NANGARHAR UNIVERSITY
INTERNATIONAL JOURNAL OF BIOSCIENCES
ORIGINAL ARTICLE
e-ISSN: 2957-9988
NUIJB Special Issue | 2024

Received: 15 Dec 2023 Accepted After Revision: 20 Jan 2024 Published Online: 10 Feb 2024

Soil properties evaluation under different irrigation sources in the Semi-arid Region of Kandahar, Afghanistan

Obaid Hikmatullah [1*], Fazil Karamatullah [1], Sharifi Shrifullah [2], Ehsan Qudratullah [1], Nazir Rahmatullah [1], Zaryal Khalilullah [1], and Seerat Wakeel Ahmad [2]

[1]Department of Agronomy, Faculty of Plant Science, Afghanistan National Agricultural Sciences and Technology University
[2]Department of Soil Science and Water Irrigation, Faculty of Plant Science, Afghanistan National Agricultural Sciences and Technology University
*Corresponding author email: hikmat_obaid@yahoo.com

ABSTRACT

Wastewater reuse is a non-conventional source of water containing high amounts of nutrients but also other undesirable components. However, little is known about the impact of wastewater irrigation on farmland soil properties, particularly in Afghanistan. Therefore, this paper reports for the first time a comprehensive understanding of the presence and effect of soil properties under wastewater irrigation and freshwater irrigation in Kandahar, Afghanistan. Accordingly, the properties of soil were evaluated by collecting soil samples from the sites of Haji-Arab (HA), Bala-Karz (BKZ), Mahal-e-Nejat (MN), and Char-Bagh (CB) in Kandahar province. The agricultural fields at the HA, BKZ, and MN sites are irrigated with wastewater, while at the CB site farms are entirely irrigated by freshwater. The results of this study revealed that the lowest pH and maximum EC levels were recorded in the BKZ soil samples, followed by the HA, MN, and CB soil samples. The soil texture class was silt loam and sandy loam at the wastewater-irrigated and freshwater-irrigated sites, respectively. Discoveries from this study have identified implications for informing policymakers on the need for appropriate wastewater treatment systems and regulations to ensure the safe and sustainable use of wastewater for irrigation purposes.

Keywords: Irrigation, Effluence, Soil, Wastewater

INTRODUCTION

The volume of sewage generated by households has increased in line with population growth and urbanization growth, so the freshwater (FW) resources may not be able to support the burgeoning demand (Qadir et al., 2020). The global temperature has risen as a result of the previously listed variables, and crops now require more water. Climatic conditions contribute to the prevalence of contamination in semi-arid land since the higher evapotranspiration rate than precipitation (Yaseen et al., 2020). The situation has compelled farmers to reuse wastewater (WW) for irrigation, either treated or untreated, even though the practices create more destructive outcomes for the ecosystem (Ahmad et al., 2019). Achieving maximum and best-quality crop production depends on several factors; the most important of which are soil conditions and fertility. Soil is characterized primarily by its physicochemical and biological properties, and a decent condition of these properties can support crop growth and maximize plant productivity (Delgado and Gómez, 2016).

The effects of effluent irrigation on soil alteration properties are related to different traits; for example, irrigation sources, amount, and application period. However, long-term wastewater-irrigation (WI) impacts soil physicochemical properties, leading to increased soil degradation (Poustie et al., 2020). Continuous WI reduces the pH and increases the salinity of the soil, which further increases the availability of toxic metals for plants. The long-term irrigation practice is also not sustainable and detrimental to soil health (Du et al., 2022; Borsato et al., 2020). Therefore, it is imperative to study the effects of WI on soil texture, pH, and EC (electrical conductivity), to understand soil fertility and promote sustainable agriculture development (Du et al., 2022). However, no study has been conducted to assess the effects of WI on soil properties in Kandahar Province. Therefore, sites irrigated by WW were selected to assess soil alteration properties under WI by monitoring soil quality indicators according to the objective of this research. For the purpose, soil samples were collected to determine the following soil quality indicators: particle range, texture class, pH, and EC of the soil.

MATERIALS AND METHODS

Study Area

The study was conducted at Kandahar province (31.6289° N, 65.7372° E), which is located in the southwest part of Afghanistan.

Samples Collection

Inspected soil samples (9 composite samples of each site) were randomly collected from the upper horizon (0–20 cm) at two growing seasons (spring), and (summer). Four agriculture areas, namely Bala-Karz (BKZ), Char-Bagh (CB), Haji-Arab (HA), and Mahal-e-Nejat (MN) were selected. Among these sites, BKZ, HA, and MN sites receive WW and sometimes bore-well water for farm irrigation, whereas the CB area utilizes FW for irrigation. In season-I, 5 cultivation farms were selected at each study site, and 3-5 composite soil samples were collected from the selected fields; likewise, from the same fields in season-II. Soil particles and texture class were determined by the method of the hydrometer and the USDA textural triangle. The pH and EC values of soil (1:2.5 soils to deionized water ratio) were measured by pH-meter and conductivity meter, respectively.

Statistical Analysis

Statistical analysis was carried out using IBM SPSS version 20 software, and the Origin 8.5 SR1 program was used to generate the figures. The results of observations were expressed in terms of mean and standard error of mean (SE.m). Multiple comparisons of the data were made Duncan's test to evaluate the significant differences. Additionally, the significant differences were also determined between the two cropping seasons by Independent-samples t-test.

RESULTS

Soil Clay Content and Textural Class

Soil particle ranges, including clay content and soil textural class, varied within WW and FW irrigated sites in both growing seasons (Table 1). At the study sites, silt was the dominant soil particle, followed by sand and clay. The BKZ site was considered to have a higher clay content compared to HA and MN study sites. In both growing seasons, maximum clay content (8.4%) was measured in the BKZ soil samples and minimum in the HA soil sample. In both growing seasons, the clay content trend was as followed: BKZ > CB > MN > HA. In addition, in both growing seasons, soil textures were classified as silt loam in WW-irrigated sites, whereas sandy loam in FW-irrigated fields. However, the results further show that the clay content in the soil samples slightly increased in Season-II compared to Season-I, but the trend of clay contents of the WW-irrigated soil samples was statistically similar compared to the FW-irrigated soil samples of both growing seasons.

Soil pH and EC

In both growing seasons, soil pH was significantly decreased under WI (Fig. 1A). On average, measured pH was lower, with 0.49, 6.89, and 4.52% in WW-irrigated soil samples of BKZ, HA, and MN, respectively, compared to FW-irrigated soil samples. For both growing seasons, the trend of soil pH among the study sites was observed as follows: BKZ < HA < MN < CB. Conversely, WI significantly increased EC in both growing seasons (Fig. 1B). A maximum EC of 0.942 and 0.961 dS/m was recorded in Season-I and Season-II, respectively, from the BKZ soil samples. These obtained results were considerably higher compared to MN soil samples. However, no significant differences were observed between the EC values from BKZ and HA soil samples in both growing seasons. Similarly, the EC values of MN soil samples remained the same as the EC rates of CB soil samples in both growing seasons.

Table 1. Soil particles range and textural class under WW and FW irrigated sites.

Study site	Soil particle range			Texture class
	Sand	Silt	Clay	
Season-I (Spring)				
HA	45.3 ± 2.3	51.5 ± 3.5	3.2 ± 1.3	Silt Loam
BKZ	42.2 ± 1.7	50.8 ± 1.7	7.0 ± 1.2	Silt Loam
MN	43.7 ± 4.0	50.3 ± 3.6	6.0 ± 0.9	Silt Loam
CB	43.9 ± 4.0	49.6 ± 3.8	6.5 ± 1.0	Sandy Loam
Season-II (Summer)				
HA	43.1 ± 2.7	53.2 ± 1.9	3.7 ± 0.8	Silt Loam
BKZ	42.2 ± 1.8	50.7 ± 2.1	7.1 ± 0.8	Silt Loam
MN	43.2 ± 1.8	51.5 ± 2.4	6.3 ± 0.9	Silt Loam
CB	44.2 ± 2.1	49.2 ± 2.2	6.6 ± 1.6	Sandy Loam

Sample size (n = 9), ± Stander of mean.

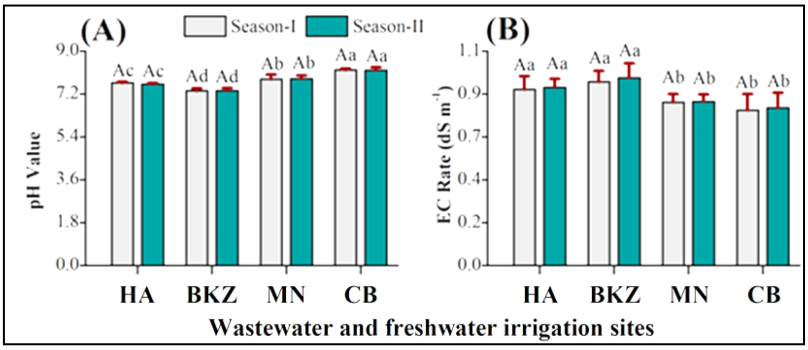

Figure 1. Soil pH (A) and EC (B) levels in the HA, BKZ, MH, and CB study sites (sample size, n = 9). Error bars indicate the SE of means. Different letters on top of the columns (A and B) and (a, b, c, and d) indicate significant differences between successive growing seasons and among the study sites, respectively.

DISCUSSION

The results of this study revealed that soil particle sizes, including clay contents, was statistically similar between WW-irrigated and FW-irrigated soil samples, in both growing seasons. In contrast with these results, Abd-Elwahed (2018) reported clay content reduction associated with long-term wastewater irrigation (WI) that can be explained by clay dispersion caused by effluent usage, causing this fraction to transfer to deeper layers of the soil. These explanations may apply to the HA site, where average clay contents were approximately 50% lower in both growing seasons than at the CB site. Soil texture classes were classified as silt loam and sandy loam at WW and FW irrigated sites, respectively. This difference could be due to the high levels of organic matters (OMs) in WI sites, which transformed the soil texture from coarse to fine as well as improved soil aggregation and soil structure. Constant cultivation practices over the growing seasons also changed the coarse texture of the soil to a finer texture as WW continues to irrigate the site, coupled with the remaining crop residues, manure, and compost inputs, with soil moisture features predominantly in the soil (Li et al., 2022).
The present findings show lower pH values at the WW irrigated sites compared to FW irrigated site. Lower pH values are most likely due to the high amount of mineral nitrogen and organic matters (OMs) in WW, which promotes a strong nitrification reaction and releases a specific number of protons (H+), thus lowering pH of soil. As urban WW and storm water entirely flow to the HA and BKZ sites and a small amount to the MN site, the low-pH WW and acidic rain may have reduced soil pH when the soil is naturally alkaline (Zheng et al., 2012). Du et al. (2022) reported 0.21 units lower pH level of WW-irrigated soil compared to groundwater-irrigated soil. Other research has also reported that long-term WI causes a significant reduction in soil pH (Alawsy et al., 2019).

The EC values and their changes at the studied sites could be possibly related to the nature of the soil mineralogy as well as irrigation water sources, frequency, and amount of irrigation water. The mobility of ions and cations and their valences, including their total and relative concentrations, could potentially be contributing factors to the EC rise. Because WW contains high concentrations of salts, such irrigation source obviously increases the soil EC values (Gao et al., 2021). The previous study of Du et al. (2022) also reported higher EC values on the WW-irrigated plots than the FW-irrigated plots, which support the findings of the present study. Likewise, WW contains highly acidic compounds, and long-term practice can reduce soil pH, increase soil EC (Singh et al., 2022).

CONCLUSION

The continued drought spell and scarcity of FW in semi-arid areas, including Afghanistan, are forcing farmers to use WW for irrigation. The lack of canal water compels farmers in Afghanistan to become more reliant on groundwater. Meanwhile, WW generated in urban areas is utilized for irrigation without being treated, either directly or indirectly. The findings of the present study show that WI had significant effects on the soils, as indicated by the lower pH levels and higher values of EC compared to FW-irrigated fields. Specifically, the BKZ, followed by the HA soil samples, had the lowest pH rate and maximum EC value, which were significantly greater than all other tested soil samples in both planting seasons. The impacts of WI should be evaluated in the study area, not just from a socioeconomic viewpoint but also from the perspective of environmental sustainability.

Acknowledgment: We would like to acknowledge the support from the head of the plant science faculty, Professor Nasir Ahmad Nasrat. Also, thank you for the support from laboratory staff that has helped during soil analysis (Mr. Asadullah Hamdard).

Conflict of Interest: All authors express no conflict of interest in any part of the research.

Funding: This research received no external funding.

Authors Contributions: Obaid initially prepared a draft of the manuscript. Fazil, Shrifi, Ehsan and Nazir revised the important contents. Obaid, Fazil, Zaryal, and Seerat edited and finalized the manuscript.

REFERENCES

Abd-Elwahed, M. S. (2018). Influence of long-term wastewater irrigation on soil quality and its spatial distribution. *Annals of Agricultural Sciences*, 63(2), 191-199. doi:https://doi.org/10.1016/j.aoas.2018.11.004

Ahmad, K., Wajid, K., Khan, Z. I., Ugulu, I., Memoona, H., Sana, M., . . . Sher, M. (2019). Evaluation of Potential Toxic Metals Accumulation in Wheat Irrigated with Wastewater. *Bulletin of Environmental Contamination and Toxicology*, 102(6), 822-828. doi:https://doi.org/10.1007/s00128-019-02605-1

Alawsy, W. S. A., Alabadi, L. A. S., & Khaeim, H. M. (2019). Effect of sewage water irrigation on growth performance, biomass and nutrient accumulation in maize and barley. *International Journal of agricultural and statistical sciences*, 14(2), 519-524. doi:https://doi.org/10.13140/RG.2.2.28409.31847

Borsato E, Rosa L, Marinello F, Tarolli P, D'Odorico P (2020). Weak and strong sustainability of irrigation: A framework for irrigation practices under limited water availability. Frontiers in Sustainable Food Systems 4, 17.

Delgado, A. & Gómez, J. A. (2016). The Soil. Physical, Chemical and Biological Properties, in Villalobos, F. J. and Fereres, E. (Eds.), Principles of Agronomy for Sustainable Agriculture, p. 15-26. Cham: Springer.

Du, Z., Zhao, S., She, Y., Zhang, Y., Yuan, J., Rahman, S. U., . . . Li, P. (2022). Effects of Different Wastewater Irrigation on Soil Properties and Vegetable Productivity in the North China Plain. *Agriculture*, 12(8), 1106. doi:https://doi.org/10.3390/agriculture12081106

Gao, Y., Shao, G., Wu, S., Xiaojun, W., Lu, J., & Cui, J. (2021). Changes in soil salinity under treated wastewater irrigation: A meta-analysis. *Agricultural Water Management*, 255, 106986. doi:https://doi.org/10.1016/j.agwat.2021.106986

Li, H., Van den Bulcke, J., Mendoza, O., Deroo, H., Haesaert, G., Dewitte, K., . . . Sleutel, S. (2022). Soil texture controls added organic matter mineralization by regulating soil moisture—evidence from a field experiment in a maritime climate. *Geoderma*, 410, 115690. doi:https://doi.org/10.1016/j.geoderma.2021.115690

Poustie, A., Yang, Y., Verburg, P., Pagilla, K., & Hanigan, D. (2020). Reclaimed wastewater as a viable water source for agricultural irrigation: A review of food crop growth inhibition and promotion in the context of environmental change. *Science of The Total Environment*, 739, 139756. doi:https://doi.org/10.1016/j.scitotenv.2020.139756

Qadir, M., Drechsel, P., Jiménez Cisneros, B., Kim, Y., Pramanik, A., Mehta, P., & Olaniyan, O. (2020). Global and regional potential of wastewater as a water, nutrient and energy source. *Natural Resources Forum*, 44(1), 40-51. doi:https://doi.org/10.1111/1477-8947.12187

Singh, P. K., Yadav, J. S., Kumar, I., Kumar, U., & Sharma, R. K. (2022). Risk assessment of heavy metal contaminated vegetables and cereal crops from carpet industrial effluents irrigated areas of northern India. PREPRINT (Version 1) available at Research Square. doi:https://doi.org/10.21203/rs.3.rs-1622081/v1

Yaseen, Z. M., Al-Juboori, A. M., Beyaztas, U., Al-Ansari, N., Chau, K.-W., Qi, C., . . . Shahid, S. (2020). Prediction of evaporation in arid and semi-arid regions: a comparative study using different machine learning models. *Engineering Applications of Computational Fluid Mechanics*, 14(1), 70-89. doi:https://doi.org/10.1080/19942060.2019.1680576

Zheng, S. A., Zheng, X., & Chen, C. (2012). Leaching behavior of heavy metals and transformation of their speciation in polluted soil receiving simulated acid rain. *PLoS One*, 7(11), e49664. doi:https://doi.org/10.1371/journal.pone.0049664