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Basanti Brar
HABITAT Genome Improvement Primary Producer Company Ltd., Biofertilizer Production Unit CCSHAU, Hisar, Haryana, India

Sonu
HABITAT Genome Improvement Primary Producer Company Ltd., Biofertilizer Production Unit CCSHAU, Hisar, Haryana, India

Naveen
Department of Botany, Maharishi Dayanand University Rohtak, Haryana, India

Dr. Jagveer Rawat
HABITAT Genome Improvement Primary Producer Company Ltd., Biofertilizer Production Unit CCSHAU, Hisar, Haryana, India

Corresponding Author
Basanti Brar
HABITAT Genome Improvement Primary Producer Company Ltd., Biofertilizer Production Unit CCSHAU, Hisar, Haryana, India

Wastewater reuse for irrigation of a vegetable crops and its impacts

Basanti Brar, Sonu, Naveen and Dr. Jagveer Rawat

Abstract
Globally water scarcity is one of the foremost problems and millions of individuals have no access to clean water. It has been estimated that due to climate change two-thirds of the man kinds will face water shortage by 2025 and worldwide food demands increase at least by 50% to feed the growing population by 2050. To meet this demands wastewater is most commonly used for agriculture sectors, is one of the globally serious environmental and public health concerns. Use of untreated wastewater in irrigation of food and vegetable crops is main reason of soil pollution with heavy metals, excess salts and pathogens. Globally more than 10% of the population consumes food and vegetables irrigated from wastewater; hence pathogens are transmitted through food chains cause's diseases mainly in women and children. Instead of using untreated wastewater in irrigation, use of treated wastewater has been found more suitable and environment friendly option. The efficiency of different irrigation systems in limiting the risks of wastewater reuse. In this paper, we explore the situations of water scarcity, irrigation with the wastewater use in vegetable production and their possible impacts on environment, human, soil health etc. Here we highlight that irrigation with wastewater provides an actual perspectives for recovery of wastewater, serving to decrease the scarcity and preserve water resources with enhancing food security. With the food security, food safety is one the most important aspect and it should be maintained if we must properly treated the waste water before use in vegetable as well as in other food production irrigation that limits the risks on environment and human health.

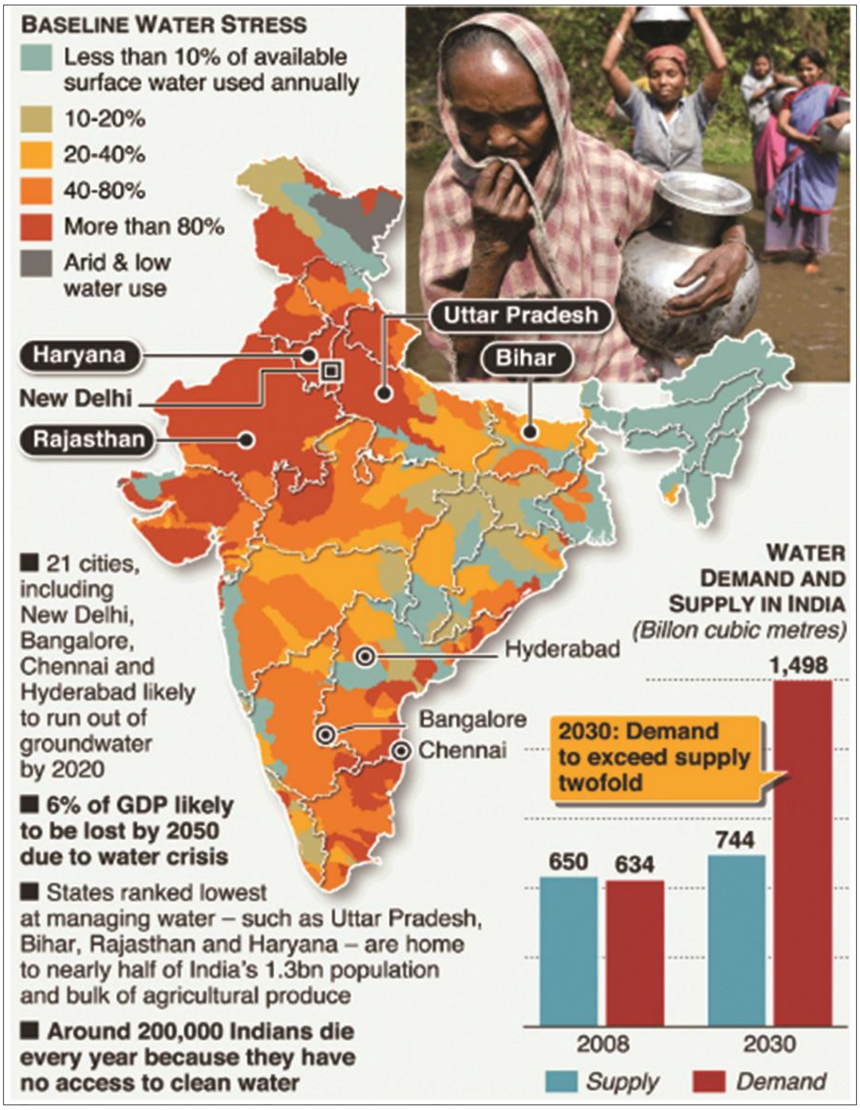
Keywords: Agriculture, environment, human health, nutrients, pathogens, soil health, vegetables

Introduction
Water Scarcity
Changing climate has become a fact that humanity faces every day as a result of the development of various sectors and factors which contribute to the increase in greenhouse gas emissions. Changes in climate have a severe detrimental impact on water quality and availability, food security, and human health all across the world. By 2100, global mean temperature could increase by 3.5 ^{0}C compared to the same period of time mentioned above (Gerten *et al*., 2013) [29], with regional average variations of global temperatures between 1.4–5.8 ^{0}C (DeNicola *et al*., 2015) [19]. Climate change is expected to account for roughly 20% of the global expansion in water scarcity (FAO, 2007) [25], which will have an impact on the development and operation of communities globally, both socially and economically. According to an FAO report (FAO, 2007) [25], each person would have had access to 5000–6000 m^3 of freshwater per year in the ideal circumstance, when all accessible water on Earth would have been evenly divided to a uniformly dispersed population. According to specialists, humans feel water shortage below a threshold of 1700 m^3 per person; therefore the ideal condition would have been for each individual to have access to plentiful freshwater resources. In reality, neither freshwater resources nor people are spread equitably over the world. Water scarcity manifests itself at different levels of danger due to varying densities of human communities and uneven distribution of water resources.

The shortage of freshwater resources is influenced by a variety of factors, including population increase, urbanisation, per capita consumption, water pollution, and climate change. Water scarcity is a key indicator of health and a source of poverty, affecting people mostly in rural areas with high population density (FAO, 2012) [26]. A total of 1.2 billion people are estimated to reside in river basins with physical water scarcity, with another 1.6 billion living in water-deficient areas without access to cheap water delivery systems (FAO, 2012) [26]. The water stress index, which is calculated as the ratio of yearly water extraction from ground and surface water to total renewable freshwater resources, is used to quantify the severity of water scarcity in a region or a country (Sofroniou *et al.*, 2014; Ungureanu *et al*, 2020) [45, 46]. Arid, semi-arid, and dry-subhumid land cover 40% of the total land area on the planet (Becerra-Castro *et al.*, 2015) [7]. According to Bixio *et al.* (2006) [11], half of European countries are experiencing water stress, and Aquarec (2020) [5] categorised Member States into four risk groups based on the water stress index, underlining that water scarcity affected 10% of European territory and 14% of the population.

According to an FAO report (2018) [27], a country encounters water stress when it withdraws more than 25% of its renewable freshwater resources; physical water shortage occurs when withdrawals exceed 60%, and severe physical water scarcity occurs when withdrawals exceed 75%. Libya, Israel, Egypt, Jordan, Saudi Arabia, Turkmenistan, and Uzbekistan are among the countries experiencing extremely high water stress (>80%), whereas China, India, Afghanistan, and South Africa are experiencing significant water stress (40–80%). Low–moderate water stress (10–20 %) exists in the United States and Kazakhstan, while low water stress (10 %) exists in South America, Canada, and Russia. Hofste *et al.* (Hofste *et al.*, 2019) [33] conducted an analysis of data collected in 2019 by Aqueduct, a tool developed by the World Resources Institute, and discovered that water stress is extremely high in 17 nations, high in 27 countries, medium-high in 24 countries, low-medium in 32 countries, and low in 63 countries.

The quantity of water withdrawn for irrigation will increase to 2.9 thousand km^3 globally by 2050, with low-income countries accounting for the majority of the net increase (Bruinsma *et al.*, 2011) [13] and the worldwide net irrigated area will grow by at least 20 million hectares, nearly mainly in land-scarce developing countries. In India by 2030, implying the worst water shortage because the country's demand is goes to be double the available supply. It has been reported by 2020, that 21 Indian cities, including, Bangalore, New Delhi, Hyderabad and Chennai, are likely to ran out of groundwater (Figure 1). States such as Bihar, Uttar Pradesh, Haryana and Rajasthan ranked lowest at managing water and these states are nearly half of 1.3bn population along with the bulk of its agricultural produce (My Republica, 2018). [36]



(**Sources:** NITI Aayog, wild water resources My Republica, 2018) [36]

Fig 1: Water Crisis in India and current as well as future situations

Wastewater Reuse in vegetable Irrigation

Households, factories, and agriculture produce massive amounts of wastewater on a regular basis. Wastewater accounts for 50–80% of domestic household water consumption (Hussain *et al.*, 2019) [34], and global wastewater discharge is predicted to be 400 billion m^3/year, contaminating roughly 5500 billion m^3 of water/year (Zhang *et al*., 2017) [50]. Wastewater typically contains 99 percent water and 1% suspended, colloidal, and dissolved particles (Hanjra *et al*., 2012) [32]. Organic matter, suspended solids, nutrients (primarily nitrogen and phosphorus), heavy metals, emerging contaminants (antibiotics, hormones, personal care products, pesticides, polycyclic aromatic hydrocarbons, phenolic compounds, volatile organic compounds, antibiotic resistant bacteria and genes) and pathogenic microorganisms (bacteria, viruses, protozoans and parasitic worms) are all known to be present in wastewater, depending on its source. Wastewater contains a high concentration of nutrients and hence has a high potential for use in agricultural irrigation since it provides organic carbon, nutrients (NPK), and inorganic micronutrients to plants (Alcalde-Sanz and Gawik, 2017) [3].

Wastewater reuse for agricultural crop irrigation is a market-driven action based on agricultural sector requirements that can contribute to the circular economy by collecting nutrients from reclaimed water and applying them to crops using various irrigation methods. Reuse of wastewater for agriculture irrigation is mostly practiced in low-income, arid and semi-arid countries (Drechsel *et al*., 2010) [20] where evapo-transpiration outpaces precipitations for most of the year (Bedbabis *et al*., 2014) [8]. Farmers' crop options are expanded due to the availability of wastewater in adjacent communities. The literature survey has been showed that wastewater has been effectively used to irrigate a variety of vegetable crops (Table 1).

Table 1: Use of wastewater in vegetable production

Sr. No.	Crops	Type of wastewater used in production	References
1	Lettuce	Both untreated and treated municipal wastewater	Winpenny *et al*., 2010 [48]; Emongor *et al*., 2012 [22], Beltran *et al*., 2020 [9]; Farhadkhani *et al*., 2018 [23]; Lonigro *et al*., 2016 [41]; Woldetsadik *et al*., 2017 [49]
2	Tomatoes	untreated wastewater	Emongor *et al*., 2012 [22]; Lonigro *et al*., 2016 [41]; Christou *et al*., 2017 [16]; Cirelli *et al*., 2012 [18]; Gatta *et al*., 2015 [10]; Akponikpe *et al*.,2011 [2]; Cirelli *et al*., 2012 [18]
3	Potatoes	untreated wastewater	Winpenny *et al*., 2010 [48]
4	Carrots	untreated wastewater	Hussain *et al*., 2019 [34]
5	Radishes	Both untreated and treated municipal wastewater	Beltran *et al*., 2020 [9]**;** Balkhair *et al*., 2016 [6]
6	Cucumbers	untreated wastewater	Chojnacka *et al*., 2020 [14]
7	Spinach	untreated wastewater	Hussain *et al*., 2019 [34]
8	Onions	Both untreated and treated municipal wastewater	Winpenny *et al*., 2010 [48]; Farhadkhani *et al*., 2018 [23]
9	Fennel	Both untreated and treated municipal wastewater	Lonigro *et al*., 2016 [41]
10	Asparagus	untreated municipal wastewater	Winpenny *et al*., 2010 [48]
11	Broccoli	untreated municipal wastewater	Beneduce *et al*., 2017 [10]; Libutti *et al*., 2018 [10]
12	Cabbage	Treated and untreated municipal wastewater	Winpenny *et al*., 2010 [48]
13	Eggplant	Treated wastewater	Cirelli *et al*., 2012 [18]
14	Kidney beans	Untreated wastewater	Ajmal and Khan, 1985 [1]
15	Lady's fingers	Untreated wastewater	Ajmal and Khan, 1985 [1]
16	Turnips	Treated and untreated municipal wastewater	El Hamouri *et al*., 1996 [21]
17	Zucchini	Treated and untreated municipal wastewater	El Hamouri *et al*., 1996 [21]

This practise is gaining popularity in many regions of the world due to its numerous advantages. Although the young generation, which has access to quality education and information about the benefits of recycling wastewater as irrigation water, has a good attitude toward the practise, the elderly population is still hesitant to eat food grown with wastewater (Anastasiadis *et al*., 2014) [4]. The following are some of the benefits of using wastewater (treated, partially treated, or diluted) in agriculture: availability of large amounts of water throughout the year without being impacted by environmental conditions, high nutrient content that can reduce the use of chemical fertilisers, raising productivity on less fertile lands, reducing the loss to freshwater ecosystems caused by eutrophication and algal blooms, and so on (Ungureanu *et al*., 2018). Although there are numerous advantages to using wastewater in agriculture, there are also a number of drawbacks, including various diseases in farmers and consumers of food from wastewater-irrigated crops; accumulation of heavy metals, salts, antibiotics, growth hormones, and other hazardous substances in the soil; low hydraulic conductivity due to clogging of soil pores with suspended solids from wastewater and decreased quality of agricultural crops due to tainted soil. Many studies emphasize on the usefulness of wastewater and especially of treated water for crop irrigation, in terms of benefits expressed by increased crop productivity (Hanjra *et al*., 2012; Maaß *et al*., 2018) [32, 42] due to the high content of nutrients in these waters. It has been reported a 15% increase in rice productivity (Jang *et al*., 2013) [37] and obtained a 14.9% increase in tomato irrigated with wastewater (Emongor *et al*., 2012) [22]. According to a recent study (Chojnacka *et al*., 2020) [14], the reuse of treated urban wastewater in countries like Brazil, Poland, and Saudi Arabia would cover 100 percent of both phosphorus and potassium requirements for maize crops due to the nutritional content. Farmers must be aware about the hazards and best practises in this activity in order to benefit from wastewater in agriculture in a way that is safe for their health and the environment. The finest example of excellent practise is to use solely treated wastewater wherever possible, as this decreases freshwater use as well as health and environmental dangers.

Another measure is continuous monitoring of effluent quality or wastewater that will be reused, in order to ensure compliance with country-specific requirements (if applicable) or WHO minimum criteria. To minimise clogging of soil pores and irrigation system emitters in the absence of complete treatment technology, wastewater must be treated by settling and/or filtering. In certain locations, sanitation systems are completely absent, putting farmers and agricultural workers in these areas at danger of pollution and health problems. As a result, they must wear protective garments when working with wastewater, prevent direct handling of wastewater irrigation products, and sanitise their hands after coming into direct contact with wastewater or wastewater irrigated products. If wastewater treatment is not possible, it is best to avoid irrigating vegetable crops and use it only for fodder crops and fruit trees. If untreated wastewater is used to irrigate vegetables, drip irrigation should be utilised to avoid direct contact between the wastewater and the plant leaves, as well as to save water and keep agricultural employees away from the wastewater. Farmers must check the qualities of wastewater-irrigated soils, as well as irrigation schedule, because irrigating the crop before the edible component develops can lower the chance of pathogen infection. Before harvest, wastewater should no longer be used to irrigate crops.

Potential Impacts of Wastewater use in irrigation

Figure 2 depicts the potential effects of untreated wastewater on human health, crops, soil and groundwater resources, ecological and social implications. Pathogenic microorganisms such as bacteria, viruses, and parasites can be found in wastewater and have the ability to cause disease. Human parasites, such as protozoa and helminth eggs, are particularly important in this regard because they are notoriously difficult to cure and have been linked to a variety of infectious gastrointestinal disorders in both affluent and poor countries. However, while assessing health effects, it is important to note that the real risk that causes individuals to become ill, not the presence of pathogens in water, must be quantified. While the potential risk may be great, the actual risk is determined by a variety of other factors. Untreated wastewater irrigation poses a significant health danger to people of all ages. The level of risk, however, may differ depending on the age group. Hookworm and Ascariasis infections in children are more common in areas with untreated wastewater irrigation (Feenstra *et al*. 2000) [25]. If taken in high enough proportions, heavy metals in wastewater constitute a health concern and can be fatal. Plants cannot tolerate large concentrations of these pollutants and die off before they represent a concern to humans, therefore heavy metal uptake by crops and the risk posed to consumers may not be an issue (Cifuentes *et al*. 2000 and Habbari *et al*. 2000) [17, 30]. Shuval *et al*. (1986) [43] conducted a comprehensive investigation was done for the impacts of pathogen and heavy metals present in wastewater used for irrigation on human health impacts and reported the genuine risks they bring to human health. These findings have significant implications for determining the value of public health concerns connected with wastewater irrigation. To begin with, they state that valuing public health risk is an essential decision variable in wastewater irrigation, and that both adults and children should be considered as exposure groups. Second, the entire population, living within and outside the wastewater irrigation zone, should be considered as the potential exposure groups for economic valuation purposes.

In general, wastewater (both treated and untreated) is widely used in agriculture since it is a rich source of nutrients and contains all of the moisture required for crop growth. Most crops yield more than their potential with wastewater irrigation, which reduces the need for chemical fertilisers and saves farmers' money. If the total nitrogen given to the crop via wastewater irrigation exceeds the necessary nitrogen dose for best yields, it may accelerate vegetative growth but delay ripening and maturity, as well as cause loss of yield in extreme cases. Crop scientists have tried to measure the impacts of treated and untreated wastewater on a variety of quality and yield parameters under a variety of agronomic settings (Anastasiadis *et al*., 2014) [4]. According to a review of these studies, treated wastewater can be utilised to produce higher-quality crops with larger yields than would be achievable otherwise. The use of untreated municipal wastewater, which is common in many nations, creates a slew of issues. Even though larger nutrient concentrations may not necessarily boost crop yields, the high concentration of plant food nutrients offers an incentive for farmers to use untreated wastewater since it decreases fertiliser expenditures. For maximum productivity, most crops, particularly those cultivated in peri-urban agriculture, require certain quantities of NPK. Crop development and yield may be significantly impacted if the recommended level of NPK is exceeded. Urea factory effluents, for example, are a great source of liquid fertiliser, but in concentrated forms, they reduce rice and corn yields (Singh and Mishra 1987) [44]. It is also necessary to consider the composition of municipal wastewater. Chemical contaminants, which may be hazardous to plants at larger concentrations, are brought in by the predominance of industrial waste. While some components may make their way into the food chain, most studies show that such pollutants are detected in concentrations safe for human consumption. On the other hand, a high saline level caused by the predominance of domestic wastewater may damage the productivity of salt-sensitive crops.

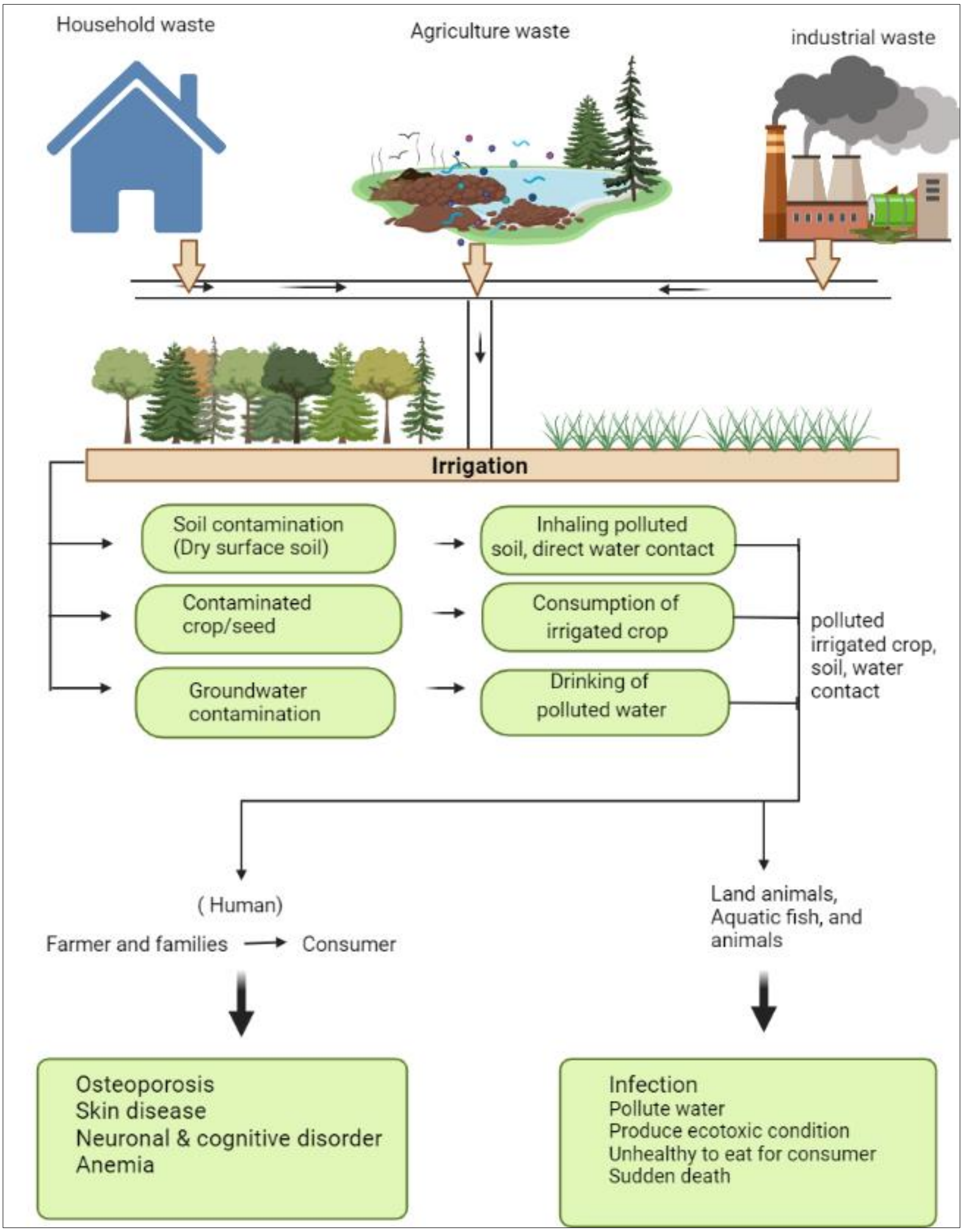


Fig 2: The potential effect of untreated wastewater on human health, crops, soil and groundwater resources, ecological and social implications.

The presence of excess nutrient contents (Nitrogen and Phosphorus), high total dissolved solids, and other elements such as heavy metals, which are added to the soil through time, have a major impact on agricultural soil. Salts in wastewater can collect in the root zone, posing a threat to soil health and agricultural output. Soil and groundwater pollution may result from the leaching of these salts below the root zone (Bond, 1999) [12]. Long-term usage of saline and sodium-rich wastewater poses a risk to soil because it can erode the structure and reduce production. In the long run, this could lead to land use being unsustainable. Wastewater-induced salinity may impair agricultural output due to general growth suppression, nutritional imbalance, and harmful ion-induced growth suppression at the pre-early seedling stage (Kijne *et al*. 1998) [38]. Crop yields may be reduced, and farmers' revenue may be lost as a result of the overall effect on growth. Wastewater irrigation has the potential to carry heavy metals to soils, contaminating crops and harming soil flora and fauna. Some of these heavy metals can bioaccumulate in the soil, whereas others, like Cd and Cu, can be redistributed by soil fauna like earthworms (Kruse and Barrett 1985) [39].

Wastewater irrigation of crops under proper agronomic and water management practices

may provide the benefits such as- higher yields and productivity, more water for irrigation, fertilizer value saved, Increase the farmer income, Nutritional enhancement and sustainability of water resources.

Conclusion and future perspectives

To summarise, wastewater can partially fill the need for water for irrigating agricultural crops in the context of exacerbated climate change and declining freshwater supplies. Although there are numerous advantages to reusing wastewater, such as reducing volumes discharged into receiving watercourses, increasing crop yields, and reducing the need for chemical fertilisers due to nutrients in wastewater, it should not be forgotten that untreated wastewater can have disastrous health consequences. Given the expanding practise of wastewater recovery, as well as the desire to limit dangers to human health and the environment, it is evident that using only effluents of appropriate quality for agricultural irrigation is the best alternative. The most recent and mandatory rules for the safe reuse of wastewater will reduce the hazards to human health and the environment dramatically. Operators of wastewater treatment plants should enhance their treatment procedures and equipment until the regulations takes effect, in order to obtain polished effluents with physico-chemical and bacteriological parameters that are within the allowed limits for agricultural reuse. In light of the foregoing, the authors of this study are convinced that assisting developing countries, which are most vulnerable to famine and serious diseases, in the construction of sewage systems, treatment plants to ensure appropriate microbiological and physico-chemical quality effluents, and large-scale examples of good practises for wastewater recovery in irrigation that are currently being implemented in developed countries, will contribute to the development of these countries.

Conflict of Interest: none

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