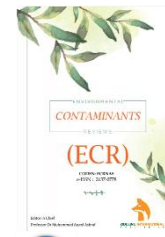


ZIBELINE INTERNATIONAL
PUBLISHING

ISSN: 2637-0778 (Online)

CODEN: ECRNAE

Environmental Contaminants Reviews (ECR)

DOI: <http://doi.org/10.26480/ecr.02.2020.87.91>

RESEARCH ARTICLE

ENVIRONMENTAL IMPACT OF UNTREATED WASTEWATER IRRIGATION IN KATHMANDU VALLEY: A REVIEW

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ARTICLE DETAILS

Article History:

Received 19 April 2020

Accepted 28 May 2020

Available online 16 June 2020

ABSTRACT

Irrigation water scarcity is a common problem in agriculture throughout the world. With 80% of the annual precipitation occurring between June and September, leaving the remaining eight months relatively dry, Nepal is said to be water stressed. Increasing population in and around the Kathmandu valley generates a huge amount of waste water. This wastewater is dumped directly into the local water bodies. The main river system of Kathmandu valley is heavily polluted with wastewater and is used to irrigate the nearby agricultural land to produce food for the urban population. Easily accessible and available all year round, about 80% of irrigation inside the Kathmandu valley is done with wastewater. Some studies report an increase in yield attributed to increased nutrient content, while others report drying and wilting symptoms in crops. Soil acidification, salinization, increased heavy metal concentration, coliform bacteria counts, etc., are some concerns that need to be addressed before applying wastewater directly on fields. This article aims to analyse the extent and possible effect of wastewater irrigation on soil in Kathmandu valley. Parameters like Sodium adsorption ratio, potassium, total nitrogen, coliform count, bicarbonate, chloride, phosphorus, cadmium, etc., and their effect on soil profile are reviewed from available literature.

KEYWORDS

Heavy metals, Soil, Water scarcity, Bagmati.

1. INTRODUCTION

"The wars of this century were fought over oil, the wars of the next century will be fought over water" (Barnaby, 2009). About 97% of the total mass of water on earth is in the form of salt water in the ocean and four-fifth of the remaining 3% of water is out of circulation, frozen in the polar ice caps and glaciers, thus making fresh water a scarce resource. The scarcity of water owing to water pollution and global warming has made the assumption of water as being amongst the 'free goods' a thing of the past (Albrecht, 2000). Similar is the case in agriculture where lack of water availability for irrigation is a major issue in many parts of the world, and is expected to increase with the growing population (Elliott et al., 2014).

1.1 Importance of Wastewater Irrigation

The rapidly increasing urban population in developing countries like Nepal, through their domestic, commercial and industrial sectors, generate a huge amount of wastewater (Shrestha, Regmi, and Mishra, 2015). Only 15-25% of the withdrawn water is consumed while the remaining water is returned as wastewater. In urban areas, untreated sewage is discharged directly into local water bodies, resulting in the pollution of those water bodies. Owing to the scarcity of fresh water and the unchecked pollution of the irrigation water sources with this wastewater, use of wastewater for irrigation is becoming unavoidable (Hanjra, Blackwell, Carr, Zhang, and Jackson, 2012). This is especially true

for the small suburban farmers targeting their produce to the urban market and having no other irrigation sources. At least one-tenth of the world's population is consuming food produced with wastewater (Abegunrin, Awe, Idowu, and Adejumo, 2016). About 10% percent of total irrigated land in developing countries uses this resource (UN, 2003).

Thus, wastewater irrigation is an important issue in agriculture. The importance of the quality of irrigation water can be estimated from the history of irrigated agriculture in the Tigris-Euphrates Valley, where a whole civilization emerged, flourished and perished within a time frame of 4700 years owing to salt accumulation in the soil profile (Muyen et al., 2011; Johnston et al., 2009).

2. MATERIALS AND METHODS

Various research papers regarding wastewater irrigation, conference and workshop proceedings, government reports regarding the status and guidelines on wastewater irrigation were consulted.

3. RESULT AND DISCUSSION

3.1 Research Evidences

Wastewater contains significant concentrations of solids, dissolved and particulate matter, micro-organisms, nutrients, heavy metals and other

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DOI:

10.26480/ecr.02.2020.87.91

micro pollutants. Wastewater is considered to be both a resource and a problem (Hanjra et al., 2012), having different composition as compared to fresh water, its application can be beneficial and/or harmful to the crops. A potential benefit with the use of wastewater for irrigation is due to the presence of a higher amount of inorganic plant nutrients and organic matter. It increases the amount of organic carbon, available nitrogen, potassium and calcium in the soil (Singh and Agrawal, 2012). It is reported to increase the micronutrient content like iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) (Mohammad and Ayadi, 2004). Singh and Agrawal (2012) reported an increase in urease and dehydrogenase activity in wastewater irrigated sites. Similarly, metabolic activities of soil microorganisms were also found to be higher with wastewater. It is considered to be a good fertilizer and soil amendment, contributing to the soil fertility and productivity (Hoda, 2015). Nutrient rich wastewater increases the nutrient available for the plant. Yao et al. (2013) reported an increase in total carbon, nitrogen and phosphorus content in the soil profile with the use of treated wastewater. This is valuable in respect to reuse of nutrients and water.

On the contrary, the long-term use of wastewater could lead to excessive accumulation of the nutrients and other toxic chemicals beyond their specific requirements to an undesirably high level in both soil and plant system, affecting the productivity and quality of both crop and soil (Rusan, Hinnawi, and Rusan, 2007). Wastewater irrigation effects the soil pH, buffering capacity and cation exchange capacity. Nitrification of the high amount of ammonium in wastewater acts as a source of hydrogen ions, decreasing the soil pH while its salt content can increase the soil alkalinity (Rusan et al., 2007). If not leached out, they accumulate through evaporation to a concentration that is harmful to the plants. The composition of wastewater may vary depending upon the source, however, in general, wastewater has an elevated sodium level that deteriorates the soil physical properties. Dispersion of clay with subsequent collapsing of the soil structure and pore blockage lead to decreased permeability. It impedes leaching and contributes to salinization, hampering the plant performance (Muyen et al., 2011). Under such conditions, application of calcium source like gypsum is desirable, but its availability and price might be an issue (Qadir et al., 2010). Wang, Chang, Wu, and Crowley (2003) reported wastewater causing soil compaction and reduction in the ability to hold nutrients like Mg. In the long term, it can also reduce the micronutrient content as the high organic load with a stronger affinity for these micronutrients makes it unavailable for the plant (Rusan et al., 2007; Sharma and Chettri, 2005).

3.2 Heavy Metals in Wastewater

Wastewater is considered to be one of the major sources of heavy metals in agricultural soil (Sharma and Chettri, 2005). Soil acts as a long term sink to huge quantities of heavy metals like zinc, copper, lead, cadmium, arsenic and mercury. Siebe and Cifuentes (1995) reported a significant build-up of heavy metals on the upper layer of the soil after 20-30 years of wastewater. Untreated or partially treated industrial effluents and indiscriminate disposal of domestic sewage drainage are the major sources of heavy metals in river water. Kayastha (2015) reported the soil contamination to be closely related with the pollutants in the irrigation water. Increase concentration of heavy metal in soil were found in many studies with long-term application of wastewater (Rusan et al., 2007; Mohammad and Ayadi, 2004; Tabari et al., 2008). These metals and nutrients if leached below the root zone can affect the groundwater quality. The impact varies depending upon the scale of irrigation, depth of water table, soil drainage, hydraulic conductivity and so on (Hanjra et al., 2012). Rusan et al. (2007) also reported that the level of Pb and Cd increased with the increasing period of wastewater irrigation.

Wastewater irrigation is more popular in fodder cultivation, where the continuous requirement of irrigation and salt tolerance makes it ideal for fodder species. Fodder cultivation coupled with wastewater irrigation that supplies urban and peri-urban livestock-based production can lead to the accumulation of heavy metals in humans (Scott, Faruqui, and Raschid-Sally, 2004). Siebe and Cifuentes (1995) reported an elevated level of Cd, Pb and Mn in the blood and urine of the farmers exposed to raw wastewater.

3.3 Dilution Factor in Wastewater Irrigation

Composition of the wastewater changes on seasonal basis. Dilution factor accounts for the maintenance of water quality in the wet season, whereas the driest months of the year shows a substantial increase in the levels of ammonia, BOD, total coliform counts and other undesirable substances. Seasonal streams which used to get dried in winter seasons are augmented by the wastewater to a point where they flow all year round (Rutkowski, Raschid-Sally, and Buechler, 2007). Irrigation from the wastewater is typically more in these drier months where water quality is at its worst.

Water quality is not just important for immediate crop production but also for its long term sustainability. Continuous irrigation with low quality water can permanently damage soil physical, chemical and biological properties.

3.4 Wastewater Irrigation in Kathmandu Valley

Nepal is said to be water-stressed for much of the year, with approximately 80% of the annual precipitation falling between June and September, leaving the remaining eight months relatively dry. Especially in the Kathmandu valley (KV), increasing settlement and infrastructure development has decreased the vegetative land cover, consequently decreasing the ground water recharge. In addition, pollution of the rivers has made it practically unusable (Gautam, Shrestha, and Shrestha, 2013).

With a bustling population of 2.51 million, KV generates 93 million litres per day (MLD) of domestic wastewater and 6.5 MLD of industrial wastewater (Shukla, Jha and Timilsina, 2015). About 75% of this wastewater is disposed of in the water-bodies directly without any treatment or only with partial treatment (Shrestha et al., 2016). Centralized efforts regarding the treatment of wastewater started after the 1970s, prior to this, only work done was to collect and dispose of wastewater to rivers and surface water bodies (Shukla et al., 2015). Easy access to these polluted rivers and lack of other irrigation facilities have been amongst the major contributors to wastewater irrigation. Approximately fifty nine percent of the land of KV is agricultural and about eighty percent of the irrigation in this land occurs through wastewater (Rutkowski et al., 2007). Like in many parts of the world, this practice is more common in the rapidly growing suburban areas like Kirtipur and Bhaktapur, compared to more densely populated areas of KV, where scarcely any agricultural land is available.

Due to lack of treatment facilities, untreated wastewater is directly pumped from rivers to agricultural land for irrigating crops, particularly for vegetables in KV (Shrestha et al., 2016). This water includes grey and black water produced from cleaning, washing, bathing and other sanitary uses and industrial waste like synthetic organic compounds, inorganic compounds and minerals (Shukla et al., 2015; Mishra et al., 2017). Dissolved organic carbon and trace elements were found to be increasing downstream of the Bagmati River (Bhatt and Gardner, 2009).

Many farmers have reported a decrease in the crop productivity over a period of time, attributing to high nutrient content in wastewater. Drying and wilting of crops was observed with the repeated application of wastewater from Hanumante River (Shukla et al., 2015). This might be due to accumulation of those nutrients over time to a toxic level in the soil profile. Besides crops grown with untreated wastewater may not be of export quality (UN, 2003).

The contamination of heavy metals in agricultural soils along the riverside of Kathmandu is more prevalent (Sharma and Chettri, 2005). It is anticipated that most of the green leafy vegetable such as mustard, garden cress, coriander, fennel and spinach grown in KV and neighbouring areas are contaminated with heavy metals. These heavy metals were found to be more concentrated in the root portion of the vegetables that is usually discarded while cooking, however, the shoot portion is still not completely safe for consumption (Shakya and Khwaounjoo, 2013). Increase in concentration might be directly through the wastewater composition or

indirectly by increasing the solubility of the indigenous insoluble soil heavy metals through its chelation or acidification action (Rusan et al., 2007). About 6% of the total wastewater came from industries like carpet

dyeing and washing, this water is acidic and may contain heavy metals (Rutkowski et al., 2007).

Table 1: River water quality parameters in Bagmati River and its tributaries.

| S.N. | Parameter | Unit | Levels reported | | References |
|------|-------------------------------|-------------------|---------------------------------|-------|------------------------------|
| 1 | SAR (Sodium Adsorption Ratio) | - | 4.36 | | (Sharma et al., 2020) |
| 2 | Potassium | (mg/l) | 19.27 | | |
| 3 | Sodium | (mg/l) | 59.16 | | |
| 4 | Bicarbonate | (mg/l) | 206.72 | | |
| 5 | Sulphate | (mg/l) | 37.41 | | |
| 6 | Chloride | (mg/l) | 937.2 | | |
| 7 | EC (Electric conductivity) | (μ S/cm) | 972.20 | | (Khadka et al., 2016) |
| 8 | Total coliform count | (MPN/index 100ml) | 2.2 \times 10 ⁸ | | (Rutkowski et al., 2007) |
| 9 | BOD | (mg/l) | 339 | | |
| 10 | COD | (mg/l) | 640 | | |
| 11 | Total Nitrogen | (mg/l) | NH ₄ -N ¹ | 62.76 | |
| | | | NO ₃ -N ² | 34.22 | (Shrestha et al., 2015) |
| 12 | Total phosphorus | (mg/l) | 7.73 | | (Devkota and Watanabe, 2005) |
| 13 | Manganese | (mg/l) | 0.47 | | (Bhatt and Gardner, 2009) |
| 14 | Arsenic | (μ g/l) | 6 | | |
| 15 | Cadmium | (mg/l) | 0.01 | | (Karmacharya, 2012) |
| 16 | pH | - | 6.07 | | (Sharma et al., 2020) |
| | | | 8.94 | | (Pant et al., 2019) |

¹ NH₄-N and ² NO₃-N means chemical equivalent of elemental nitrogen in the form of NO₃ and NH₄

Table 2: Nepal Water Quality Standards for Irrigation Water (Reprinted from CBS, 2013)

| S.N. | Parameter name | Target Water Quality Range | Remarks |
|-------------------------------|--------------------------------|----------------------------|---|
| Microbiological constituents: | | | |
| 1 | Coliform(faecal) | <1 count /100ml | 1-1000 count/ 100 ml could be used for plants for which edible parts are not wetted |
| Physical constituents: | | | |
| 1 | pH | 6.5-8.5 | Adverse effects on plants outside this range |
| 2 | Suspended Solids | < 50 mg/l | Above the limit problem with sedimentation and irrigation system |
| 3 | Electrical Conductivity | <40 mS/m | Upto 540 mS/m depending upon sensitivity of crops. |
| Chemical constituents: | | | |
| 1 | Aluminium | <5 mg/l | Upto 20 mg/l max. acceptable conc. |
| 2 | Arsenic | < 0.1 mg/l | > 2 mg/l creates severe problem |
| 3 | Beryllium | <0.1 mg/l | 0.1 - 0.5 mg/l max. acceptable conc. |
| 4 | Boron | <0.5 mg/l | Upto 15 mg/l depending upon species. |
| 5 | Cadmium | <0.01 mg/l | 0.01 - 0.05 mg/l max. acceptable conc. |
| 6 | Chloride | <100 mg/l | Upto 700 mg/l depending upon species |
| 7 | Chromium | <0.1 mg/l | Upto 1.0 mg/l max. acceptable conc. |
| 8 | Cobalt | <0.05 mg/l | Upto 5.0 mg/l max. acceptable conc. |
| 9 | Copper | <0.2 mg/l | Upto 5.0 mg/l max. acceptable conc. |
| 10 | Fluoride | <2.0 mg/l | Upto 15 mg/l max. acceptable conc. |
| 11 | Iron | <5.0 mg/l (non-toxic) | > 1.5 mg/l creates problem in drip irrigation system |
| 12 | Lead | <0.2 mg/l | Upto 2.0 mg/l max. acceptable conc. |
| 13 | Lithium | <2.5 mg/l | For citrus < 0.75 mg/l |
| 14 | Manganese | <0.02 mg/l | Upto 10 mg/l max. acceptable conc. |
| 15 | Molybdenum | <0.01 mg/l | Upto 0.05 mg/l max. acceptable conc. |
| 16 | Nickel | <0.2 mg/l | Upto 2.0 mg/l max. acceptable conc. |
| 17 | Nitrogen(inorganic) | <5 mg/l | Higher concentration may affect sensitive plants and may contaminate groundwater |
| 18 | Selenium | <0.02 mg/l | Upto 0.05 mg/l max. acceptable conc. |
| 19 | Sodium Adsorption Ratio (SAR) | <2.0 | Upto 10 depending upon sensitivity of crops. |
| 20 | Sodium | <70 mg/l | Upto 460 depending upon sensitivity of crops. |
| 21 | Total Dissolved Solids (as EC) | <40 mS/m | Upto 540 mS/m depending upon sensitivity of crops |
| 22 | Uranium | <0.01 mg/l | Upto 0.1 mg/l max. acceptable conc. |
| 23 | Vanadium | <0.1 mg/l | Upto 1.0 mg/l max. acceptable conc. |
| 24 | Zinc | <1.0 mg/l | Upto 5 mg/l max. acceptable conc. |

Bagmati is the main river of KV, having five tributaries – Hanumante, Dhobi-khola, Tukucha, Bishnumati and Nakhukhola. Especially used in irrigation for vegetable production in KV, these rivers are heavily polluted and reported to be contaminated by heavy metals (Sharma and Chhetri, 2005).

Shrestha et al. (2015) reported an increase in the nitrate and phosphate concentration in Bagmati river due to mixing of household greywater rich in nutrients. Both Khasyang Khusung and Hanumante river showed higher nitrate and phosphate concentration than the FAO standards for irrigation water quality at some point downstreams. These nutrients are responsible for increase in the crop yield (Rutkowski et al., 2007). BOD was also found to be much greater (upto 79.9mg/l) than 15mg/l. Dissolved oxygen is another important parameter that determines the behaviour of trace elements and hydrophobic contaminants (Bhatt and Gardner, 2009). Shukla et al. (2015) reported dissolved oxygen(DO) of less than 0.7mg/l in Hanumante when waterbodies of DO less than 2mg/l are considered to be extremely polluted (Mishra et al., 2017).

Rutkowski et al. (2007) also reported about fifty percent of the sampled farmers experiencing skin problems such as itching and blisters on hands, feet and lower legs. Coliform count was found to range from between tens of thousands to millions MPN/100 ml. This clearly indicates the risk that wastewater irrigation possesses to human health. Dilution capacity of perennial rivers like Hanumante was higher as compared to seasonal rivers like Khasyang khusung khola which regulated the fluctuation of water quality between the end of monsoon and start of dry season.

Depending upon the effluents that were dumped into the water bodies, the composition, benefits and hazards related to the wastewater irrigation varied accordingly. Hoda(2015) compared the effects of mixed water irrigation(wastewater mixed with fresh water) with fresh water in terms of soil properties and fruit quality of citrus fruit. He found an increase in the soil pH and EC in the surface layer of the soil. However, the fruit quality was not affected with it, moreover, wastewater had a fertilizing effect.

Despite its popularity in Nepalese agricultural system, only a handful of studies have been done in wastewater irrigation. This practice is largely informal and has no institutional regulation (Shukla et al., 2015). Though we can clearly see from the above research that application of wastewater has considerable effects on crop production and soil properties, but it is poorly documented. Haphazard application of wastewater to the agricultural soil could lead to loss of both production and quality of soil.

4. CONCLUSION

Wastewater irrigation supports countless livelihoods of the small, urban and peri-urban farmers. Its volume is likely to increase in the near future with population growth and urbanization. The quality of wastewater is also becoming further degraded as the population is increasing rapidly. Mishra et al. (2017) used the WEAP model to predict that BOD would increase to 131.98 mg/l by 2020 in Bagmati River. Increasing population entails increase in demand of fresh water, leaving wastewater as the only option left to irrigate the remnant green spaces. Thus, the use of wastewater in irrigation is likely to increase. Direct dumping of wastewater into the water bodies not only pollutes the rivers, making the surface water unfit for use, but also contaminates the soil, and groundwater. Concerning the prevalent water scarcity in KV, wastewater could be a pragmatic alternative for irrigation, but needs adequate treatment before use. Improved management of the wastewater must be followed to reduce the health and environmental impacts. Under the circumstances, crop selection and rate of application of wastewater could be a management option for wastewater irrigation (Mohammad and Ayadi, 2004). Segregation of wastewater according to its quality is also an option, however, regarding the current scenario its feasibility is questionable. Management of wastewater is needed to prevent the entry of unwanted chemicals into the food chain.

This review calls attention to highly prevalent wastewater irrigation

practice in Kathmandu valley, however, it further needs to be supported by other researches. A sharp fluctuation was observed in the water quality parameters as per different research articles in different season and places. Thus, future studies need to be focused on assessment of these parameters and their impact management on soil and crop system. Most researches have prioritized health risks brought by the wastewater use, but the plausible impact of irrigation water quality on soil, plant and environment also needs to be emphasized.

ACKNOWLEDGEMENT

The author would like to thank Prof. Roshan Man Bajracharya, PhD for his guidance.

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