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## Wastewater Use In Irrigated Agriculture: Management Challenges In Developing Countries

Iqbal Singh

Lecturer in Zoology, Dr. Bhim Rao Ambedkar Govt. College, Sri Ganganagar, Rajasthan, India

**ABSTRACT:** The volume of wastewater generated by domestic, industrial and commercial sources has increased with population, urbanization, improved living conditions, and economic development. The productive use of wastewater has also increased, as millions of small-scale farmers in urban and peri-urban areas of developing countries depend on wastewater or wastewater polluted water sources to irrigate high-value edible crops for urban markets, often as they have no alternative sources of irrigation water. Undesirable constituents in wastewater can harm human health and the environment. Hence, wastewater irrigation is an issue of concern to public agencies responsible for maintaining public health and environmental quality. For diverse reasons, many developing countries are still unable to implement comprehensive wastewater treatment programs. Therefore in the near term, risk management and interim solutions are needed to prevent adverse impacts from wastewater irrigation. A combination of source control, and farm-level and post-harvest measures can be used to protect farm workers and consumers. The WHO guidelines revised in 2006 for wastewater use suggest measures beyond the traditional recommendations of producing only industrial or non-edible crops, as in many situations it is impossible to enforce a change in the current cash crop pattern, or provide alternative vegetable supply to urban markets.

There are several opportunities for improving wastewater management via improved policies, institutional dialogues and financial mechanisms, which would reduce the risks in agriculture. Effluent standards combined with incentives or enforcement can motivate improvements in water management by household and industrial sectors discharging wastewater from point sources. Segregation of chemical pollutants from urban wastewater facilitates treatment and reduces risk. Strengthening institutional capacity and establishing links between water delivery and sanitation sectors through inter-institutional coordination leads to more efficient management of wastewater and risk reduction.

**KEYWORDS:** wastewater, irrigated, management, developing, agriculture, countries, measures, household

### I.INTRODUCTION

Cities in developing countries are experiencing unparalleled growth and rapidly increasing water supply and sanitation coverage that will continue to release growing volumes of wastewater. In many developing countries, untreated or partially treated wastewater is used to irrigate the cities' own food, fodder, and green spaces. Farmers have been using untreated wastewater for centuries, but greater numbers now depend on it for their livelihoods and this demand has ushered in a range of new wastewater use practices.<sup>1</sup> The diversity of conditions is perhaps matched only by the complexity of managing the risks to human health and the environment that are posed by this practice. An integrated stepwise management approach is called for, one that is pragmatic in the short- and medium terms, and that recognises<sup>2</sup> the fundamental economic niche and users' perceptions of the comparative advantages of wastewater irrigation that drive its expansion in urban and peri-urban areas. Comprehensive management approaches in the longer term will need to encompass treatment, regulation, farmer user groups, forward market linkages that ensure food and consumer safety, and effective public awareness campaigns. In order to propose realistic, effective, and sustainable management approaches, it is crucial to understand the context-specific tradeoffs between the health of producers and consumers of wastewater-irrigated produce as well as the quality of soils and water,<sup>3</sup> on the one hand, and wastewater irrigation benefits, farmers' perceptions, and institutional arrangements on the other. This introductory chapter to the current volume on wastewater use in agriculture highlights a series of tradeoffs associated with continued use of untreated

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wastewater in agriculture. Empirical results from the case studies presented in the volume shed light on devising workable solutions.<sup>4</sup>

Wastewater is becoming an important alternative resource to reduce water foot prints in many sectors. Agricultural irrigation sector accounts for the maximum (approximately 70%) use of fresh water worldwide.<sup>5</sup> With increasing scarcity of fresh water resources, many developing countries have been using untreated or partially treated wastewaters for irrigation. Aim of this review is to present the status of wastewater generation, treatment and reuse in irrigation across major developing nations. These countries were selected on the basis of high population, low national water stress ranking (NWSR)<sup>6</sup> and data availability. Further, current challenges of presence of pathogens, antibiotics and antibiotic resistant bacteria in high concentrations in wastewaters reused for irrigation have been critically discussed. The wastewater generation data across these nations show a large range of 0.0805 - 58.92 km<sup>3</sup>/year, out of which barely 0.022 - 17.89 km<sup>3</sup>/year receives treatment.<sup>7</sup> The vegetables (mostly lettuce) irrigated with wastewaters have reported high contamination of pathogens such as Enterococci, Salmonella, Vibrio, Clostridium, Klebsiella, helminth eggs. Similar results have been obtained for ARBs. Antibiotics concentrations reported in wastewater used for irrigation were up to 368 mg/L and up to many µg/Kg of antibiotics in plant tissues have been found to accumulate in edible crops raised with such waters. Antibiotics SMX and CIP were most widely present in wastewaters due to their excessive use in these countries as well as their persistence. Existing treatment technologies have not been found to be suitable to remove all these emerging pollutants from wastewaters. Moreover, lack of data on such pollutants from developing nations is the major challenge to tackle the problems associated with safe wastewater reuse and calls for appropriate policy reforms and development of upgraded technology<sup>8</sup> to combat such issues. Therefore, it is suggested that regular detailed research inputs are required to ensure long term sustainability for a safe reuse of this misplaced resource to conserve human and environmental health. Wastewater management demands an updated data set for wastewater generation, treatment and reuse. Recently, global data for wastewater generation, treatment and reuse were reported, which have been collected from 113 countries for wastewater generation, 103 countries for treatment and, 62 countries for wastewater reuse. However, data for wastewater reuse in agricultural irrigation were not reported at global scale. This was justified as underreported data come from the fear some countries have that revealing information may lead to economic sanctions be imposed if low quality water has been used to produce food<sup>9</sup>. There is no global inventory on the extent to which wastewater is used in either treated or untreated form in irrigation. Most cities in developing countries fail to treat their wastewater comprehensively. Consequently, farmers downstream use poor-quality water for irrigation. This practice implies risks for farmers, consumers and the environment. Conversely, this water supply supports the livelihood of these farmers and other stakeholders along the value chains. Linking safer options for wastewater management with irrigation could therefore be a win-win solution: removing the risks for society and maintaining the benefits for farmers.<sup>10</sup> However, in developing countries, the high investment costs for the required treatment are problematic and the willingness of farmers to pay for the water (cost recovery) is often questionable. Using a choice experiment, this paper gives insight into farmers' preferences for wastewater use scenarios, quantifying their willingness to pay. The case study is Hyderabad, India. Farmers there prefer water treatment and are prepared to pay a surplus for this. Considering the cost-recovery challenge, this information could be valuable for planning small on site wastewater treatment systems.<sup>11</sup>

## II.DISCUSSION

Even though water makes up around 70% of the earth's crust, just a small portion of it is suitable for terrestrial life.<sup>39</sup> Water is essential for life. The small percentage of freshwater with low salt concentration in the Antarctic and Arctic (68.7%) is only 2.5% of the total water stock in the hydrosphere and is largely in the form of ice and permanent snow cover. This writing serves as a review. Journals, publications, and earlier project works pertinent to the subject at hand were thoroughly examined and strategically sampled.<sup>12</sup> To gather the data needed for the paper's creation, many works were examined and summarized. Agriculture is a large consumer of wastewater globally.<sup>38</sup> It is believed that finding suitable irrigation resources is crucial for protecting natural water bodies and ensuring food safety. Wastewater reuse has emerged as a practical option for pollution reduction when water reuse replaces effluent discharge to vulnerable surface water bodies,<sup>13</sup> preserving and extending available water supplies. This is due to the difficulties associated with the discharge of untreated wastewater into the environment. As treating and utilizing wastewater for irrigation would

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make it easier to achieve sustainability, using wastewater for irrigation is an efficient strategy to lower costs and improve environmental health and safety in today's economy.<sup>14</sup>

Agriculture production is highly dependent on water and increasingly subject to water risks. It is also the largest using sector and a major polluter of water. Improving agriculture's water management is therefore essential to a sustainable and productive agro-food sector. In recent years, agricultural regions around the globe have been subject to extensive and increasing water constraints. Major droughts in Chile and the United States have affected agricultural production while diminishing surface and groundwater reserves. These and other extreme weather events, like floods or tropical storms, are also expected to be more frequent. Climate change is projected to increase the fluctuations in precipitation and surface water supplies, reducing snow packs and glaciers and affecting crop's water requirements.<sup>15</sup>

Coupled with these changes, farmers in many regions will face increasing competition from non-agricultural users due to rising urban population density and water demands from the energy and industry sectors. In addition, water quality is likely to deteriorate in many regions, due to the growth of polluting activities, salination caused by rising sea levels and the abovementioned water supply changes.<sup>16</sup>

These water challenges are expected to strongly impact agriculture – a highly water-dependent sector – undermining the productivity of rain-fed and irrigated crops and livestock activities particularly in certain countries and regions. These changes could in turn further impact markets, trade, and broader food security. An OECD assessment of future water risk hotspots projects that without further action, Northeast China, Northwest India, and the Southwest United States will be among the most severely affected regions, with domestic and global repercussions.<sup>17</sup>

For as much as agriculture is impacted by these changes, it also contributes to the problem as a major user and polluter of water resources in many regions. As such, agriculture has a central role to play in addressing these challenges<sup>37</sup>. Irrigated agriculture remains the largest user of water globally, a trend encouraged by the fact that farmers in most countries do not pay for the full cost of the water they use. Agriculture irrigation accounts for 70% of water use worldwide and over 40% in many OECD countries. Intensive groundwater pumping for irrigation depletes aquifers and can lead to negative environmental externalities, causing significant economic impact on the sector and beyond. In addition, agriculture remains a major source of water pollution; agricultural fertiliser run-off, pesticide use and livestock effluents all contribute to the pollution of waterways and groundwater.<sup>18</sup>

## III.RESULTS

The challenges that lie ahead are both extremely complex and locally diverse. It will be important for policymakers to focus on efforts that increase the overall efficiency of water use by the agricultural sector, reduce the sector's impact on freshwater resources, and improve its resilience to water risks. To this end, the OECD advocates for multiple policy responses at different levels, each adapted to specific water resource systems.<sup>19</sup>

In order to facilitate a transition to a more sustainable and productive agricultural sector that is resilient to water risks, governments should act at the farm, watershed and national levels to (1) strengthen and enforce existing water regulations, (2) create incentives for farmers to improve their water use and better manage the use of polluting agricultural inputs; and (3) remove policies that support excessive use of water and polluting activities.<sup>36</sup>

To assist policy makers in addressing this challenge, OECD analysis and indicators contribute to formulating policy responses, defining pathways to make the necessary policy changes, and facilitating their implementation to move agriculture towards the sustainable management of water. OECD's work on agriculture and water is also highlighted in the 2016 OECD Council Recommendation on Water.<sup>20</sup>

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The OECD also supported efforts in the G20 by Agriculture Ministers to adopt a declaration and action plan entitled “Towards food and water security: Fostering sustainability, advancing innovation” in 2017, which includes a number of significant commitments to improve agriculture’s water use, limit its impact on water quality, and reduce its exposure to water risks.<sup>35</sup>

The use of partially treated and untreated wastewater for irrigation is beneficial in agriculture but may be associated with human health risks. Reports from different locations globally have linked microbial outbreaks with agricultural reuse of wastewater. This article reviews the epidemiological evidence and health risks<sup>21</sup> associated with this practice, aiming toward evidence-based conclusions<sup>33</sup>. Exposure pathways that were addressed in this review included those relevant to agricultural workers and their families, consumers of crops, and residents close to areas irrigated with wastewater (partially treated or untreated). A meta-analysis gave an overall odds ratio of 1.65 (95% CI: 1.31, 2.06)<sup>22</sup> for diarrheal disease and 5.49 (95% CI: 2.49, 12.10) for helminth infections for exposed agricultural workers and family members. The risks were higher among children and immunocompromised individuals than in immunocompetent adults. Predominantly skin and intestinal infections were prevalent among individuals infected mainly via occupational exposure and ingestion. Food-borne outbreaks as a result of crops (fruits and vegetables) irrigated with partially or untreated wastewater have been widely reported. Contamination of crops with enteric viruses, fecal coliforms, and bacterial pathogens, parasites including soil-transmitted helminthes (STHs),<sup>23</sup> as well as occurrence of antibiotic residues and antibiotic resistance genes (ARGs) have also been evidenced. The antibiotic residues and ARGs may get internalized in crops along with pathogens and may select for antibiotic resistance, exert ecotoxicity, and lead to bioaccumulation in aquatic organisms with high risk quotient (RQ). Appropriate mitigation lies in adhering to existing guidelines such as the World Health Organization wastewater reuse guidelines and to Sanitation Safety Plans (SSPs). Additionally, improvement in hygiene practices will also provide measures against adverse health impacts.<sup>24</sup>

## Implications

The reuse of partially treated or untreated wastewater for irrigation has been linked to diarrheal and parasitic infections (1–4) as well as skin disorder and other systemic infections (5–8). An effective managing strategy of these health risks is challenging and depend on water quality (e.g., the type of wastewater: untreated<sup>32</sup>, partially treated, or treated) as well as societal and behavioral factors which will vary between different settings (9–11). Health risks are not only dependent on exposure to microbial hazards (i.e., infectious pathogens) but also to chemicals or pharmaceuticals<sup>25</sup>

Populations exposed to wastewater are most often categorized into four main groups;

- a) agricultural workers and their families;
- b) crop merchants, handlers, and technical/operational staff;
- c) consumers of farm produce, vegetables, meat, or milk products;<sup>31</sup>
- d) residents of areas irrigated with wastewater, including children, the elderly, and immunocompromised individuals, who are at the highest risks in particular

The first two groups (a and b) would mainly be exposed occupationally, due to direct contact with the wastewater during application and handling. Consumers (group c) are directly exposed dependent on their diet. Residents (group d) of areas close to sites irrigated with wastewater can also be exposed through farm run-off, groundwater contamination and aerosols.<sup>26</sup>

Wastewater reuse has environmental sustainability benefits when practiced safely . Adverse health outcomes associated with its reuse have been documented, both directly through epidemiological studies ,and indirectly using quantitative risk assessments . Despite these reported health outcomes, the use of wastewater for irrigation is a widespread practice, partly due to its year-round availability and nutrient content<sup>30</sup>.It will thereby contribute to the urban food basket and the overall improvement of the urban environment .To protect public health and ensure that the full benefits associated

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with the reuse are achieved, regional, national, and international authorities have set guidelines for safe wastewater use in agriculture. However, it may be questioned if wastewater use in agriculture still causes adverse health effects, despite the existence of these guidelines for safe use.<sup>27</sup>

## IV. CONCLUSIONS

The purpose is the evidence associated with the health impacts resulting from exposure to pathogens in partially or untreated wastewater used for agricultural purposes. Specifically, we report on the relevant exposure pathways and summarize epidemiological evidence of diarrheal, intestinal parasitic, and skin infections associated with direct exposure as well as indirect through produce from agriculture.<sup>29</sup> The later refer to foodborne outbreaks from irrigated produce. We estimate health risks from partially treated and untreated wastewater irrigation using quantitative microbial risk assessment, and the risks associated with contaminants such as antibiotics and antibiotic resistance genes. Finally, we conclude by presenting approaches to mitigating the risks associated with the use in agriculture.<sup>28</sup>

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