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## SUSTAINABLE DEVELOPMENT OF WATER RESOURCES, WATER SUPPLY AND ENVIRONMENTAL SANITATION

**Wastewater use in India: the impact of irrigation weirs on water quality and farmer health***J. H. J. Ensink, S. Brooker, S. Cairncross and C. A. Scott, India*

*Water quality in the wastewater polluted Musi River, India was assessed in a 14 month survey, while the impact of exposure to polluted river water was assessed in an epidemiological study. The water quality survey found very high intestinal nematode and BOD concentrations in Musi water in the city of Hyderabad. Water quality improved dramatically downstream of the city as a result of irrigation weirs that were placed on the river and which promoted sedimentation. River water, at two of the selected sample points, was found to be unfit for use in agriculture based on WHO guidelines. Hookworm infection was found to be the main health risk associated with the use of polluted Musi water and a significantly increased risk of infection was found in farmers using untreated wastewater. In the absence of wastewater treatment facilities, regular anthelmintic treatment programs are recommended to protect farmer health.*

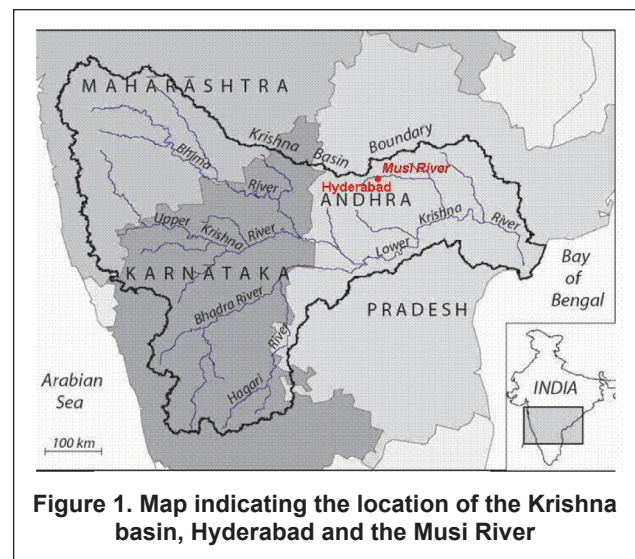
**Background**

In 2001 it was estimated that 73% of India's wastewater was disposed of untreated into rivers, irrigated canals and other surface water bodies and that an investment of US\$ 65 billion would be needed to build the required wastewater treatment facilities: 10 times the amount which the Indian government plans to spend (Kumar, 2003). This situation is likely to deteriorate further as in the next quarter of a century India's population will grow by almost 400 million people, with a large majority of this growth taking place in cities (UNPD, 2003). The rapid growth of urban centers will lead to higher water withdrawals within river basins and potentially to the loss of irrigated land. As a consequence of increased water withdrawals by urban centers, wastewater return flow back into river basins will also increase, with possible negative impacts for downstream water uses and users. This paper presents the findings of a 14 month water quality assessment in the Musi River in and downstream of the city of Hyderabad, India. The impact of water quality on farmer health was assessed in an epidemiological study.

**The Musi River and Hyderabad**

The Musi River is one of the smaller tributaries of the Krishna River and is located on the Deccan Plateau in Southern India (Figure 1). The catchment area of the river is 11,300 km<sup>2</sup>, which constitutes approximately 4% of the total Krishna River basin. The Musi River originates in the Anantha Giri Hills 60 kilometers upstream of the city of Hyderabad and enters the Krishna River 200 kilometers downstream. Annual rainfall in the Musi River basin is 680 mm year<sup>-1</sup>. In the 1920s two large reservoirs, Osman Sagar and Himayat

Sagar, were created upstream of Hyderabad to meet the city's increased (drinking) water demand and to mitigate the effect of frequently occurring floods. As a result the river, which used to have an intermittent and low base-flow, dried up completely downstream of the reservoirs.



**Figure 1. Map indicating the location of the Krishna basin, Hyderabad and the Musi River**

Since the 1920's the population of Hyderabad has grown rapidly and in 2005 was estimated to stand at 6.8 million. The local water and sanitation utility estimated that it supplied 680,000 m<sup>3</sup> of water daily to the city, which was further complemented by 100,000-120,000 m<sup>3</sup> of groundwater withdrawn by local industry. Approximately 70% of the

city is connected to a sewerage system, with the remaining population disposing of its wastewater into open drains and tanks (small reservoirs). These tanks eventually drain into the Musi River and according to conservative estimates between 550,000 m<sup>3</sup> and 650,000 m<sup>3</sup> of wastewater daily is being disposed of into the Musi River. The majority of this wastewater enters the river untreated because the city has only one functioning secondary treatment plant, which treats approximately 5% of all wastewater. As a result of wastewater disposal into the river, the river has effectively become a large wastewater drain downstream of the city.

For centuries the Musi River has served as the major source of irrigation water for the cultivation of rice in the rural areas downstream of Hyderabad. Through the construction of *anicuts* and *ayacuts* (traditional weirs with their corresponding irrigation command area) on the river, water was retained in large and small tanks from which it was diverted through irrigation canals to the fields. There are a total of 22 different weirs situated on the Musi River downstream of Hyderabad, irrigating an area of just over 10,000 hectares. In the rural areas the main crop is rice (*Oryza sativa*), while closer to the city the main crops are para grass (*Brachiaria mutica*) and vegetables. Para grass is a fodder used to feed dairy cattle.

### Water quality assessment

Three different sample points (Table 1) along a 40 kilometer stretch of the Musi River downstream of Hyderabad were selected for routine sampling. Samples were collected on a fortnightly basis in the period November 2003 – January 2005 and analyzed for intestinal nematode ova. Samples for intestinal nematode ova were analyzed following the modified Bailenger method (Ayres and Mara, 1996). An additional water sample was collected at each sample point and analyzed for Biochemical Oxygen Demand (BOD) in a local laboratory.

**Table 1. Sample points, distance from the centre of Hyderabad and observed water uses at each point**

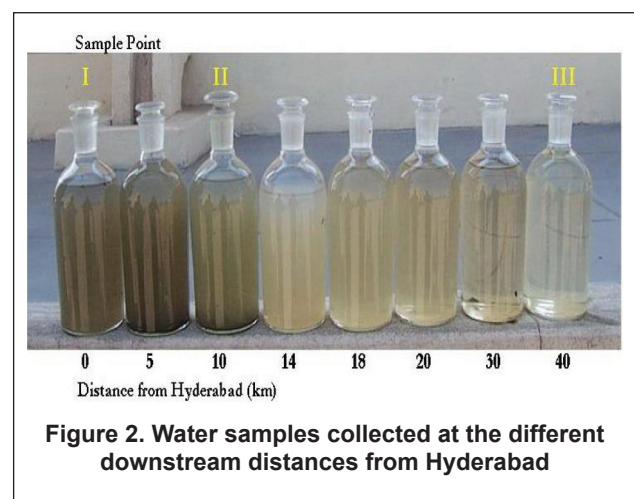
Sample point	Observed uses of river water (other than irrigation)	Distance downstream from Hyderabad (km)
I	Garbage disposal	0
II	Cattle bathing	10
III	Cattle bathing/Laundry/ Fishing/ Bathing/ Duck rearing/ River sand collection	40

### Water quality results

Throughout the 14 month water quality survey a clearly visible water quality improvement with distance along the Musi River was observed (Figure 2).

### Intestinal nematodes

A total of 84 water samples were collected at the 3 selected sample points along the river: 56 (67%) of these samples were found to be positive for intestinal nematode ova. The first and the second site were found to be positive throughout the year, while the last sample point was found to be free of intestinal nematode ova during the entire sampling period. In the water samples three different intestinal nematode ova were detected: *Ascaris lumbricoides* (*Ascaris*), hookworm and *Trichuris trichiura* (*Trichuris*). Hookworm was the most common, found in 67% (56/84) of all samples and 98% (55/56) of those samples that tested positive for any nematode. This was followed by *Ascaris*, positive in 64% (54/84) of all samples and 96% (54/56) of nematode-positive samples; and by *Trichuris*, positive in only 13% (11/84) of all samples and 20% (11/56) of nematode-positive samples.



**Figure 2. Water samples collected at the different downstream distances from Hyderabad**

Intestinal nematode concentrations in untreated wastewater (sample point I) ranged from 53 to 344 ova l<sup>-1</sup>, with a mean concentration of 152 ova l<sup>-1</sup>. The hookworm and *Ascaris* concentrations at point I were comparable with mean concentrations of 72 and 76 ova litre<sup>-1</sup> respectively. *Trichuris* concentrations in untreated wastewater with a mean concentration of 4 ova litre<sup>-1</sup> were found to be much lower. Concentrations of all three intestinal nematodes decreased rapidly following sedimentation behind the first irrigation weir (sample point II) (Figure 3).

Intestinal nematode concentrations at point II ranged from 10 to 66 ova l<sup>-1</sup>, with a mean concentration of 27 ova l<sup>-1</sup>. Hookworm concentrations were found to be highest (15 ova l<sup>-1</sup>), followed by *Ascaris* (12 ova l<sup>-1</sup>) and *Trichuris* (0.3 ova l<sup>-1</sup>). The reduction in intestinal nematode ova from sample point I to II was over 80% and statistically significant for hookworm (Student's t-test, P < 0.001), *Ascaris* (P < 0.001) and *Trichuris* (P = 0.01).

### Biochemical Oxygen Demand (BOD)

The visual improvement in water quality (Figure 2) was corroborated by BOD concentrations at the three different

sample points in the Musi River (Figure 4). The high BOD concentrations at sample point I confirmed that the Musi River in Hyderabad was effectively untreated domestic sewage. Significantly lower BOD concentrations were found at sample points II and III.

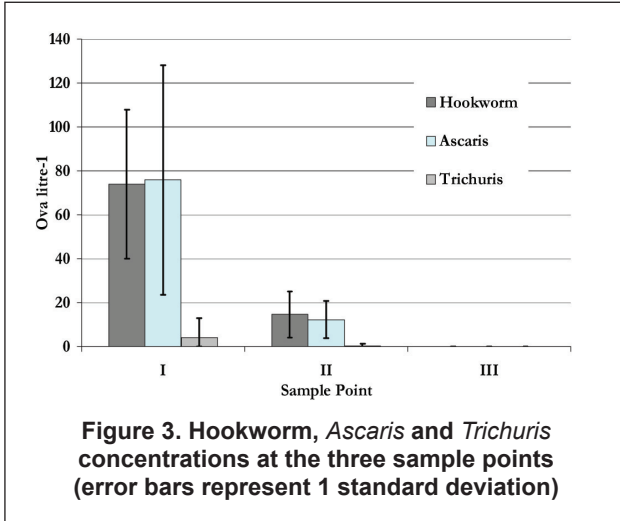


Figure 3. Hookworm, *Ascaris* and *Trichuris* concentrations at the three sample points (error bars represent 1 standard deviation)

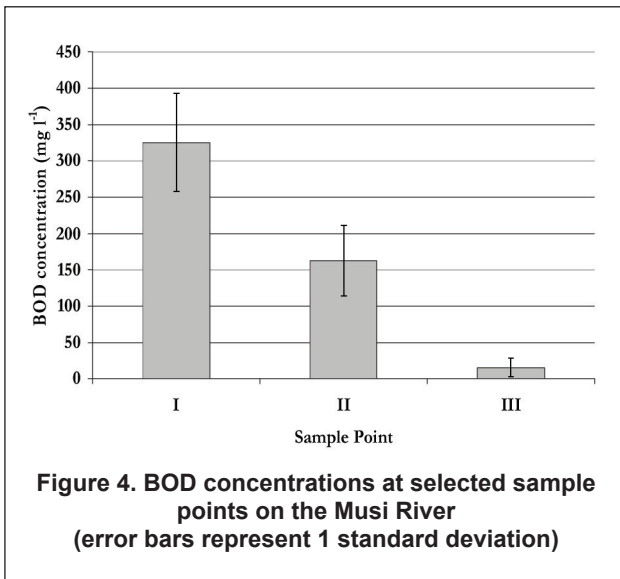


Figure 4. BOD concentrations at selected sample points on the Musi River (error bars represent 1 standard deviation)

### Wastewater remediation

The results of this 14 month long survey on the Musi River showed the large scale disposal of untreated wastewater into the Musi River by the city of Hyderabad. The Musi River in the city had typical urban domestic wastewater properties with high BOD and intestinal nematode concentrations. Water quality improved dramatically following sedimentation in the reservoir in front of the first weir on the river and further improved with each consecutive weir and with increased distance. After 40 kilometers, and 12 irrigation weirs, from the heart of the city river water was found to be free of

intestinal nematode ova and safe for the use in agriculture based on WHO guidelines (WHO, 1989).

### Health Study

The results of the water quality survey showed a gradually improving water quality downstream of the city of Hyderabad with mean intestinal nematode ova concentrations in wastewater ranging from 150 ova l<sup>-1</sup> in the city to water free of intestinal nematode ova, 40 kilometers downstream. The gradient in water quality led to the formulation of the hypothesis that higher intestinal nematode concentrations in wastewater would lead to a higher prevalence of intestinal nematode infections in farming families using Musi River water. To test this hypothesis an epidemiological study was conducted in farming families using Musi River water from the three selected water quality sample points. Stool samples were collected in the period from August 2004 to May 2005 and analyzed for all intestinal nematode infections. Household and personal data were collected through questionnaires and observations. A total of 251 households or 1,078 people agreed to participate in the study.

### Health study findings

In the period August 2004 to May 2005 1,007 stool samples were collected, a compliance of 93%. A total of 315 people (31.2%) were found to be positive for at least one of the three intestinal nematode infections; of these three, hookworm was found to be the most prevalent with an overall prevalence of 29.8% (300/1007), followed by *Ascaris lumbricoides* 5.6% (56/1007) and *Trichuris trichiura* 3.1% (31/1007).

However as figure 5 shows, farmers who used Musi River water at sample point I had a much higher hookworm, *Ascaris* and *Trichuris* prevalence as compared to farmers using River water from samples points II and III.

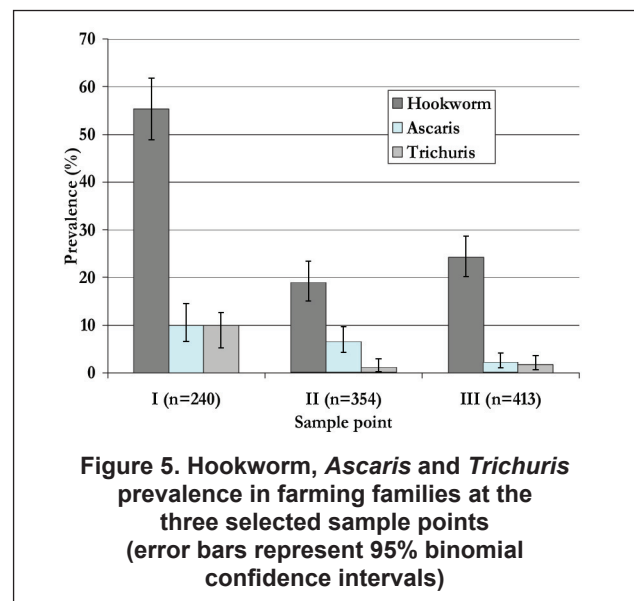


Figure 5. Hookworm, *Ascaris* and *Trichuris* prevalence in farming families at the three selected sample points (error bars represent 95% binomial confidence intervals)

This difference in prevalence was significant for hookworm, *Ascaris* and *Trichuris* when farming families at sample point I were compared with farming families at sample points II and III. No significant difference in prevalence between the samples points II and III was detected for hookworm and *Trichuris*, however farming families at sample point II had a significantly higher *Ascaris* prevalence as compared to farming families using river water from sample point III.

### Water quality and farmer health

The result of water quality surveys showed a strong improvement in water quality as a result of sedimentation behind irrigation weirs and distance from the city. This improvement in water quality resulted in a lower prevalence of hookworm, *Ascaris* and *Trichuris* infection in farming families living further away from Hyderabad. Farming families using irrigation water with a mean *Ascaris* concentration of 12 ova l<sup>-1</sup> (Sample point II) had a significantly higher prevalence of *Ascaris* infection as compared to farmers who used irrigation water free of *Ascaris* ova. This finding was in contrast to hookworm infection, as farmers irrigating with water with a mean hookworm concentration of 15 ova l<sup>-1</sup> (Sample point II) did not have a significantly different hookworm prevalence from farmers who used irrigation water free of hookworm ova. These findings would suggest that in the case of hookworm infection an intestinal nematode water quality guideline of 15 ova l<sup>-1</sup> is sufficient to protect farmer health and that the current WHO guideline is too strict (WHO, 1989).

### Interventions

Wastewater treatment would be the most obvious way to protect the health of farming families using Musi River water and although the city is planning to built several new wastewater treatment plants, full treatment of all water currently used for irrigation seems, at least for the near future, unachievable. However the disposal of wastewater into the Musi River also has positive impacts as irrigation water is now available to farmers year round. To ban wastewater use would be counterproductive as it would deprive hundreds of farmers of their livelihood and would also have negative consequences for the dairy industry in the city.

The best short term intervention would therefore be the regular treatment of farmers exposed to 'wastewater' with anthelmintic medication. Anthelmintics are safe, with minor or no side effects, are locally produced and thus widely available and cheap. School-based anthelmintic treatment programmes have proved to be a very effective strategy and should be encouraged in addition to treatment targeted to urban and peri-urban farmers.

Hookworm prevalence in all of the three investigated communities was found to be high, while access to improved drinking water and sanitation facilities was generally found to be low. Improvements in drinking water supply, hygiene and sanitation have shown to have a significant impact on the

prevalence of intestinal nematode infections but also many other infectious diseases and therefore improvements in local drinking water and sanitation facilities would likely have a much greater public health impact as large scale investments in wastewater treatment technology.

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