PAPER PREPARED FOR PRESENTATION IN THE INSEE CONFERENCE 2009

Wastewater Irrigation in India

An Analysis of its Health Impact

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This paper forms a part of an ongoing larger study on 'Ensuring Health and Food Safety from Wastewater Irrigation' sponsored by BMZ, Germany and implemented by the International Water Management Institute (IWMI), Hyderabad. The authors gratefully acknowledge the BMZ and IWMI in supporting this study. Thanks are due to Priyanie Amerasinghe, Robert Simmons and Madar Samad for useful inputs at various stages of the study. Research Assistance of D. Mohana Rao is also acknowledged.

Abstract

Untreated or partially treated wastewater 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 the wastewater pose health risks directly to agricultural workers and indirectly to consumers of the wastewater grown produce. This paper briefly reviews the health risks of using wastewater for irrigation and elicits the health problems of those who are directly exposed to wastewater based livelihood activities. It further estimates the morbidity and its determinants and estimates the cost of illness incurred by the households in the vicinity of wastewater irrigated area. Primary data collected from six wastewater and one fresh water irrigated villages have been used for the analysis. The study finds that there exists significantly higher morbidity in the wastewater irrigated villages when compared to freshwater irrigated village and the cost of illness incurred by these households is substantial. The study recommends adequate treatment of wastewater and public health education for adopting precautionary and preventive measures for those directly exposed to wastewater.

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 refers to water whose quality might pose a threat to sustainable agriculture and / or human health, but which can be used safely for irrigation provided certain precautions are taken (Cornish *et al*, 1999 quoted in van der Hoek, 2002). It consists of mainly two types: wastewater from urban and peri-urban areas and saline and sodic agricultural drainage water and groundwater (Wichelns, et al 2007). Saline and sodic water although contain salt which can impair plant growth they hardly contain any heavy metals or pathogens. On the other hand, wastewater contains a variety of pollutants including heavy metals and pathogens which can potentially harm human and animal health as well as environment. This is because municipal wastewater comprises not only domestic sewage but also contains substantial proportion of industrial effluents discharged to public sewers. In fact, the major constituents of wastewater are water together with concentrations of suspended and dissolved organic and inorganic solids. Major organic substances found are carbohydrates, fats, soaps, synthetic detergents, proteins, etc. It also contain different types of inorganic substances from domestic and industrial sources, including a number of potentially toxic elements such as arsenic, cadmium, chromium, copper, lead, mercury, zinc etc. Due to spatial and temporal differences, the actual proportion of each constituent within any given urban sewage load will however vary.

The use of waste water for irrigation exposes consumers as well as producers at various health risks. This paper examines the health impact of wastewater use for irrigation among the households living in the wastewater irrigated villages in and around Hyderabad city in India. The rest of the paper is organised as follows. Section 2 discusses the health risks of using wastewater for irrigation. The study context is presented in section 3 followed by study objectives and analytical framework in section 4. Data and methodology is presented in section 5. Section 6 discusses the important results followed by conclusion and policy implication in the last section. The limitations of the study are briefly mentioned here.

2. Wastewater Irrigation and Health Risks

There are different ways in which wastewater is used for irrigation in water scare regions in different parts of the world. Health impact differs according to the ways in wastewater is used which determine the degree of human exposure to it. The various types of wastewater use identified in literature include (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. In this, the irrigation source is wastewater that is directly taken from the sewerage system or from storm water drains that carry large sewage flows. This type of use exists in countries like Pakistan and Kenya. On the other hand, the direct use of treated wastewater is the use of treated wastewater 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. This method is better known as the use of reclaimed water, meaning water received at least secondary treatment, and is used after it flows out of a domestic wastewater treatment facility. Apart from these two types of direct use, indirect use of wastewater is also widely prevalent in several developing countries. Indirect use of wastewater is defined as the unplanned application to land of wastewater from a receiving water body (van der Hoek, 2002). For example, municipal and industrial wastewater is discharged without treatment or monitoring into the watercourses draining an urban area from where farmers draw water for irrigation. Asano (1998) also makes a distinction between planned and unplanned use of wastewater. For example, imagine a situation where natural rivers passing through cities become so heavily polluted with wastewater and they become *de facto* sewers like the Musi River in Hyderabad, India. In such situations, diversion of water from a river downstream of a discharge of wastewater is an incidental or unplanned reuse. Indirect reuse normally constitutes unplanned reuse whereas direct reuse normally constitutes planned reuse (Asano, 1998). In short, wastewater use is prevalent in several countries though the type of use might differ from place to place.

Irrigation with wastewater is said to have both beneficial and harmful effects as it contains substantial amounts of beneficial nutrients and toxic heavy metals (Chen *et al* 2005; Singh *et al*, 2004). Reliability and nutrient richness are considered as two important attributes of wastewater beneficial for agriculture. It is believed that nutrients present in wastewater results in higher crop yields and thereby considerably reduces the need to apply artificial fertilizers. Reliability of wastewater supply is yet another factor which makes it a valuable resource. The supply of water to the city ensures wastewater because the depleted fraction of domestic and residential water use is typically only 15-25 per cent with the remainder returning as wastewater (Scott *et al* 2004). On the other hand, wastewater use poses several threats both to environment and to human as well as livestock health. The contaminants present in the municipal and industrial wastewater are sequestered in the soils and thereby poses environmental problems. The presence of heavy metals is one of the major sources of concern. It has been reported that 45 per cent of wastewater irrigated areas in China are contaminated with heavy metal at the most serious level (Lei et al 2008). Cadmium and lead are the elements most seriously contaminating soils. Not only in China, this has been a problem in several other countries like Germany, France and India (Ingwersen and Strect, 2006; Dere, et al (2006); Singh and Kumar (2006) as well. The excessive accumulation of heavy metals in agricultural soils through wastewater irrigation, may not only result in soil contamination, but also lead to elevated heavy metal uptake by crops, and thus affect food quality and safety (Muchuweti et al., 2006). Humans are exposed to the risks through the consumption of food crops contaminated with heavy metals and are one of the important pathways for the entry of toxic substances into the human body. Some of the harmful impacts of intake of toxic metals become apparent only after several years of exposure (Bahemuka and Mubofu, 1999; Ikeda et al., 2000). Some studies reports that 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; Tu¨rkdogan et al., 2003).

This apart, the microbial quality of wastewater pose a major threat to the health of those who are directly or indirectly exposed to wastewater of which the greatest concern are pathogenic micro-and macro- organisms. Pathogenic viruses, bacteria, protozoa and helminths present in the wastewater pose health problems. The pathogens and associated health risks can be ranked by taking into account factors such as persistence in the environment, infective dose, immunity, and transmission routes that contribute to the transmission of pathogens by raw wastewater irrigation, in developing countries. For example, Shuval et al (1986) have ranked the pathogens and their associated health risks in the following manner. They are: (1) helminths, the intestinal nematodes constitute a risk to agricultural workers and to consumers of wastewater irrigated produce; (2) bacteria and protozoa for the transmission of dysentery, cholera, typhoid and other bacterial and amoebic diseases to consumers of wastewater irrigated produce and; (3) viruses for the transmission of viral infections to agricultural workers or to those living close to wastewater irrigated fields. In addition to these, the organic or non-organic toxicants such as heavy metals and pesticides contained in the water also pose health risks to workers and farmers.

In short, the health effects of wastewater irrigation can be both direct as well as indirect and even affect unsuspecting people. Wastewater irrigated vegetables and fodder may serve as the transmission route for heavy metals in the human food chain. While farmers can suffer from harmful health effects from the contact with wastewater, consumers are at the risk from eating vegetables and cereals irrigated with wastewater. The long term health effects of wastewater use are not yet well documented. Although there are studies on soil and crop contamination with heavy metals and their associated health risks to our knowledge there are not many studies, especially in the Indian context which has tried to estimate the health costs of using wastewater. This paper is an attempt to fill up this gap in the literature and focuses on the households in the wastewater irrigated villages.

3. The Study Context: Hyderabad in India

In India wastewater is generally used as aquaculture stabilisation ponds and for irrigating crops. Although official estimates are not available Strauss and Blumenthal (1990) estimates the area under wastewater irrigation to be over 73000 ha. It occurs along rivers which flow through such rapidly growing cities as Delhi, Kolkata, Coimbatore, Hyderabad, Indore, Kanpur, Patna, Vadodara, Varanasi, Dharward, etc. Along the rivers' the water is diverted via anicuts (weirs) to canals and often to tanks and then channelled to the fields for irrigation. If such uses were included, a much higher figure than 73000 ha would be obtained as in Musi river, Hyderabad alone there are approximately 40500 ha irrigated with wastewater (van der Hoek, 2004). The Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB) is a statutory authority in charge of providing and maintaining water supply and sewerage facilities in GHMC. Over a decade, till the year 2002, the city of Hyderabad was served with a quantity of 145 Million gallons of drinking water through Osmansagar, Himayatsagar, Singur / Manjira against a demand of 200 Mgd. Another 25 Mgd of ground water is also drawn through bore wells. The Krishna Drinking Water Supply Project was perceived and proposed to be taken up in three phases as the gap between demand and supply was ever increasing. The proposal was to tap 16.5 TMC of raw water from River Krishna and supplying 270 MGd treated water to the city. The stage I and II of the Phase I of the project was completed in April 2004 and April 2005 respectively thus supplying 90 Mgd of water. There are also proposals to bring in more water from the Godawari river to the twin cities of Hyderabad and Secunderabad. It needs to be remembered that almost 80 per cent of the water supplied to the city returns as wastewater. According to the Hyderabad City Development Plan, the sewerage system in the city connects over 95 per cent of the total water supply connections in the Municipal Corporation of Hyderabad area. In the peripheral municipalities and urban areas (now part of Greater Municipal Corporation of Hyderabad), a large population is not covered by safe sanitation facilities due to lack of well-established sewerage system. The treatment capacities being inadequate resulted in discharge of untreated sewage into water bodies, particularly River Musi and Durgam Cheruvu and other nallahs passing by the city. As per the Hyderabad City Development Plan, 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. These two together has a treatment capacity of 133 MLD at the primary level against the generation of 589 MLD or 23 per cent of the generated sewage. Here it is assumed that

80 per cent of the water supply is returned as sewage. Also only about 3 per cent of this sewage water is recycled and reused. The discharge of untreated sewage into River Musi which rises in the Anantagiri hills and flows almost due east, passing through the middle of Hyderabad into Nalgonda district where it joins the Krishna river in Vadapalle has made it highly polluted. Under the National River Action Assistance, the HMWSSB has submitted proposals to government of India to contain dry weather flows (sewage) entering into river Musi from 18 nos of open Nalas on either side of river and to transmit the same to nearest sewage treatment plants through conveying mains and treating them to river disposable standards and letting into the river Musi to maintain the river ecology[1].

The wastewater flowing out of the Hyderabad city and entering Musi rier is used for irrigation in the peri urban areas mostly in Ranga Reddy and Nalgonda districts. An earlier study carried out by International Water Management Institute identifies about 22 villages with a population of about 28000 in the Musi river basin. Many of the households in these villages are depending upon wastewater either directly or indirectly. Agriculture and livestock rearing are amongst the most important livelihoods of the villagers. As noted by van der Hoek (2004) approximately 40500 ha is irrigated with wastewater in Hyderabad along Musi river. Both direct and lift irrigation from canals using pumps exists. Vegetables and paragrass are cultivated mostly in the periurban zones whereas paddy is the major crop in the rural zone. Livestock rearing is also an important livelihood activity. A chain of other indirect livelihood activities which are centred on the above said main activities also thrive in these villages. An analysis of yield difference of paddy carried out as a part of the present project has observed significantly lower yield in the case of wastewater irrigated villages in comparison to the freshwater irrigated village. While 94 per cent of the total yield is contributed by area under cultivation in freshwater irrigated villages it is about 75 per cent in the case of wastewater

[1] This information is taken from www. (HMWSSB website accessed on). The project received administrative sanction from government of India for a cost of Rs 339.08 crores to be shared by GOI at 70 per cent and 30 per cent by GOAP. The project proposals include construction of four sewage treatment plants (Amberpet -339 mld, Nagole 172 Mld, Nallacheruvu -30 Mld, Attapur 51 Mld).

irrigated village. The rest of the variations are explained by use larger quantity of seeds and higher costs incurred for land preparation indicating that wastewater use is adversely affecting the productivity of paddy.

Map

4. Objectives and analytical framework of the study

As noted above the broad objective of the paper is to assess the health impact of wastewater irrigation on the households in the villages irrigated with wastewater. The specific objectives are:

1. to examine whether there exists any significant difference in the illnesses or morbidity reported by the households in wastewater irrigated villages in comparison with freshwater irrigated villages and if so to examine its determinants.

2. to estimate the economic cost of illness for the households due to wastewater irrigation.

Availability of wastewater for irrigation in the water scarce peri-urban areas is an externality imposed by the fast growing urban areas in the developing countries like India. In the present study context, wastewater irrigation is both a positive and negative externality of urbanisation. In water scarce peri-urban areas the availability of wastewater although of marginal quality makes agriculture possible. In the absence of wastewater, the households in these villages have to mostly engage in distress migration or remain unemployed. The possibility of carrying out agricultural activities itself is a positive externality. Irrigation with untreated or partially wastewater is a negative externality because the households in the peri-urban areas are exposed to the hazards associated with it. The sewage flow is likely to contaminate the ground water even risking the quality of drinking water. The major health hazard of using wastewater is for the persons who are in contact with it and for those who consume the products contaminated with wastewater. The products grown using wastewater finds its way to the consumers in the urban areas exposing them to the risks of eating crops contaminated with wastewater. In other words, there exist both benefits and costs associated with wastewater use. However, the aim of the present paper is not to measure all the social benefits and social costs associated with wastewater use. The scope of the study is limited to assessing the health cost associated with the use of wastewater for the households living near the wastewater irrigated places.

5. Data and methodology

The analysis of morbidity as well as the economic cost of illness has been carried out using data obtained from a socio economic survey of households selected adopting the sampling procedure explained later in this section in six villages irrigated with wastewater as well as in a village irrigated with freshwater. Detailed information on health and related aspects of each member in the household has been collected using structured questionnaires. Details on illness pertaining to three reference periods prior to the survey mainly (1) during last one month, (2) before 2 to 6 months and (3) before 7 to 12 months thus covering a period of one year prior to the survey has been collected. Information on major illnesses like cancer, heart problems, kidney failures etc have been collected but have been excluded from morbidity analysis. Although we had separate information for the above three reference periods, we have used the information to arrive at figures for a one year period. This is mainly due to take into account the seasonality biases. A preliminary analysis showed that the illnesses reported are general ones like fever, headache, skin itching, body ache, nail problems, swellings, stomach ailments and others which are quite difficult to associate purely with the wastewater use. Therefore, in order to see if there are any significant differences in the morbidity reported by households in wastewater villages we compared the figures with that of a freshwater village. For comparison purpose, we estimated morbidity rates after the initial counts of the number of people reporting any type of illness. Following the methodology given in Sundar *et al* (2002) the morbidity estimates has been constructed in the following manner based on detailed information of morbidity among the current living members of households actually sampled.

Let

T_k = total number of sample household in village k,

S_k = the number of households reporting a sick member

NS_k =the number of households reporting no sickness.

S_{fk}= total number of female members among all households that reported at least one sick member.

S_{mk} = total number of male members among all households that reported at least one sick member.

s_{sfk}=number of sick female members of sampled households

s_{smk}=number of sick male members of sampled households

Let NS_{fk} and NS_{mk} denote the corresponding numbers for all households not reporting any sickness

Given this, we estimated the morbidity rates among the sampled households as follows

Total morbidity among the households reporting at least one sick member = $(s_{sfk}+s_{smk})/s_{fk}+s_{mk})$

Male morbidity among the households reporting at least one sick member = s_{mk}/s_{mk}

Female morbidity among the households reporting at least one sick member =s_{sfk}/s_{fk}

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

$M_{fek}=(S_{sfk}/S_{fk})*(S_{fk}/ (S_{fk} +NS_{fk}))$

$M_{mek}=(S_{smk}/Smk)*(S_{mk}+NS_{mk}))$

The morbidity rates M_{fe} and M_{me} for the total population of all settlements taken together 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. The morbidity rate for the total population is defined to be M_e which is a weighted average of M_{fe} and M_{me}.

Determinants of morbidity: Specification of the econometric model

A logit analysis has been carried out to know the determinants of reporting morbidity by the households. A dummy dependent variable assuming value 1 if the estimated household morbidity was greater than 0, that is the household reporting at least one sick member during the reference period and otherwise zero has been generated.

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 ascariasis infection 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. *As* far as the selection of explanatory variables in this study is concerned, it is assumed 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 of the households make them more vulnerable to diseases than others

(4) Socioeconomic conditions of the households can influence the health status of the households and thereby morbidity.

Based on this assumption, the following variables were included as explanatory variables. The rationale for including the below given independent variables and the signs expected are as follows. It is hypothesised that the households belonging to wastewater irrigated area are more likely to report morbidity because of either direct or indirect exposure to wastewater. Therefore, the coefficient of the variable 'vil_c' is expected to have a positive sign. The ownership of land (ow_land) represents whether the households are landless or not. While it can be argued that ownership of land increases the probability of getting exposed to wastewater by way of engagement in agricultural activities, here we argue that ownership alone does not mean more exposure and households having more land can be employing labourers to work in their fields. Based on this argument we hypothesize that those owning land is less likely to report morbidity. It also reflects better economic status of the households and better standard of living and therefore a better health status.

Table1. Description of variables included in the logit model with their expected signs

Variable	Explanation	Expected sign	Attribute represented
Ow_land (Dummy)	Ownership of land 1= those owning land 0= otherwise	Negative	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	Exposure
H-agila (Dummy)	Hired agricultural labour 1= Yes; 0= otherwise	Positive	Exposure
Totmem	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
Age_av	Average age of the members in the household	Positive	Vulnerability to diseases
Edu_head	Education of the head of the household	Negative	socioeconomic
Fuel (Dummy)	Fuel used for cooking 1= solid fuel; 0= otherwise	Positive	Vulnerability to diseases and living conditions
Migla (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
Vil_c	Whether the households belong to wastewater or freshwater irrigated villages 1=wastewater irrigated village; 0= otherwise	Positive	Exposure

The quality of drinking water is a major cause for many water borne diseases. In the study villages boiling is the major form of treating drinking water. Therefore, it was hypothesised that those who treat water before drinking are less likely to report morbidity and a negative sign is expected for the coefficient of the variable ‘treat’. Livestock rearing is an important way of transmitting nematode eggs and other viruses or bacteria to humans. Households owning livestock (ow_livestock) are more likely to be exposed to the risks involved in getting diseases and therefore the coefficient of the variable is expected to have a positive sign.

The education of the head (edu_head) of the household was also included as an explanatory variable. It is assumed that education of the head of the household improves the level of awareness of the family and the need to adopt precautionary methods to protect the household members from the risks of wastewater irrigation. On this ground, the coefficient of the variable was expected to have a negative sign.

Being an agricultural labourer (agri_lab) increases the exposure and contact with wastewater which in turn increases the probability of reporting morbidity. Therefore, the coefficient of the variable agri_lab was hypothesised to have a positive sign. Similarly, as family size (family_size) increases the probability of reporting morbidity also increases. As a result, the coefficient of the variable family_size is expected to have a positive sign. Similar is the case of the average age of the household members based on the assumption that households with older people are more likely to report morbidity. A positive sign for the coefficient of the variable avg_age was expected.

It was also hypothesised that the morbidity effects could differ even across wastewater villages according to the proximity to the city which in fact is also correlated with the quality of wastewater. A household in those villages which are in the peri-urban areas where the quality of water is relatively poor is hypothesized to report higher morbidity. Therefore, it was expected that the coefficient of the variable 'ru-urban' to have negative side.

In addition to the above mentioned variables, 'caste' which represents the socioeconomic backwardness of the households was also expected to have a positive sign. The household's hygienic and sanitary practices could also be an important determinant of morbidity. It is also further expected that being a migrant labour increases the exposure to wastewater risks and therefore they are more likely to report morbidity. The coefficients of these variables were expected to have positive signs.

The estimable logit model has been specified as:

The estimable logit model has been specified below (see Gujarati, 1988; Green, 1993) and the results are discussed in section 6.

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

Cost of illness

In this study, we have tried to establish values for illness reported by the households by identifying the cost-generating components and attempts to attribute a monetary value to them. This in fact can be termed as an 'opportunity cost' the value of the forgone opportunity to use money and other resources that are lost due to illness in a different way. The cost of illness in this study 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. Ideally, we would have liked to be able to estimate these expenditures at the most disaggregate levels. We ran into a number of difficulties and constraints in attempting that. A major difficulty was that given the low levels of literacy and awareness of the households we did not obtain much information from the respondents on different items separately. While some households were able to give disaggregate figures, majority was able to give only the aggregate figures on medical expenses incurred for one episode of illness. Although direct costs include a number of items such as medical care expenditures for diagnosis, treatment, continuing care etc, we had difficulties in obtaining data. Medical care expenditures may also include those for in-patient and outpatient expenditures. In our study context, there were no in-patient medical expenses reported for the reported illnesses. Furthermore, it is possible that the presence of an illness may influence the direct costs in the future, which are not accounted for. Some of the other costs included but not separately reflected upon in the study include costs of transportation to health providers or hospitals. Indirect costs are those mainly resulting from the loss of workdays because of illness or mortality. The indirect costs include the loss in work income and averting expenditures incurred by the households to limit their direct exposure to wastewater or to protect themselves from the adverse effects of it. The major components of output loss are earning loss. In addition to the loss of opportunity to work due to illness, it is possible to have adverse effects on productivity while on the work. For averting expenditures, it has been difficult to ascertain the cost incurred for boiling water which the major is averting expenditure incurred by the households. 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 is not taken into account in this study, as data was not available.

Sample selection

In this study, we had selected six wastewater irrigated and one freshwater irrigated villages for in-depth study. The villages were purposively selected based on the results of previous studies conducted by the International Water Management Institute and was according to the difference in the quality of the wastewater used for irrigation. These villages belonging to Nalgonda and Ranga Reddy districts represent different zones such as urban-periurban and rural (Table 1). The freshwater irrigated village, the control village in the study was selected after carrying out water quality analysis of irrigation water. We selected a village where the quality of water used for irrigation was within the permissible limits for irrigation. In each of the seven villages, in the first stage a survey was conducted to collect baseline information and to list all the households. In the second stage, sample households were selected based on stratified random sampling procedure. Here ownership of land has been the stratum used. About 15 per cent 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 gives the details of sampling.

Table 2: Distribution of Sample Households

Village	District	Total number of households	Sample households
Pillaipally	Nalgonda	552	84
Chinna Ravirala	Ranga Reddy	246	39
M Anantaram	Nalgonda	265	41
Qutbullapur	Ranga Reddy	492	73
Kachivani Singaram	Ranga Reddy	465	70
Parvatapur	Ranga Reddy	291	54
Vallala	Nalgonda	733	110
All Villages		3044	471

6. Results and Discussion

Before presenting the analysis of morbidity, it is worthwhile to provide a brief socio economic profile of the sample households. Out of the 471 households surveyed 275 (58 per cent) are landless. Among those, owning land 61 per cent and 22 per cent are respectively marginal and small farmers having average land of 1.17 acres and 3.14 acres. Socially over 60 per cent belong to backward communities (BC) and about 20 per cent each to other communities (OC) and to Scheduled Castes (SC). The average size of the household is 4.5 and ranges from 3.8 in the freshwater irrigated village to 5 in Parvatapuram and Makta Anantaram. The overall sex ratio is 946, and high figures of 1111 and 1019 have been observed in Qutbullapur and Kachivani Singaram whereas the lowest is in Vallala. Literacy levels of the villages are very low. When we consider the literacy levels of all the members in the households it is seen that only 36 per cent are literates where as illiteracy is as high as 60 per cent among the heads of the household. The main activity of the about 30 per cent of the head of the households is own farm activity, followed by 16 per cent working as agricultural labourers and another 13 per cent as non-agricultural labourers. About 102 households (22 per cent) are engaged in livestock rearing and dairy activities. Against this backdrop, we undertook a detailed analysis of health related aspects as per the methodology given in the previous sections.

A number of illnesses have been reported by the households in the study villages. However, most of them were common illness like head ache, fever, skin itching, body ache, nail problems, swellings, stomach ailments, and other health problems. Out of the 471 households surveyed nearly 50 per cent (231 households) reported illness of at least one family member during the reference period of the survey. This is approximately 337 or sixteen percent of a population of about 2096. Based on the counts the major illnesses reported by the households are fever, body aches, skin itching and stomach ailments. When the reported number of cases of illness is categorised gender wise, it is seen that more number of females have reported various illnesses. Similarly, in comparison with children more illness is reported for the adult members during the reference period. However, these absolute figures provide only a glimpse of the health scenario and not much can be conclusively drawn on its basis. In order to get more insights we estimated the morbidity rates in the study area using the methodology given in an earlier section.

Table 3. Distribution of illness reported by household members

Village	Head ache	fever	skin itch	body ache	Nail problems	Swelling	stomach ailments	other health probl	Male	Female	children	adults	To
Pillaipally	2	13	18	8	7	6	4	25	16	67	2	81	83
Chinna Ravirala	2	22	6	4	1	3	3	7	12	36	3	45	48
M Anataram	0	4	6	11	1	0	5	13	8	32	4	36	40
Qutbullapur	1	16	5	9	0	8	4	14	12	45	3	54	57
Kachivani Singaram	0	10	4	9	4	1	7	2	6	31	3	34	37
Parvatapur	0	3	8	7	6	2	2	2	6	24	1	29	30
Vallala	0	16	0	10	0	1	9	6	3	39	4	38	42
All Villages	5	84	47	58	19	21	34	69	63	274	20	317	33

Two sets of morbidity figures have presented in the following table. One is for the households reporting at least one sick member in the reference period and the other is for the entire households surveyed. As pointed out earlier 231 households reported at least one member reporting illness. The estimated morbidity rates per thousand have been 146 for males and 693 for females. Irrespective of gender, the morbidity rate is 394 per thousand population. However inter village differences in morbidity rates have been observed.

The morbidity estimates following the procedure delineated above gives some interesting insights. Firstly, it appears that there are inter village differences in the levels of morbidity both for the entire sample and for those households who reported at least one sick member during the reference period. In both cases stark differences in the male and female morbidity rates have been observed with female morbidity rates several times higher than that of male morbidity. This trend is true for both freshwater irrigated as well as wastewater irrigated villages. The highest male and total morbidity rates have been observed in Chinna Ravirala whereas it is in Makta Anantaram for female morbidity. Similar high rates of morbidity are found in Qutbullapur, Pillaipally, and Makta Anantaram although the ranking differs slightly across gender specific morbidity rates. The differences exist whether one takes into the account the morbidity of households which reported at least one sick member or for the entire sample households surveyed in the respective villages as well. The highest morbidity rates have been observed in Chinna Ravirala followed by Pillaipally and Makta Anataram.

Table 4 Estimates of Morbidity in the Study Area

	For the households reported at least one sick member				For the entire sample		
Village	Male	Female	Total	No. of hhs	Male	Female	Total
Pillaipally	151	713	422	53	95	432	258
Chinna Ravirala	335	830	517	21	166	481	314
M Anantaram	153	886	395	25	93	539	303
Qutbullapur	159	649	443	41	82	353	225
Kachivani Singaram	112	537	324	32	45	253	150
Parvatapur	84	611	317	21	32	237	129
Vallala	79	684	332	38	28	244	127
Total	146	693	394	231	70	345	203

From the above tables, it is clear that there is a need to look more closely at the morbidity reported in the study villages and to examine whether the differences observed across villages including freshwater villages are statistically significant. It is also important to examine the determinants of morbidity at household level. The important question to be addressed here is whether the reported morbidity is due to the wastewater or not. We used a logit model to understand the determinants of morbidity and to figure out which type of households is more likely to report morbidity. The results of the logit model yield interesting insights. Most of the variables are having the expected signs.

As was expected when compared to landless those owning land households are less likely to report morbidity. Similarly, those who adopt some type of defensive measures like boiling drinking water are also less likely to report morbidity. Those households who are more exposed to wastewater or wastewater based activities are more likely to report morbidity. For example, the coefficients of the variables H_agrila, miglab are positive and statistically significant at one per cent and 5 per cent significance levels respectively. Likewise, those households who possess livestock and therefore, more exposed to wastewater are likely to report illness. The coefficient of the variable age_av was positive and statistically implying that households with older members are likely to report more 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. However, although the coefficient had expected sign was not statistically significant. Similar is the case with households belonging to schedule castes, those with larger family size, and those with literate or educated heads.

Table 5 Determinants of Morbidity in the Study Area

	Coef.	Std. Err	t-Value	Significance level
Vil_c	1.17816	0.29599	3.98	0
Ow_land	-0.47819	0.23788	-2.01	0.044
Treat	-0.82024	0.48111	-1.7	0.088
Ow-Livestock	0.46832	0.25320	1.85	0.064
edu1	0.00163	0.05699	0.03	0.977
Agri_lab	0.76531	0.22443	3.41	0.001
Totmem	0.00483	0.06597	0.07	0.942
Fuel	0.12505	0.20283	0.62	0.538
Age_av	0.02223	0.00929	2.39	0.017
Ru_urban	-0.57246	0.23753	-2.41	0.016
Caste	0.24962	0.24078	1.04	0.3
Pvt_toilet	-0.03769	0.12746	-0.3	0.767
Migla	2.23759	1.13148	1.98	0.048
Constant	-1.71520	0.60234	-2.85	0.004
Number of Observations =471 LR Chi2 (13) = 57.01 Prob> Chi2=0.000 Pseudo R^2=0.0873				

The coefficient of the variable of pvt_toilet although has negative sign as per expectation was not statistically significant. However, two variables representing the proximity of wastewater and the intensity of wastewater based activities are presenting interesting results. The variable vil_c which represent whether the villages are wastewater irrigated or not is positive and statistically significant at 1 per cent level of significance. This means that when compared to freshwater irrigated villages, the households in the wastewater irrigated villages are more likely to report morbidity. Similarly, the variable ru_urban is also conveying important results. This variable represents whether the villages are in the peri-urban or rural zones. Here the coefficient is negative and statistically significant. Although the quality of wastewater is relatively better in rural zone, the high incidence of morbidity could be because of the reason that the households members in the rural zone have more contact and exposure to wastewater and wastewater based activities in comparison with urban households. In the peri-urban zone a large number of households are engaged in non-agricultural and non-wastewater based activities and have less contact with wastewater.

On the whole, it is seen that the higher morbidity observed in wastewater irrigated villages in comparison with freshwater irrigated village is statistically significant. It is also seen that female and adult morbidity are more when compared to male and child morbidity. This can be due to the reason that by way of various agricultural activities females and adults in general have more exposure to wastewater. However, since the illness reported are mainly common ailments like fever, headache, skin itching, body ache, nail and stomach problems it is difficult to trace out the cause and effect relationships. From the analysis it is clearly seen that those who own land, who belong to peri-urban areas where the proportion of population engaged in wastewater based activities is 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.

Given this situation, the cost of illness was estimated as per the methodology given above. The average cost of illness per household across all villages in year is about Rs 3048. It is seen that the cost of illness which includes both wage loss and the medical expenditure incurred by the family ranges from Rs 2058 in Kachivani Singaram to Rs 4454 in Qutbullapur per household per year. This is equivalent to 2 to 4 days of wage income loss per month for a male worker in the 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. 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 freshwater irrigated and wastewater irrigated villages are not statistically significant.

Table 6: Estimates of the cost of illness incurred by the households in a year (in Rupees)

Village	Average wage loss for the household in a year (Indirect cost)	Average medical expenditure per household in a year (direct cost)	Average cost of illness per household in a year (direct+indirect)
Pillaipally	1166.60 (53.13)	1029.25 (46.87)	2195.85
Chinna Ravirala	1597.14 (39.29)	2468.10 (60.71)	4065.24
M Anantaram	1771.25 (63.59)	1014.17 (36.41)	2785.42
Qutbullapur	1443.66 (32.41)	3010.24 (67.59)	4453.90
Kachivani Singaram	784.69 (38.13)	1217.19 (59.14)	2058.13
Parvatapur	292.86 (7.53)	3597.62 (92.47)	3890.48
Vallala	1781.84 (66.15)	864.47 (32.09)	2693.68
Total	1287.13 (42.22)	1745.61 (57.26)	3048.39

Cost-of-illness estimates are considered a lower bound of the actual costs incurred as the estimate does not include the social costs incurred (Drummond, 1992; Jefferson, et al., 1996; Wilson, 2000).

7. Conclusion

Irrigation with wastewater is considered as a beneficial use of it in water scarce regions. Being of marginal quality, irrigation with wastewater not only affects agricultural productivity but also give rise to health problems as well. This is because of the contaminants present in the water. This paper attempted to elicit the health problems faced by the villagers in wastewater irrigated areas in comparison with freshwater irrigated ones. Significant differences in the morbidity rates were observed in both types of villages with households in wastewater irrigated villages reporting high morbidity. It is seen that female morbidity is higher than that of male morbidity. The type and extent of exposure to wastewater places the households in high or low risk groups. The analysis shows that households belonging to wastewater irrigated villages are more likely to report morbidity so is the case where households belonging to rural zone. Although the quality of water is relatively better in rural zone, households are engaged in activities, which expose them directly to the risks associated with wastewater. The analysis also shows that morbidity also results in significant economic cost for the households. At the current wage level the loss in income due to illness is approximately equivalent 2 to 4 days of wage income loss per month for a male worker in the household or 3 to 6 days for a female worker when estimated at the prevailing wage rates in the villages. This is not only a substantial welfare loss for the households but also it is borne disproportionately by certain categories of households. Although the availability of wastewater is a beneficial in the water scarce regions fact that it gives significantly lower yields for the same amount of inputs used and that it gives rise to various health problems calls for better treatment of wastewater. Therefore, treating wastewater up to the standards recommended for irrigation is of utmost importance not only due to health reasons but also for improving agricultural productivity. The recent steps taken by the Greater municipal Corporation of Hyderabad to set up treatment plants is a welcome step in this direction. Along with this steps must also be taken to create better awareness among the people who are in direct contact with wastewater to adopt precautionary and defensive measures like the use of gloves etc. An interview of the medical practitioners also pointed out the need to adopt defensive measures as in the case of most patients symptoms disappeared when their contact with wastewater is minimised or fully controlled.

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