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Wastewater irrigation in the developing world—Two case studies from the Kathmandu Valley in Nepal

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ABSTRACT

Wastewater irrigation in the Kathmandu Valley is a widespread but poorly documented practice. This paper presents data from two case study sites, the Kirtipur and Bhaktapur municipalities of the Kathmandu Valley. An overview of existing urban wastewater disposal infrastructure, wastewater agriculture practices and quality of water used, the health implications of these practices and the level of institutional awareness of wastewater related issues are presented and compared with wastewater irrigation in other regions of the world where irrigation with wastewater is practiced. Data for the analyses on agricultural practices and health implications were obtained from a sample of 109 farmers using wastewater within the two municipalities. Bhaktapur typified direct utilization of wastewater by pumping from sewers whereas Kirtipur farmers used it indirectly by gravity flow from polluted rivers. Central to the discussion is that farmers here do not always choose to use wastewater but exploit its benefits when obliged to do so. Since the wastewater also changes the hydrology of the watercourse rendering it perennial, many farmers see the benefit of utilizing the resource. The negative attitude of some farmers towards wastewater stemmed from their inability to control wastewater application leading to flooding and loss of crops. The majority of farmers are well aware of negative health impacts particularly those related to skin infections, and they attempt to protect themselves through washing. No change in water quality can be expected without infrastructure investments and wastewater management changes, which are slow in coming due to the lack of institutional awareness about the complexity of the problem. Interaction amongst the various stakeholders through a formalized mechanism, to influence the disposal and reuse of wastewater is suggested.

1. Introduction

Wastewater irrigation has recently emerged as a focus of study in the developing world where its use by urban and peri-urban farming communities is increasingly becoming a livelihood reality. Poor wastewater infrastructure on the one hand leading to contamination of otherwise clean irrigation water sources, and increasing water shortages on the other, have created the conditions under which farmers turn towards wastewater as a reliable source of irrigation. In arid regions, wastewater is especially valued for its reliability besides the added benefits from contained nutrients (Van der Hoek et al.,

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2002). In humid regions, such as Nepal and Vietnam, wastewater agriculture is largely the result of the unplanned pollution of irrigation sources with wastewater (Raschid-Sally et al., 2004a).

The extents of direct and indirect[1] use have not been systematically documented globally. Limited studies conducted by IWMI show that in the city of Kumasi Ghana, around 11,900 ha of peri-urban agriculture areas use untreated wastewater, compared with less than 6000 ha of "formal" irrigation for the entire country (Keraita et al., 2002). In Vietnam, a nationwide survey using size-stratified sample cities, indicated approximately 7000 ha of wastewater irrigated area within metropolitan boundaries of cities, but it was clear that this was not representative of total areas which extend well beyond city boundaries (Raschid-Sally et al., 2004b). A similar exercise in Pakistan estimated 30,600 ha (Ensink et al., 2004). Along the Musi River in India, an estimated 9675 ha of agricultural land is irrigated by wastewater within a 70 km radius, within the boundaries as well as downstream of the twin cities of Hyderabad–Secunderabad (Buechler and Gayathri Devi, 2005). In water scarce situations, recycling of treated or partially treated wastewater is a common practice. Available data suggest that approximately 350,000 ha in 75 cities are directly irrigated with wastewater, and 550,000 ha in 17 cities are irrigated indirectly (Van der Hoek, 2004). A non-exhaustive literature review undertaken to assess the extent of the practice in specific regions of the world, indicate that in Latin America a total of more than 500,000 ha of agricultural land is irrigated with wastewater (Chanduvi, 2000). Of these 350,000 ha are in Mexico alone (Peasey et al., 2000). In the near eastern region, which is one of the most water scarce regions in the world, documented evidence shows that wastewater irrigation is extensive notably in Saudi Arabia, Kuwait, Israel, Jordan, Tunisia and Morocco (AQUASTAT–FAO database, 1997). In countries of the former Soviet Union, literature indicates that at least 70,100 ha are irrigated with wastewater (FAO Water Reports, 1997). These examples are indicative of the importance of wastewater recycling both in developing and developed contexts. Extensive use has also been documented in water scarce developed regions of Northern America, Europe and Australia (Angelakis et al., 1999; Crook, 2003; Lallana et al., 2001).

A review of literature for the situation in Nepal has shown that wastewater irrigation is not well documented in spite of it being widespread. The Kathmandu Valley is a burgeoning metropolitan area of 1.4 million inhabitants with poor wastewater disposal infrastructure, drained by the Bagmati River, and, surrounded by agricultural lands. Fifty-nine percent of the valley is agricultural of which 20% is formally irrigated. Informal irrigation occurs in parts of the urban and peri-urban areas of the valley, where lack of adequate wastewater treatment facilities and low rainfall during the dry winter season (November–April) has led to extensive use of wastewater for agriculture. This paper presents an overview of existing urban wastewater disposal infrastructure, wastewater agriculture practices and the quality of water used, the health implications and the level of institutional awareness of wastewater related issues in the Kathmandu Valley, using two case study sites, the Kirtipur and Bhaktapur municipalities. Its central focus is to elucidate farmer perception and responses to a situation over which they have essentially no choice or control and their perception of its health implications.

2. Methodology

The study was conducted through a literature review, field reconnaissance for familiarization and identifying sample locations, farmer surveys, water quality sampling and a rapid review of wastewater infrastructure and institutional awareness of how authorities perceive its use. The study sites selected were the Bhaktapur and Kirtipur municipalities of the Kathmandu metropolitan area, with populations of 62,199 and 40,835, respectively (see Fig. 1).

Water sampling in the Bhaktapur case study area was done in the Hanumante River and the Khasyang Khusung Khola (stream). Bi-monthly grab samples were taken from each river from two sampling locations one upstream and one downstream of the main city wastewater discharge points covering the period September–December which is just after the monsoon rains. The intention was to characterize the extent of dilution during the wet season. Data for the dry season were not collected in this study on the assumption that wet season values would be indicative of the best conditions occurring at the sampling locations. If these values were below the requirement of irrigation water quality guidelines then the dry season values would be even less acceptable. The parameters analysed were dissolved oxygen (DO), biochemical oxygen demand (BOD_5), ammonia, orthophosphate, nitrates and fecal coliforms, using international standard methods for wastewater analyses (Leonore et al., 1999). Water quality data for the Kirtipur case study area were not analysed in this study but were obtained from Kirtipur Environmental Mapping Project (NSET, 2000). Orthophosphate data were not available in the Kirtipur study but these parameters were tested in Bhaktapur because of its influence on agricultural yields.

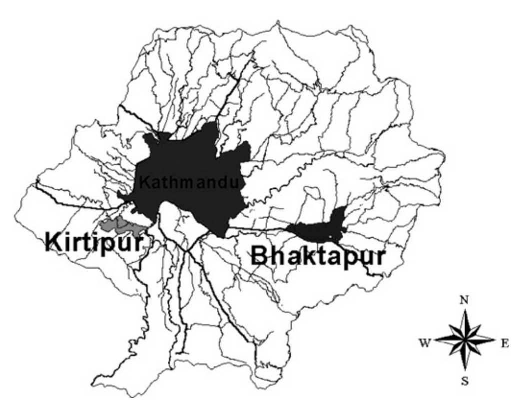

Fig. 1 – Location of study areas within the Kathmandu Valley.

[1] The terms direct and indirect refer to the conditions under which wastewater is applied in irrigation. Direct use refers to undiluted use of wastewater extracted from its source. Indirect refers to a certain level of dilution taking place through natural or artificial means, before use.

Table 1 – Chikhu Khola water quality data

Parameter	Sampling locations			
	Just downstream of city discharge		1.3 km downstream	
	September 1999	February 2000	September 1999	February 2000
Temperature (°C)	20	16	20	12
pH	7.40	7.20	7.70	7.64
Conductivity (dS/m)	0.333	1.028	0.492	0.398
Ammonia (mg/l)	10.98	81.6	12.63	25.5
Nitrate (mg/l)	1.44	6.09	6.31	1.37
Dissolved oxygen (mg/l)	1.95	0	4.28	4.5
BOD_5 (mg/l)	5.64	339.00	14.82	11.80
COD (mg/l)	65	640	40	31
Total coliform count (MPN/index 100 ml)	1.1×10^3	1.1×10^6	1.1×10^3	1.1×10^5

Source: Kirtipur Environmental Mapping Project (2000).

One hundred and nine farmers in Bhaktapur and Kirtipur, 89% of whom were using wastewater, were interviewed using a standard questionnaire which addressed land holdings, cropping pattern, irrigation practices (frequency, sources, methods) and negative health impacts related to wastewater irrigation. There was no defined recall period for health effects as the intention of the survey question was to understand if they perceived a health effect related to wastewater exposure.

Information on sanitation practices and wastewater infrastructure including industrial wastewater was collected from existing reports and grey literature and through discussions with municipality officials using a structured interview format. This included also a rapid review of the institutional environment and the level of knowledge and awareness amongst officials from the irrigation department and extension services about wastewater agriculture in the valley.

3. Results

3.1. *Overview of urban wastewater infrastructure in the metropolitan area*

3.1.1. *Domestic wastewater*

On an average, only 50% of households in the five municipalities of the Kathmandu metropolitan area were connected to combined sewers, carrying both domestic waste and storm water. About 40% of households still used septic tanks but more than one-half of this number drained directly into rivers without passing through soakage pits. Estimates of wastewater generated in the area varied, ranging from 62 million liters per day (MLD) (Metcalf and Eddy, 2000) to 120 MLD (Darnal, 2002).

3.1.2. *Industrial wastewater*

Industries contributed 20% to Nepal's Gross Domestic Product with Carpet, Readymade Garments and Leather contributing 65% to total exports. Six percent of total wastewater generated was estimated to be from industry, mostly carpet dyeing and washing wastewater (Green, 2003) which is acidic and usually highly colored. These effluents may also contain heavy metals. Effluents from wool processing and dyeing industry, tested at Nepal Bureau of Standards and Metrology Laboratory[2] indicated that they do not comply with the Nepal standard 229 Part 2 for effluents from the wool processing industry.

There were three main industrial areas accommodating about 16% of the industrial units and the rest were scattered across the valley. Only one of the industrial areas was served with a wastewater treatment plant (Metcalf and Eddy, 2000). No information was available on the quality of the treated effluent. Domestic and industrial wastewaters were collected in the same network.

3.1.3. *Wastewater treatment*

There were five municipal wastewater treatment plants with a theoretical capacity of 36.3 MLD but current treatment capacity was estimated to be between 15 and 30% of wastewater generated. Four of the treatment plants used lagoon system but all were either partial or non-operational at the time of the study and in poor condition (Green et al., 2003). The result was that nearly 75% of wastewater generated, at best only partially treated, drained into the valley's waterways affecting irrigation water sources.

3.2. *Water quality in the study locations*

In Bhaktapur, wastewater drained into the Hanumante River (perennial) and the Khasyang Khusung Stream (seasonal), while in Kirtipur, the Chikhu Khola Stream (seasonal) received wastewater. In the dry winter season, these seasonal streams usually run dry. Currently, however, stream flows are augmented by domestic sewage to the point where the streams flow year-round.Water quality data from Kirtipur's Chikhu Khola (Table 1) as reported by Kirtipur Environmental Mapping Project (2000) showed that wet season (September) values for the parameters tested do not change substantially between city discharge location and downstream locations possibly due to the dilution factor. However, in February, the driest month of the year, the study reported high levels of ammonia, BOD_5 and total coliform counts in samples just downstream of city discharge indicating sewage pollution of

[2] From a report prepared by a Finnish Technical Assistance Project: http://www.fncci.org/ecolabelproject/casestudy/case.html.

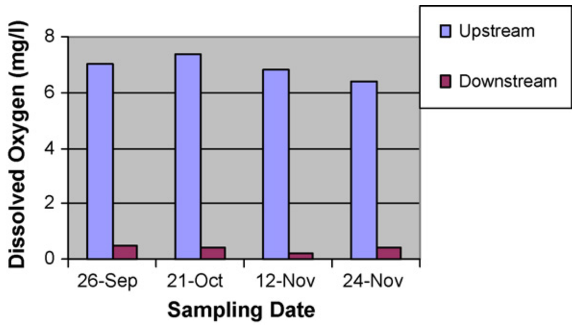

Fig. 2 – Hanumante River, dissolved oxygen.

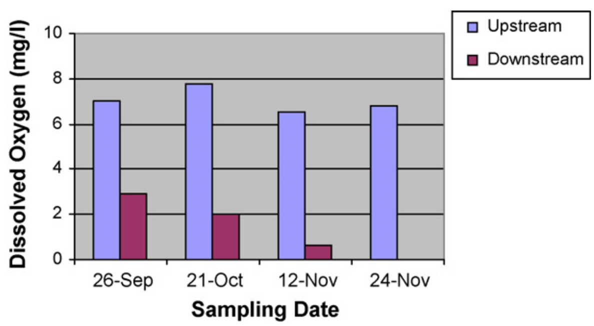

Fig. 3 – Khasyang Khusung Stream, dissolved oxygen.

the stream. Discharge data at a point 1.3 km downstream showed higher flows which may lead to dilution and explain the prevalent better water quality (except for ammonia). Irrigation water quality standards are however not met.

A more detailed temporal analysis of water quality in Bhaktapur case study area (Figs. 2–5) was carried out spanning the wet season only, to gain an understanding of variation in water quality within a season in a perennial river (Hanumante) and a seasonal river (Khasyang Khusung). For dissolved oxygen, all eight downstream samples were far below 5 mg/l which is a typical raw water standard for a drinking water intake (Metcalf and Eddy, 2000). The Hanumante showed no major fluctuation in values between the end of the monsoon to the start of the dry season but the Khasyang Khusung showed variation because of decreasing dilution capacity.

For the biochemical oxygen demand, all samples exceeded 10 mg/l which is the typical BOD value for raw water sources to be used for drinking water supply. At the start of the dry

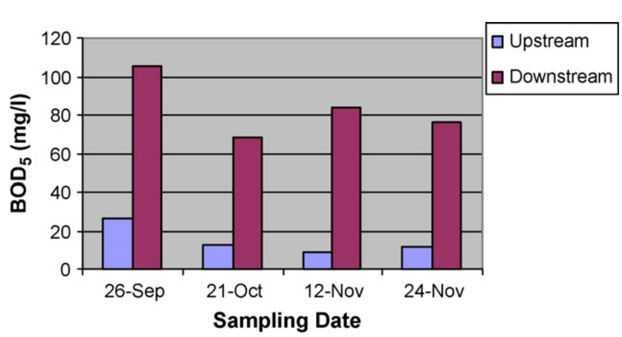

Fig. 4 – Hanumante River, BOD_5.

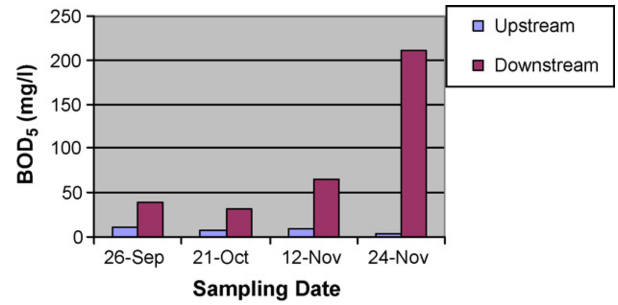

Fig. 5 – Khasyang Khusung Stream, BOD_5.

season, the seasonal Khasyang Khusung showed high BOD indicating that it is carrying mainly wastewater.

The Hanumante River shows preliminary high levels of BOD at the start of the rainy season, due to surface runoff carrying wastes from urban areas, followed by lower levels due to dilution. These BOD levels are equivalent to those of weak and medium strength domestic sewage, respectively (McGhee, 1991).

Fecal coliform levels were noticeably high at both downstream locations (Table 2). The highest fecal coliform level, 2.2×10^8, was sampled in the Hanumante River downstream of the municipal discharge point. All downstream fecal coliform levels exceed the WHO irrigation standard for unrestricted irrigation (10^3 coliforms per 100 ml).

Orthophosphate and nitrate levels exceeded FAO standards in some cases. The FAO orthophosphate standard of 2 mg/l was exceeded in three out of the eight downstream samples but the nitrates only in one. Khasyang Khusum being seasonal was the most affected by these parameters with the highest values recorded as 6.1 mg/l of phosphate and 10.26 mg/l of nitrate.

Electrical conductivity and chloride levels (which are translated into salinity measurements) were within acceptable standards.

3.3. *Farming profile and wastewater irrigation practices*

3.3.1. *Landholdings*

The study was limited to a sample of 109 farmers thought to be using wastewater for irrigation. The sample of farmers had a total land holding of 14.2 ha.

Seventy-one percent of the land in the study areas was owned by the farmers. About 84% of the land area is irrigated with mainly wastewater of which 40% is direct sewage irrigation.

The average size of landholding in Bhaktapur and Kirtipur was 0.16 and 0.11 ha, respectively, which compares with farmers in Ghana (Keraita et al., 2002). The farming households typically use family labor for irrigation, weeding and harvesting, a pattern which is also observed in Pakistan (Van der Hoek et al., 2002) and Cameroon (Raschid-Sally et al., 2004a). Laborers are sometimes hired to help with paddy (rice) planting.

3.3.2. *Cropping pattern*

The predominant summer crop is rice (Table 3). In the winter season, though farmers cultivate both vegetables and wheat,

Table 2 – Fecal coliforms (counts per 100 ml)

Date	Hanumante River		Khasyang Khusung Stream		WHO (1989) guideline fecal coliforms (geometric mean no per 100 ml)
	Upstream	Downstream	Upstream	Downstream	
26 September 2003	290	2.2×10^8	5×10^3	7.1×10^5	Unrestricted $< 10^3$
21 October 2003	350	1.48×10^5	640	350	
12 November 2003	260	3.2×10^5	250	4.3×10^5	
24 November 2003	1460	1.49×10^5	230	1.96×10^5	Restricted $< 10^5$

Table 3 – Cropping pattern (% of respondents)

	Summer crops		Winter crops	
	Rice	Vegetable	Vegetable	Wheat
Bhaktapur	61	37	96	16
Kirtipur	93	15	85	58

the preference is for vegetables particularly in Bhaktapur where 84% of farmers cultivated only vegetables. Common vegetables include cauliflower, garlic, beans and onions.

3.3.3. *Source of irrigation water and method of application*

Overall 34% of the study sample of farmers used untreated domestic sewage by plugging sewers to divert the sewer water. This was predominant in Bhaktapur where nearly 70% of the farmers used it. In Kirtipur, the major source was polluted water from the river—more than 70% diverted or pumped polluted river water (Fig. 6). A small percentage of farmers interviewed (11%) have access to clean water from wells or from upstream of the river.

The preferred method whatever the source, is gravity flow irrigation (Fig. 7). However, in Bhaktapur, because of the field topography, access to river water is mainly through pumping while in Kirtipur gravity flow is possible. Between 10 and 20% of the farmers, irrigate manually with buckets, also observed in Ghana (Keraita et al., 2002). Frequency of irrigation was four to five times more in winter (the dry season) than in summer. This coincides with the highest pollution levels in the water sources used.

3.3.4. *Wastewater flooding and crop damage*

Flooding is a significant hazard for farmers located adjacent to the Chikhu Stream in Kirtipur. Seventy-five percent of Kirtipur farmers interviewed stated that their land is regularly flooded during the monsoon season and 38% of the farmers complained of resulting crop damage. Flood waters leave behind mounds of garbage, animal bones and broken glass. Farmers have tried various preventive measures like building dykes and raising the level of plots to overcome this problem. They complain of over-fertilization as a result of flooding.

3.4. *Health and environmental perception*

Eighty-nine percent of the farmers interviewed are cognizant of the fact that wastewater irrigation can negatively impact health (Table 4). At least one-half of the farmers (55% of sample) have personally experienced, or have had a family member experience skin problems as a result of irrigating with wastewater. The skin problem consists of itching and blisters on the hands, feet and lower legs. Kirtipur farmers had a much higher incidence (63%) of skin problems than those from Bhaktapur. Only two farmers related having suffered from intestinal parasites. This study focused on farmer *awareness* and not actual incidence which would require analysis of stool samples.

Farmers' response to health risk is to wash the parts of their bodies exposed to wastewater (arms and legs) with soap in order to prevent skin problems. They also apply substances like body creams and mineral oils like kerosene and diesel, to exposed skin before entering the fields. Only 5% of the farmers, all of whom are from Bhaktapur, claim to be "accustomed" to the polluted water, not having noticed any symptoms.

3.5. *Farmer awareness of benefits*

Farmers at the two sites perceive the benefits of wastewater differently because of the way irrigation is practiced. All Kirtipur farmers have a negative reaction possibly due to the effects of wastewater flooding which they are unable to control. They are unhappy about being forced to irrigate with "dirty" water.

Conversely, Bhaktapur farmers seem to take advantage of this reliable source of irrigation water by plugging sewers to have access to it, and planting entire plots of vegetable cash crops like cauliflower, garlic, beans and onions in the dry season months from November to April. This is commonly practiced by nearly 70% of the Bhaktapur respondents. Being able to control wastewater flows may be the reason for their positive reaction.

Table 4 – Combined health impacts (% of farmers interviewed)

	Aware of negative health impacts	Accustomed to polluted water	Symptoms in farmers and family members		
			Skin problems	Headaches	Intestinal parasites
Bhaktapur	92	11	45	3	2
Kirtipur	87	0	63	5	2
Combined sample	89	5	55	4	2

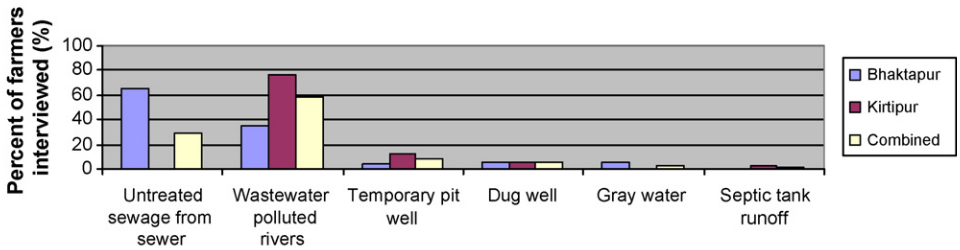

Fig. 6 – Irrigation water sources.

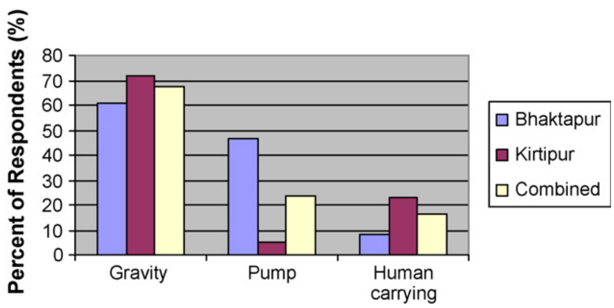

Fig. 7 – Irrigation energy sources.

3.6. *Institutional awareness of extents and practices*

Key officials interviewed at national level from His Majesty's Department of Irrigation, and at the district level from the Kathmandu Valley District Irrigation Department, have no information on the extents of formal or informal use of wastewater. Wastewater use in agriculture is not regulated. A review of legislation showed that national standards, guidelines and related planning regulations do not address health concerns linked to wastewater agriculture. Discussions with officials indicated that the different institutions dealing with irrigation, agriculture, sanitation and sewage disposal, environment and public health and spatial planning who influence the practice of wastewater irrigation do not work in harmony.

4. Discussion

4.1. *Interpretation of survey results*

Urban wastewater collection treatment and disposal infrastructure in the Kathmandu Valley is inadequate and has led to sewage pollution of water sources commonly used for irrigation as described by the two case studies.

The metropolitan area of Kathmandu is surrounded by agricultural land, 80% of which is under informal irrigation. The case study areas of Kirtipur and Bhaktapur are typical examples of informal peri-urban irrigation with untreated municipal wastewater or wastewater polluted river water. In the study area, 84% of the land is irrigated with wastewater of which 40% is directly irrigated with sewage. In the absence of alternative water sources, the majority of farmers use wastewater. Furthermore, the daily discharge of domestic wastewater into seasonal stream-beds have made these into perennial sources of water, allowing farmers to irrigate high value water dependant vegetables even in the dry season, instead of the traditional dry winter wheat crop. Irrigation applications are four to five times more frequent in winter.

The levels of pollution in these water sources particularly fecal coliform counts make them unfit for irrigation as per standard international guidelines for irrigation water quality. The preference for cultivating vegetables in the dry season when higher pollution levels are manifested, subjects the produce to higher risk of contamination. This was also noted in studies on vegetable contamination in Ghana (Amoah et al., 2005).

It was noted that nutrient levels in some instances were also in excess of international guidelines. In terms of nutrient application through wastewater, though the evidence is not conclusive, it is surmised that constant application of this water can lead to over-fertilization if conditions are not monitored. A similar situation was monitored in a Vietnam study which showed that in spite of nutrients available in the water, inability to regulate application may have detrimental effects on crops (Jensen et al., in preparation).

Flooding and crop damage are significant concerns of farmers in Kirtipur, where additionally they are exposed to risk of injury from animal bones, and glass left behind after the floodwaters recede. Similar occurrences have been documented in India in locations where untreated wastewater from canals is directed to fields for crop production (Raschid-Sally et al., 2004a).

Symptoms of skin problems in exposed farmers (itching and blisters on the hands, feet and lower legs) are similar to those experienced by farmers in Haroonabad, Pakistan (Van der Hoek et al., 2002), Hyderabad, India (Buechler et al., 2002) and in Nam Dinh, Vietnam (Trang et al., in preparation). However, we cannot deduce that the values are significantly different from a non-exposed group as this study did not survey a control group. The higher incidence of skin problems, in Kirtipur (63% of farmers interviewed), is likely due to cropping choice and wastewater flooding. Ninety-three percent of Kirtipur farmers cultivate rice which requires flood irrigation. Prolonged contact with flooded land, compared to furrow irrigation of vegetable crops for example, is likely to increase the incidence of skin problems. A similar survey in Pakistan (Van der Hoek et al., 2002) found that there was a significant difference in the reported prevalence of diarrhea between exposed and non-exposed farmers but skin problems were not significantly different.

Prevalence of intestinal parasites (as recounted by farmers) is low (2%) but this is not conclusive as a stool sample study of exposed and non-exposed groups was not done. In Pakistan, the prevalence of hookworm (through a stool sample study) was seen to be 80% among male wastewater farm-workers (Van der Hoek et al., 2002). Health statistics from Teku Hospital in Kathmandu, show that approximately 6% of patients reporting to the hospital on average, are affected with worm infections, most predominant being *Ascaris Lumbricoides* and Hookworm.

The perceived benefits of wastewater as a source of water for irrigation are linked to control over the application of this resource. Uncontrolled flooding as experienced by Kirtipur farmers leads to a negative perception of wastewater. This reaction to wastewater mirrors that of farmers in some humid regions such as Vietnam (Raschid-Sally et al., 2004b), who do not appreciate that in the dry season, irrigation authorities pump wastewater into canals serving flood-irrigated rice cultivation.

4.2. *Wastewater irrigation throughout the Kathmandu Valley*

All lowland rivers in the Kathmandu Valley, including the Dhobi, Bisnumati and Bagmati Rivers, are extremely polluted with municipal wastewater. Although large sections of these rivers' corridors are urban, extensive agricultural areas adjacent to these polluted rivers still exist. Significant numbers of farmers are irrigating with wastewater, especially in the dry season when river water quality is at its worst.

Direct irrigation from sewers is more difficult to quantify. The largest sewer systems in the Kathmandu Valley, namely those of densely populated cities of Kathmandu and Lalitpur, are most likely not being used as a source of irrigation water because of no available agricultural land in these municipalities. Our findings show that the direct use of sewage for irrigation is more likely to occur in the rapidly growing suburbs of the valley, such as Kirtipur, which are still surrounded by farmland. For instance, in the town of Bandegaon, south of Lalitpur, it was observed that a roadside ditch, filled with black and grey water, drained into a formal irrigation ditch. Local farmers are likely to be irrigating with this concentrated wastewater.

4.3. *Perspectives for wastewater treatment and the role of irrigation to improve water quality*

Centralised collection and treatment of sewage have proven to be ineffective in the Kathmandu Valley. Existing decentralised alternatives in the Kathmandu Valley are Teku septage disposal facility serving 43,000 individual household septic tanks, and small-scale constructed wetlands for hospitals and individual houses and schools. Unfortunately, these alternatives are small-scale options and cannot solve the overwhelming wastewater disposal problems in the Kathmandu Valley.

Other researchers have suggested that properly managed wastewater irrigation can be used to mitigate the polluting effects of municipal wastewater discharge to local water bodies (Scott et al., 2000; Raschid-Sally et al., 2005). As wastewater is applied to crops, naturally occurring treatment processes take place, and the water quality of the return wastewater flows, improve. This has been seen in other studies which are being documented in the Musi Valley in India. For this method to work, sufficient agricultural land needs to be suitably located to assimilate wastewater prior to discharge in the receiving water-body. Depending on the environmental conditions, the wastewater may require (partial) treatment before application. Although the Kathmandu Valley does contain vast amounts of farmland, these are predominantly located above the wastewater-generating urban areas. The Kathmandu Valley does not have enough properly situated agricultural land in the valley to absorb the large volumes of generated wastewater. The environmental and economic benefits of agricultural disposal of wastewater will have to offset the costs of transporting wastewater to the upper agricultural areas of the Kathmandu Valley, if wastewater irrigation is to become an economically viable option.

5. Conclusions

1. This study, through using a rapid appraisal method, presents an overview of the practices of wastewater agriculture in the Kathmandu Valley, and attempts to identify the drivers of the process.
2. Informal wastewater irrigation is occurring in the urban and peri-urban areas of the Kathmandu Valley of Nepal but the authorities dealing with the diverse aspects related to such practices are poorly aware of the extents and significance. Advocacy and capacity building is necessary to overcome these limitations.
3. Downstream of cities, wastewater generation has changed the hydrology of river systems substantially, providing a reliable source of water to farmers in the dry season. This water allows farmers to overcome seasonal variations of water availability, and generates better livelihoods because of possibilities to cultivate high value cash crops close to the city. However, it also changes the environmental conditions downstream of these cities.
4. Due to the lack of treatment facilities, the quality of water in these rivers will not improve in the foreseeable future. However, the high nitrate and phosphate levels can be beneficial to farmers if they can control wastewater and nutrient application. Participatory action in this direction, through agricultural extension services to farmers can be beneficial.
5. The quality of wastewater used varies from diluted wastewater to raw sewage. Farmers whose sources of water are polluted or who have recourse to sewage water because it is easily accessible or the only source; are experiencing mild to serious health impacts from exposure. More detailed studies of these consequences are necessary, accompanied by measures to help farmers minimise them.
6. Institutional awareness of the complexity of the problem is very low. Wastewater use in agriculture is not regulated and national standards or guidelines, and related planning regulations are non-existent. Interaction through a formal mechanism, among the key stakeholders who can influence the course of wastewater agriculture in Nepal, is suggested to effect beneficial changes.

7. Wastewater irrigation may play a significant role in improving water quality through sequential application on land in the Kathmandu Valley systems. For this method to work, the two main ingredients are (a) land availability and (b) consultation and interaction amongst the key stakeholders dealing with the different facets of wastewater agriculture.

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