WASTEWATER USE FOR AGRICULTURE IN INDIA: A BACKGROUND REVIEW

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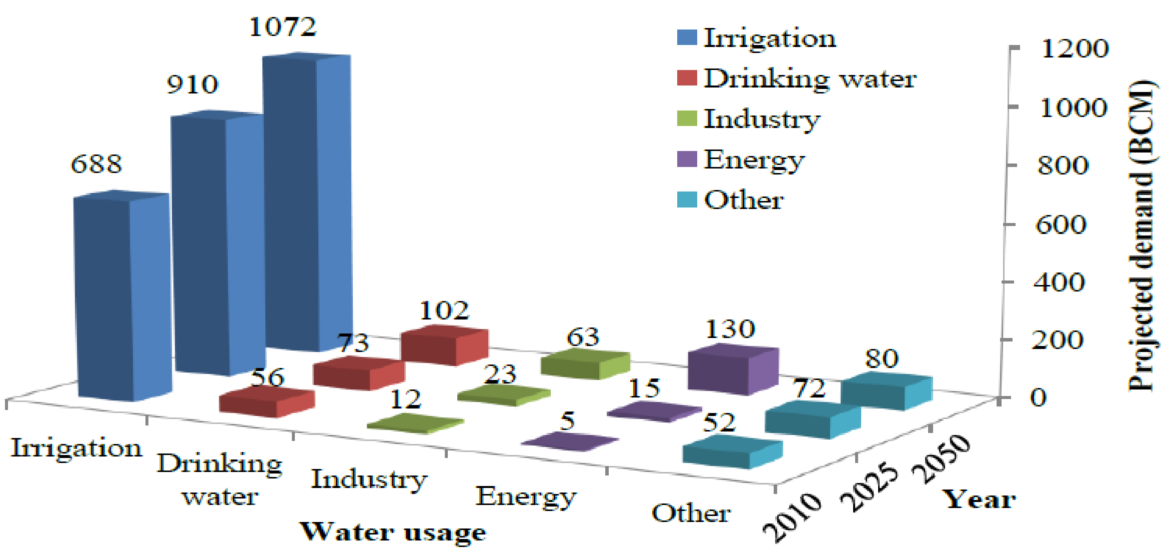
Agriculture water demand, supply and projections

Currently, agriculture accounts for more than 80% of India's water use. But growing demand from other uses such as municipal and industrial, is leading to increased competition among uses, especially near urban areas. The 2050 projections show aggregate water demand increasing to 1,447 km^3; while agriculture retains its relative dominance, other uses are projected to increase their relative share.

Figure 1: Current and future water usage in India by different sectors[1]



At the same time, the demand-supply imbalance is projected to worsen due to factors including population growth, urbanization and the impacts of climate change. The per capita water availability was estimated to be 1,545 m^3/yr which is projected to decrease to 1,140 m^3/yr by 2050 (less than 1,700 m^3 is considered water stressed and less than 1,000 m^3 is considered water scarce)[2]. Official estimates by the Ministry of Water Resources have put total utilizable water at 1,123 billion cubic meters (BCM) as against current usage of 634 BCM, reflecting a surplus scenario. But other international experts have estimated India's total utilizable water at only 654 BCM, uncomfortably close to actual usage[2]. As surface water has become over-allocated, the reliance on groundwater for agriculture (as well as domestic supply) has increased dramatically as depicted in Figure 2. This has been enabled by a proliferation of bore wells and pumps, heavily subsidized (to maximize food production) so that it costs little or nothing to farmers, leading to an alarming drop in water tables in many parts of the country.

Figure 2: Shares of ground water and surface water to net irrigated area in India[2]

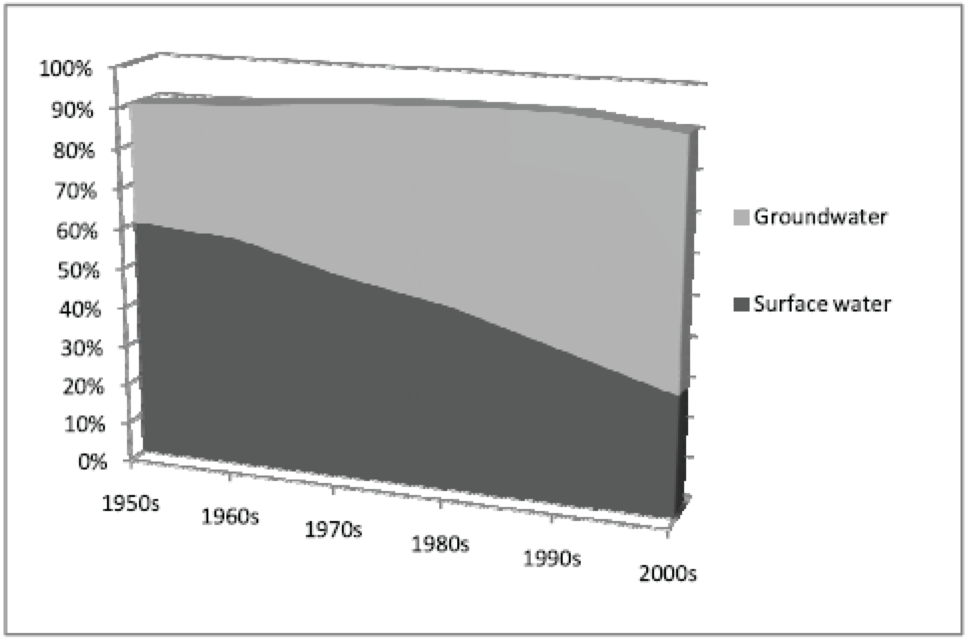
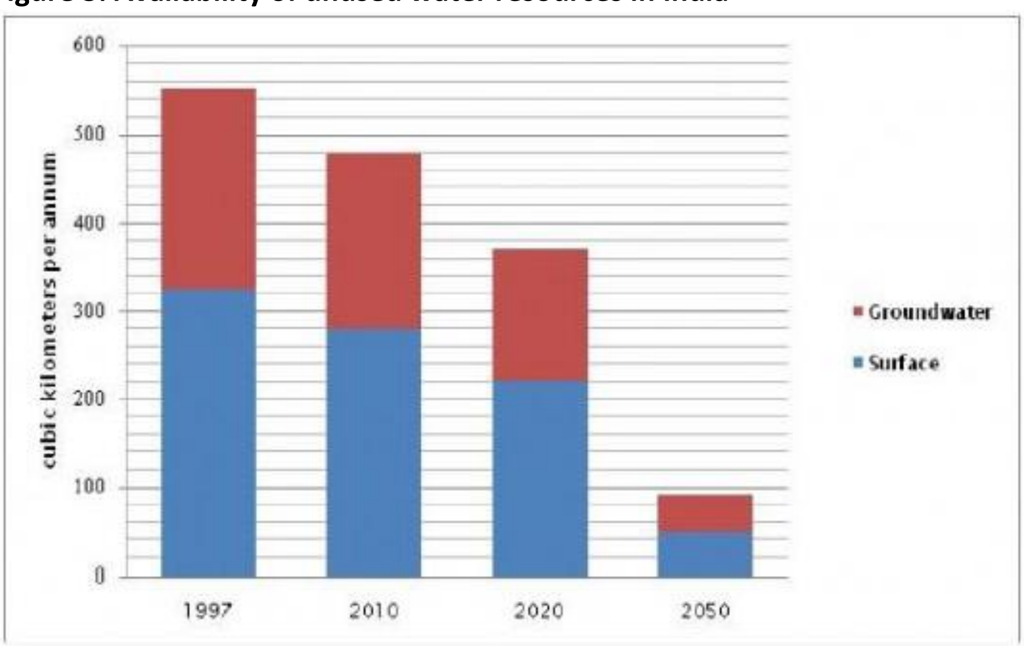


Figure 3 shows a rapid decline in future availability of so-far-unused water resources. In a future of serious water stress, alternatives such as irrigation efficiency and augmenting supply by reusing wastewater will have to become critical considerations in the decades to come.

Figure 3: Availability of unused water resources in India[3]



Municipal wastewater availability and potential

In India, the estimated sewage generation from Class I cities and Class II towns (representing 72% of urban population) is 38,524 million litres/day (MLD), of which there exists treatment capacity of only 11,787 MLD (about 30%)[4]. However, the actual performance of the sewage treatment plants is often different from their installed treatment capacity. A 2005 study by the Central Pollution Control Board (CPCB) found that only 86% of the studied plants were operational, nearly 40% of the plants did not meet general discharge standards, and the average capacity utilization was 72%[5].

Based on current estimates of available municipal wastewater, the International Water Management Institute has calculated the irrigation potential as shown in Table 1.

Table 1: IWMI estimates of irrigation potential with municipal wastewater from Class I and II cities in India[6]

Type of Wastewater	Volume of Wastewater (mld)	Potential Irrigable Land (ha)
Treated	11,787	70,722
Untreated	26, 467	1,032,213

Comparison of available wastewater and potentially irrigable land to actual irrigation water used in India and actual agricultural land is depicted in Tables 2 and 3.

Table 2: Available municipal sewage (major cities) vs. total agricultural water use in India

Available Municipal Sewage from Class I and II Cities in India 2010 (A)	Total Agricultural Water Use in India 2010[1] (B)	A as a % of B
14 trillion litres	688 trillion litres	2%

Table 3: Irrigation potential with municipal sewage vs. agricultural land in India

Potential Irrigable Land from Available Municipal Sewage estimated by IWMI, 2013 (C)	Net Sown Area in India[7] (D)	C as a % of D
1.1 million hectares	141 million hectares	0.8%

At first glance it may appear from the tables above that the potential for urban wastewater reuse for agriculture is insignificant. While the wastewater availability in terms of total agricultural water needs does appear to be quite small, even a relatively small resource augmentation can make a big difference in a water stressed region. Besides, several important caveats are necessary. First, the studies from which the above data is derived have only looked at Class I and II cities in India, mainly because these are the cities which have, or are attempting to, put in place wastewater treatment systems. However, there are thousands of smaller towns all over India which cannot afford, now or in the foreseeable future, expensive modern wastewater treatment plants. If wastewater from these towns can be collected and treated inexpensively (say wetland-based bio-treatment), then a sizable resource can potentially open up. The same argument can be made for villages as well, especially larger ones. Secondly, in many peri-urban areas with freshwater supply constraints, municipal wastewater reuse can make a significant difference in peri-urban agriculture which has evolved to become very important for urban food supply. Thirdly, as urbanization increases (currently about 30% of population but projected to rise to 50% by 2050[8]), the volume of municipal wastewater available will also increase concomitantly; the CPCB estimates that by 2050, sewage generation from Class I and II cities will exceed 100,000 MLD[4]. Finally, if agriculture water use efficiency improves dramatically in future, then the available municipal wastewater will potentially become a bigger resource in relative terms.

Current status of municipal wastewater use in agriculture

Use of municipal wastewater for farming, whether treated or not, is widespread in peri-urban areas in India. Although there are no comprehensive estimates of the total agricultural area using wastewater irrigation, several isolated studies indicate that this area is considerable. An IWMI study of five selected urban areas came up with a figure of about 50,000 hectares[6], while another study on Gujarat state alone came up with a figure of 38,000 hectares[9]. It is not uncommon to find urban rivers to have minimal natural flow for much of the year due to upstream damming; treated or untreated sewage flows through these channels and is used by downstream farmers. Several factors influence the practice of sewage-based farming in peri-urban areas. These include:

- Availability of freshwater for irrigation at affordable rates: Where sufficient amounts of freshwater are available through canals or from groundwater pumping, it is typically preferred to wastewater. However, most urban areas in India are facing water shortages and any available freshwater, whether surface water or groundwater, is diverted exclusively for urban use. Groundwater pumping is restricted in many places, or the water table is too low making pumping expensive. Under these circumstances, peri-urban farmers have no choice but to depend on wastewater.
- Reliability of wastewater supply: Since wastewater generation from cities is guaranteed while freshwater availability is uncertain in many places, peri-urban farmers consider this a big advantage and are even willing to pay for it.
- Nutrient value of wastewater: Wastewater is frequently preferred due to its high nutrient value, in some cases even over freshwater as in Gandhinagar and Rajkot in Gujarat[9]. Farmers are sometimes willing to pay a price premium for wastewater due to this perceived benefit.
- Salinity in freshwater supply: In some parts of the country the local freshwater supply may be high in salinity due to geologic reasons or salinity intrusion may have taken place due to over-pumping of aquifers. Urban wastewater, since it originated from a treated

water supply to begin with, is lower in salinity and therefore preferred by farmers. An example can be found in Bhuj, Gujarat[9].

- Load of industrial effluent in wastewater: Some urban areas have significant heavy industry and as a result their wastewater stream contains considerable industrial effluent. If high toxicity of such effluent has a discernible negative impact on crops, farmers become averse to using it. This situation has been encountered in some areas of Ahmedabad[9] and Kanpur[6].

In most per-urban areas of India, untreated rather than treated sewage is used for irrigation because either adequate sewage treatment capacity is non-existent, or the farms in question are not located close to the outflow of the sewage treatment plant. In a few cases where treated sewage is used, it is used by farmers close to the sewage treatment plant, as in the case of famers close to the Keshopur and Okhla Sewage Treatment Plants (STPs) in Delhi. Wastewater irrigation in peri-urban farms can be direct or indirect: direct when sewage is used from a sewage channel close to/adjacent to the field, and indirect when the sewage flows into a water body (lake/river) and water is taken from this polluted water body.

A variety of crops are grown through sewage-fed farming in peri-urban areas, the most prevalent being vegetables for the local urban market. Other common examples include rice, wheat, fruits, flowers/ornamentals, fodder/grasses, and in the unique case of the East Kolkata Wetlands (EKW), fish farming in wetlands fed by sewage, the largest such system in the world[10]. Thousands of livelihoods and numerous communities are supported by such agriculture as Tables 4 and 5 demonstrate. One study in Gujarat found that low-income households were making a livelihood out of lifting and supplying sewage[11]. In the EKW for example, the estimated production in 1999-2000 was 12.8 million kg of rice, 6.9 million kg of fish, and 69 million kg of vegetables, supporting a population of around 60,000[12].

Table 4: Income generation (in INR millions) with treated wastewater from STPs in Delhi[6]

Area	Okhla area	Keshopur area
Villages	Jasaula, Madanpur, Khadar, Jaitpur, Ali	
Source of wastewater	Okhla STP	Keshopur STP
Type of crop	Okra	
Number of farmers	400 (80 households)	3,000 (600 households)
Area under wastewater irrigation (ha)	205	1,500
Volume of wastewater (mly)	27	200
Annual crop yield (tonnes)	17,220	90,000
Gross annual income (INR millions)	172.2	900.0
Annual expenditure (INR millions)	57.2	418.5
Net annual income (INR millions)	115.0	481.5

Table 5: Income and expenditure from one hectare of farmland in the EKW[12]

Crop	Expenditure (INR)	Income (INR)	Net return (INR)
Paddy	12,989	20,295	7,306
Fish	35,385	47,180	11,795
Vegetables and other crops	70,000	125,000	55,000

Further, much research has shown that sewage-fed farming can often be more profitable than farming using freshwater irrigation due to higher crop productivity resulting from high nutrient value of sewage and consequent lower use of fertilizer[13]. The following table summarizes selected results of a five-city study by the IWMI. It shows that in most cases sewage-fed farming is more profitable.

Table 6: Comparative incomes from freshwater and wastewater irrigation in selected cities[6]

City	Crop/Produce	Variable	With Freshwater	With Wastewater
Delhi	Okra	Net income (INR/month)	7,200	15,700
Kanpur	Buffalo	Net profit/buffalo/day (INR)	28.75	67.15
Kanpur	Rose	Net income (INR/ha)	72,319	65,201
Kanpur	Fodder	Net income (INR/ha)	15,370	2,296
Kanpur	Rice	Net income (INR/ha)	4,455	10,621
Kanpur	Wheat	Net income (INR/ha)	8,259	9,213

In many places, the practice of using sewage for agriculture has been going on for decades and has acquired some degree of formalization. Several municipalities in Gujarat collect charges for farmers for using wastewater often at the same rates as that applicable to lifting water from notified rivers. For example, the Municipal Corporation of Bhavnagar charges Rs. 750/ha and the Municipal Corporation of Rajkot charges Rs. 2,500-3,000/ha[9]. In addition, in Rajkot city, the arrangement forbids the farmers from withdrawing water from Lalpari Lake that supplies the city in exchange for access to the wastewater. Farmers’ cooperatives also take part in auctions for wastewater; examples can be found in the Kutch district of Gujarat[9].

Challenges in using municipal wastewater for agriculture

The biggest challenge in using municipal wastewater for agriculture in India is that in the vast majority of cases, untreated sewage is used for irrigation. Untreated sewage carries with it a whole spectrum of pathogenic hazards including bacterial diseases like cholera, viral diseases like hepatitis, protozoan diseases like dysentery, as well as a host of parasitic worms like hookworm, roundworm, etc. In addition, a range of heavy metals and persistent chemicals are typically present as well, more so when industrial effluent is also discharged into municipal sewers; these can cause neurological, respiratory, immunological, renal or carcinogenic disorders depending on the type of toxicant. The highest risk is to agricultural workers who are directly exposed to the contaminated water and soil. Contamination can spread to consumers eating raw vegetables directly sprayed by contaminated water, through toxicants (especially metals) taken up by crops, by eating fish with toxic residue, or even from cow's milk which got contaminated from fodder.

Unfortunately, there is no system in place in India for comprehensive monitoring of agricultural produce or fish/milk that reaches the market. But numerous isolated studies have found concerns with contaminated soil, produce and farmers' health. Heavy metals were a serious concern in Delhi as several studies showed elevated levels in commonly eaten vegetables[14, 15]. Similar concerns were raised in Varanasi[16], while another study reported high levels of helminth eggs on vegetables cultivated with sewage in West Bengal state[17]. In terms of farmers' health, the IWMI study reported farmers complaining of skin irritations and respiratory problems in Delhi, Kolkata and Hyderabad, while in industrial areas adjacent to Ahmedabad and Kanpur, farmers using sewage mixed with industrial effluent had visible skin conditions[6]. Increased worm infections were observed in farmers around Hyderabad engaged in sewage-fed farming[18], while another Hyderabad study found significantly higher morbidity rates among farmers using wastewater compared to a control group using freshwater[19]. Another study of farmers in Kanpur found elevated levels of heavy metals and pesticides in their blood and urine[20]. Health surveys that take into account the socio-economic status of farmers as well as comprehensive market surveys are necessary to gauge the full health impact of sewage use in agriculture.

One way to minimize risk is to use available sewage to grow only industrial, ornamental or non-edible crops. However, socio-economic conditions in India, like that in many developing countries, create compulsion to grow food crops that cannot be easily changed. Still, as the World Health Organization (WHO)[21] has outlined, a number of steps can be taken to reduce risk that address actual exposure pathways even under conditions of continued untreated sewage use. These include risk education of farmers and use of protective gear while farming, variation of timing and method of irrigation, periodic monitoring for high-risk toxicants (especially where industrial effluent is involved), alteration of crop choice based on characteristics of soil and wastewater (all plants do not accumulate all toxins equally), washing of produce before reaching market, public education about the risk of eating raw vegetables, and periodic testing of high-risk produce.

Another set of problems associated with sewage-fed farming is the potential for contamination of soils and groundwater, particularly when over-applied. The degree of contamination depends on both the type of soil and the composition of the wastewater; the risk is not uniformly high in all situations and cooperation from government agencies would be required to monitor areas deemed at higher risk. Severe problems include soil clogging, increase in salinity and phytotoxicity (plant poisoning) that may necessitate abandonment of cultivation in the absence of remediation. Proliferation of weeds due to excess nutrients is another frequent problem often leading to increased use of herbicides.

Use of completely treated wastewater for agriculture is the ideal scenario. But state-of-the-art sewer networks and sewage treatment plants in every Indian city and town are unlikely in the foreseeable future. Barriers include extremely high capital cost, land shortages/conflicts, lack of skilled manpower, electricity shortages, and considerable operating costs[4]. There exists a tremendous opportunity to promote adoption of low-cost, low-maintenance wastewater treatment systems such as stabilization ponds and wetland-based bio-treatment, especially in smaller towns and where toxic industrial effluent is not a major issue. Expert assistance, including that from international partners with relevant experience, would be extremely helpful in this endeavor. Scientific research is also necessary to identify crops most suited to sewage-fed farming but posing the least public health risk, to identify optimal dosage and method of sewage irrigation that maximizes yield but minimizes risk, and to develop bio-based remediation techniques for sewage contaminated soil. State and national policies need to be formulated setting standards for wastewater reuse, and urban local bodies can set up water users' committees for overseeing collection, treatment and reuse. Such committees can consist of representatives of local government, water industry, farmers, consumer groups, and public health and environmental NGOs, and the committee can formally set tariffs incentivizing treated wastewater use over freshwater for both farm and non-farm uses (eg., landscaping, parks, golf courses). If done correctly, the revenue from the sale of treated water can cover the operating costs of wastewater treatment (especially the low-cost versions), as well as the running of the committee. Perhaps the best example in India is Chennai Metro Water, which earns Rs. 12 crores a year from selling treated wastewater and covers its entire operating cost[22]. The region also stands to derive substantial indirect benefit from improved public health and water resources.

Since many cities and towns in India are currently in the process of constructing or expanding their sewerage and wastewater treatment infrastructure, it would be wise to put systems in place with the goal of gainful treated water reuse. For example, experience has shown that a common constraint for wider use of treated wastewater is the location of farms vis-à-vis the treatment plant[9]. Decentralized siting of plants and outlet channels must be done with the goal of maximizing exposure to adjacent peri-urban farms. Water Authorities typically consider new freshwater supply as less expensive than wastewater treatment. However, while a wastewater treatment plant is certainly very expensive, researchers argue that when valuing freshwater supply infrastructure, the entire system including the pipelines, canals, reservoirs, pumps and treatment plants should be taken into account. From this perspective, the cost of providing treated wastewater (at a non-potable standard) can be lower or at least competitive with that of providing freshwater as shown in the following study results.

Table 7: Comparative costs of producing freshwater and sewage treated water (STW)[22]

		(Rs/KL)
	*Levelized Costs**	
	STW	*Freshwater*
Public	(–) 4–14	(–) 11–44
Private	(–) 5–17	(–) 13–50

If this perspective is adopted by policy makers, treated wastewater will be rightfully seen as an economically viable resource with a higher priority over new freshwater supply for non-potable uses.

Industrial wastewater reuse in agriculture: Potential and challenges

Apart from municipal sewage, about 13,468 MLD of wastewater is generated by industries in India of which only about 60% is treated[23], with small and medium industries being a major contributor to untreated effluent. However, since industrial wastewater is typically more toxic, agricultural reuse efforts are likely to be concentrated mainly on municipal sewage for the foreseeable future. This disparity is also reflected in the research literature, which is full of studies on sewage-fed farming but hardly any on industrial wastewater reuse for agriculture (although much research is being undertaken on water use efficiency in industries and on-site reuse).

The exception is industries producing relatively less toxic effluent such as those in the food/beverage sector, for example breweries, sugar mills and fruit processing units. A quick glance at the brewery industry shows that 2 million KL of beer were consumed in India in 2012[24]. According to the CPCB[25], about 10 KL of effluent is generated per KL of beer produced in India on average. So this translates to 20 million KL of effluent per year or about 55 MLD. While this may seem like a small number, the beer industry in India is experiencing fantastic growth rates which are likely to continue in the foreseeable future which means a concomitant increase in effluent generated. Also, even relatively small amounts of usable wastewater can make a big difference in water stressed regions or during the dry season. Therefore, interest in these industries' wastewater reuse is growing, as evidenced in the EU funded W4C project.

Some of these industries already practice wastewater reuse for agriculture. The SABMiller brewery in Andhra Pradesh has been distributing treated wastewater free of charge to local farmers; Ugar Sugar Works in Karnataka has been selling treated effluent from its sugar mill at Rs. 3,000/ha to local farmers. While these practices sometimes generate positive media coverage, the reality is much more complex. The main problem is that there is no monitoring or oversight of these practices. Many such industries are located in rural areas and the State

Pollution Control Boards (SPCBs) do not have the resources to monitor them continuously. In absence of any monitoring, there is no way to guarantee an assured quality of treated wastewater to farmers. Without scientific studies it is impossible to say whether such wastewater reuse practices are having a detrimental effect on soils, crops or farmers' health. In addition, farmers' needs often vary by season; for example, they would want wastewater in the dry season but not in the rainy season. In the absence of any formal mechanism, there have been instances of disputes between farmers and industry. Some industries have responded to controversy by simply discontinuing wastewater supply to farmers and putting more emphasis on reuse on-site and in-process. Sometimes this takes the form of evaporation of effluent which can be energy intensive and creates solid waste that needs disposal.

A suitable monitoring mechanism can solve this problem and aid in agricultural reuse of wastewater from these industries. If an independent body can be set up comprising of scientists from local universities, local agricultural extension officers, representatives from local farmers' cooperatives and the industry involved, this body can draw up formal arrangements and be able to monitor quality and quantity of wastewater delivered. Ideally, funding for this arrangement should be shared equitably among the different stakeholders; while the industry involved should cover a relatively large share of funding, if it is solely industry funded there may be perceptions of conflict of interest. Some initial steps are being taken in this direction through the W4C project: ICRISAT is initiating research on SABMiller's wastewater reuse in Andhra Pradesh and the University of Agricultural Sciences-Dharwad is initiating research on Ugar Sugar Works' wastewater reuse in Karnataka. The findings of this preliminary research will hopefully lead to experimentation with establishing a viable model for monitoring agricultural water reuse from these industries.

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