cooking 1 = solid fuel; 0 = otherwise	Positive	Vulnerability to diseases and living conditions
Mig_lab (dummy)	Migrant labour 1 = migrant labour; 0 = otherwise	Positive	Exposure
Caste (dummy)	Social group to which households belong to 1 = SC/ST; 0 = otherwise	Positive	Socioeconomic
Pvt_toilet (dummy)	Whether the households have private toilets or not 1 = Yes; 0 = Otherwise	Negative	Vulnerability to diseases and living conditions

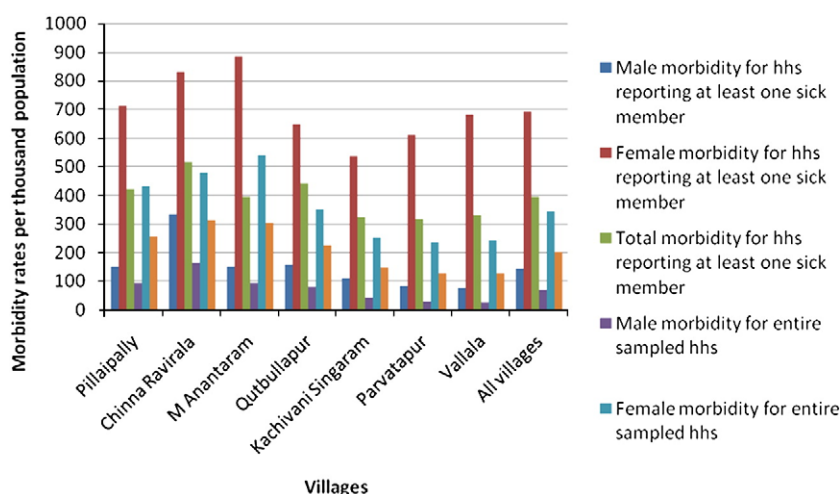


Fig. 2. Estimates of morbidity per thousand population in the study area. Source: Primary survey data.

has been difficult to measure the major averting expenditure incurred, in this case for boiling water as well as the effects on productivity while on work due to illness. Our study lacks information on a day-by-day basis the quantity of water boiled, the time and cost of fuel used for boiling, etc as this has been carried out as a part of other household chores. Additional indirect costs include the time a patient or accompanying persons or family members lost when someone in the family is ill has not been taken into account in this study, as data was not available.

## 5. Results and discussion

As a back drop to morbidity and cost of illness analyses we present the socio economic profile of the sample households briefly. Among the 471 households surveyed 275 (58%) are landless and among those who own land, 61 and 22% respectively are marginal and small farmers with an average of 1.17 and 3.14 acres of land each. Socially over 60% belonged to backward communities (BC) and about 20% each belongs to other communities (OC) and to Scheduled Castes (SC).<sup>1</sup> Average size of the household is 4.5 ranging from 3.8 in Vallala (control village) to 5 in Parvatapuram and Makta Anantaram. Sex ratio across all villages is 946, and high figures of 1111 and 1019 have been observed in Qutbullapur and Kachivani Singaram whereas the lowest is in the control village. Illiteracy is as high as 60% among the heads of the households. Over 30% of the head of the households are engaged in own farming activity. Another 16 and 13% work as agricultural and non agricultural labourers respectively. About 102 households (22%) are engaged in livestock rearing and dairy activities as well. Against this backdrop, we undertook a detailed analysis of health related aspects as per the methodology given in the previous section.

Nearly 50% (231 households) reported illness of at least one family member during the reference period of the survey. This is approximately 337 or about 16% of a population of 2096. Illnesses reported by the households include fever, body aches, skin itching and stomach ailments. A gender wise analysis shows higher female morbidity. Similarly, adult morbidity is higher than child morbidity.

The estimated morbidity rates per thousand population for the households reporting at least one sick member have been 146 for males and as high as 693 for females. Total morbidity is 394 per thousand population (Fig. 2). The figures for the entire sample households as one can expect also present similar trends with

morbidity rates of 70 for males and 345 for females per thousand population. Earlier studies pointed out that women spend more time weeding wastewater irrigated crops and therefore their risk of helminth infections from contact with the soil may also be higher (Buechler and Devi, 2002; Buechler, 2004). Irrespective of gender differences the total morbidity is 203. The trend of high female morbidity is true for the control village as well. Among all the villages Chinna Ravirala ranks first in male (166) and total morbidity rates (314) where as it is Makta Anantaram (539) in female morbidity. Both villages are in the rural zone. Similar high rates of morbidity are found in Qutbullapur (periurban), Pillaipally (rural) with differences in gender specific morbidity rates. The morbidity rates existing in the control village and in the periurban zone, except in Qutbullapur, are comparable and are considerably lower than what have been observed in the rural zone.

A *t*-test was carried out to examine if the morbidity differed significantly between wastewater irrigated and control village. It was seen that the mean morbidity difference of 105 was statistically significant at 1% level of significance. This necessitated a closer look into the morbidity rates using a logit model to understand its determinants. As given in Table 3, the variable *vil\_c* which says whether the village is irrigated with wastewater or not has a positive sign. Those households in wastewater irrigated villages and are more exposed to it either directly or indirectly have higher morbidity.

Table 3  
Determinants of morbidity in the study areas.

	Coef.	Std. Err	t-value
Vil_c	1.17816***	0.29599	3.98
Ow_land	−0.47819*	0.23788	−2.01
Treat	−0.82024	0.48111	−1.7
Ow-Livestock	0.46832	0.25320	1.85
Edu_head	0.00163	0.05699	0.03
Agri_lab	0.76531***	0.22443	3.41
Family_size	0.00483	0.06597	0.07
Fuel	0.12505	0.20283	0.62
Avg_age	0.02223**	0.00929	2.39
Ru_urban	−0.57246**	0.23753	−2.41
Caste	0.24962	0.24078	1.04
Pvt_toilet	−0.03769	0.12746	−0.3
Mig_lab	2.23759*	1.13148	1.98
Constant	−1.71520**	0.60234	−2.85
Number of Observations = 471			
LR Chi <sup>2</sup> (13) = 57.01			
Prob > Chi2 = 0.000			
Pseudo R <sup>2</sup> = 0.0873			

\**P* < 0.05, \*\**P* < 0.01 and \*\*\**P* < 0.001.

Source: Estimated from primary survey data.

<sup>1</sup> In India, Scheduled castes and scheduled tribes are communities that are given special status by the constitution of India. These communities had traditionally been marginalized, socially, educationally and economically and suffered social disadvantage and exclusion.

Similarly, the coefficient of *ru\_urban* which is negative and statistically significant is also conveying important results. This variable represents whether the villages are in the peri-urban or rural zones. Although the quality of wastewater is likely to improve further downstream, the higher incidence of morbidity could be because of the reason that the household members in the rural zone have more contact and exposure to wastewater and wastewater based activities by way of labour intensive paddy cultivation in comparison with urban households. For example, among the total workforce in rural households, 74 and 43% respectively are engaged in agricultural activities as own farm labour and hired labour whereas it is relatively low at 60 and 37% in the peri urban villages and that too in activities having lesser contact with wastewater like dairying and paragrass cultivation. In the peri-urban zone a large number of households are engaged in non-agricultural and non-wastewater based activities and as a result has lesser contact with wastewater.

Although the expected sign of the dummy variable *ow\_land* was ambiguous the results of logit analysis confirms that it is negative. Mere ownership of land does not mean more exposure as they can be employing labourers to work in their fields. On the other hand, landless have higher chances of getting exposed to wastewater as they hire out their labour to work in others agricultural fields. Livestock ownership can also be argued in similar manner. Here the coefficient of *Ow\_livestock* turned out to be positive but was significant at a slightly higher significance level only.

As the variable *treat* is negative and statistically significant, it is observed that those who adopt some type of defensive measures like drinking boiled water to protect themselves from water borne diseases are less likely to report morbidity. In most developing countries unsafe drinking water is a major source of illness. It was expected that households who use fuel wood for cooking are more prone to indoor pollution and thereby more likely to report illness, especially in the context of high female morbidity. The coefficient of *fuel* had the expected sign but was not statistically significant.

The sign and significance of the coefficients of variables *agri\_lab* and *mig\_lab* shows that those who have more direct contact or exposure with wastewater are more likely to report morbidity. Similar is the case of the coefficient of the variable *avg\_age* which is positive

and statistically significant implying that households with older members are more likely to report morbidity. This was expected if a household is in a late stage in its life cycle many members will be elderly and are prone to illness.

Some of the other variables like *pvt\_toilet*, *caste*, *family\_size*, *edu\_head* which were expected to influence morbidity turned out to be otherwise. For instance a statistically significant positive sign was expected for the coefficient of the variable *caste* which represents the socioeconomic backwardness of the households. Similarly, *Pvt\_toilet* which indicates the general sanitary and hygienic conditions of the households was also expected to reduce morbidity. Since the education of the head of the household was expected to improve the level of awareness of the family and the need for adopting precautionary measures to protect the members from the risks of the wastewater irrigation, the coefficient of the variable *edu\_head* was also expected to be significant with a negative sign. On the other hand, it was expected that households with larger family size are more likely to report morbidity.

The analysis on the whole indicates that those who own land, who belong to peri-urban areas are less likely to report morbidity along with those who adopt some kind of defensive measures like using boiled drinking water. On the other hand, the proximity to the wastewater irrigated lands, ownership of livestock and being migrant labourer places the household in high risk category for reporting illnesses.

Further we estimated the cost of illness as per the methodology given above. The average cost of illness per household across all villages in a year is about Rs 3033 (Table 4). Interestingly, the cost of illness is higher for the small and medium farmers followed by the landless households. For the first two categories, wage loss is the major share of the total costs, where as it is the medical cost for the landless. When the landless households incur a total cost of Rs 2657 per household per year, it is as above Rs 3784 for the small and marginal farmers. Medium and large farmers incur comparatively lesser cost. Differences in the cost of illness across villages are also observed. Qutbullapur (Rs 4454), Chinna Ravirala (Rs 4454) and Parvatapur (Rs 3890) occupy the top positions in the cost of illness incurred by the households. Although morbidity levels in some of

**Table 4**

Estimates of the cost of illness incurred by the households in a year Rupees.\*

		Pillaipally	Chinna Ravirala	Makta Anantaram	Qutbulla pur	Kachivani Singaram	Parvata puram	Vallala	All
Landless	A	751	1544	791	913	805	263	424	769
	B	1008	2942	1127	2351	1337	3728	679	1888
	C	1759	4486	1918	3264	2142	3990	1103	2657
	D	30	13	11	30	23	20	14	141
Marginal farmer (Below 2.5 acres)	A	1875	1134	2976	3533	758	900	3414	2315
	B	1065	1170	765	4564	988	1000	780	1470
	C	2940	2304	3741	8098	1745	1900	4194	3784
	D	20	5	10	9	8	1	10	63
Small farmer (Between 2.5 to 5 acres)	A	675	3900	1350	0	540		2517	2048
	B	1250	2715	1430	10,000	300		1055	1741
	C	1925	6615	2780	10,000	840		3572	3788
	D	2	2	3	1	1		10	19
Medium farmer (Between 5 and 10 acres)	A		0					210	140
	B		2300					1000	1433
	C		2300					1210	1573
	D		1					2	3
Large farmers (Above 10 acres)	A	450			0			1020	623
	B	500			1800			1500	1325
	C	950			1800			2520	1948
	D	1			1			2	4
All	A	1167	1597	1771	1444	785	293	1782	1287
	B	1029	2468	1014	3010	1217	3598	864	1746
	C	2196	4065	2785	4454	2002	3890	2646	3033
	D	53	21	24	41	32	21	38	230

A = Total wage loss for the household; B = Total medical expenditure incurred by the household; C = Total cost of illness; D = No. of households reporting cost of illness.

\*1 US Dollar = Rs 48 approximately.

Source: Estimated from primary survey data.

these villages like Paravatapur are comparatively low, proximity to city and access to medical care facilities are among the reasons for high medical expenditures. Like in most other villages, in control village also, it is the small and medium farmers who are more burdened with the cost of illness. In fact, the cost of illness incurred is almost equivalent to 2 to 4 days of wage income loss per month for a male worker in a household or to 3 to 6 days of wage income loss per month for a female worker when estimated at average wage rate or Rs 90 for males and Rs 60 for females in the study area. This is a substantial welfare loss for the households in the study area. The *t*-test revealed that the mean difference in the cost of illness measures between control and wastewater irrigated villages are not statistically significant. The cost of illness reported here can be considered as a lower bound of the actual cost as it does not include social costs.

## 6. Conclusion

While irrigation is a beneficial use of wastewater in water scarce regions the contaminants present in it pose several environmental and health problems. The analysis presented in this paper shows higher levels of morbidity and more importantly female morbidity in the villages irrigated with water from Musi river which is fed with wastewater in comparison to a control village. It is seen that type and extent of exposure to wastewater based activities places the households in high or low risk groups. Higher levels of morbidity have been observed in the villages further downstream of Musi River in the rural zone in comparison with villages in the peri urban zone. The ailments commonly reported are fever, headache, skin and stomach problems and as such the dose response relationship is not clear yet. Nevertheless, morbidity results in significant economic costs for the households, the burden of which is borne disproportionately by small and marginal farmers. Therefore, there is a need for a comprehensive risk assessment so that appropriate risk management approaches that encompass all steps from wastewater generation, its treatment and use for various purposes can be adopted.

In the present study context where wastewater availability itself is an externality of urban water use, it would be better to make its use a planned activity by evaluating various positive and negative externalities. Since it was observed in the study that type and exposure are important determinants of morbidity, steps must also be taken to create better awareness among the people who comes in contact with wastewater to adopt precautionary and defensive measures like the use of gloves etc. An interview of the medical practitioners in the study area also emphasizes the need to adopt defensive measures as in the case of most patients symptoms disappeared when their contact with wastewater was minimised or fully controlled. Apart from these, the government has a responsibility to take measures to treat wastewater and to set standards for wastewater discharge taking into account local conditions and the uses of wastewater. Policies need to be adopted to prevent any unplanned use of untreated wastewater which is implemented through various instruments such as laws and regulations, economic measures, information and education programmes, etc. Needless to say it must be suitable to local conditions and aimed at protecting both health and environment.

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