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Policy Measures to Curb Health Risks Related Toxic Metals Transfer in Citrus Fruits from Wastewater Irrigation at Citrus Valley of Sargodha, Pakistan

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Abstract

Wastewater irrigation in the Citrus Valley in Sargodha, Pakistan, has resulted in the accumulation of toxic metals like cadmium (Cd), chromium (Cr), iron (Fe), manganese (Mn), cupper (Cu), and zinc (Zn) in citrus fruits. Research findings have revealed that the levels of toxic metals like Cd, Cr, Fe, Mn, Cu, and Zn are prominent in the soil, water, and citrus fruits. The health risk index levels of metals like Cd, Cr, Fe, Mn, Cu, and Zn have surpassed the permissible limits. However, the levels of metals like Cd, Cr, Fe, Mn, Cu, and Zn in the daily intake have been found to be within the threshold WHO safe limits This policy brief has adopted evidence-based measures, recommending wastewater treatment, regulated irrigation, and soil amendments to safeguard citrus production and public health.

Keywords: Restriction, Heavy Metals, Translocation, Citrus, Spraying, Brackish Water.

Problem Statement and Issues Observed

Citrus Valley of Sargodha, seldom depends on untreated wastewater for irrigation due to a shortage of water, resulting in the accumulation of toxic metals in crops (Khan et al., 2014; Ghani et al., 2017).Vegetables and citrus fruits like citrus, oranges, contain Cd up to 0.3 µg g^{-1}, Cr up to 0.11 µg g^{-1}, and Fe up to 4 µg g^{-1} in wastewater-irrigated sites, exceeding WHO permissible levels (Khan et al., 2014). Recent studies have shown increased Cr, Fe, and Mn in *Citrus sinensis and Citrus limetta* from sewage-irrigated sites compared to freshwater sites, indicating a non-carcinogenic risk to health with HRI >1 (Ugulu et al., 2024; Khan et al., 2023). Zinc also accumulates in *Citrus sinensis* in response to different fertilizers and irrigation practices, reaching 0.321 mg kg^{-1} in sewage-irrigated citrus under inorganic fertilizers (Saleem et al., 2024).

Current Policies and Alternatives

In Pakistan's National Water Policy of 2018, wastewater treatment for agricultural purposes is mandatory. However, this policy is not effectively implemented in the peri-urban area of Sargodha, where industrial wastewater directly enters the canal system (Khan et al., 2014). The Agriculture

Department of the Government of Punjab suggests the practice of drip irrigation or mixing wastewater with freshwater as an alternative for irrigation. However, the practice is not effective (Khan et al., 2024). The WHO and USEPA guidelines for the international community also recommend the level of metals to be present in irrigation water, i.e., Cd < 0.01 mg L^{-1}. However, the practice of harvesting rainwater or the reuse of treated wastewater for irrigation purposes is not effectively implemented (Ugulu et al., 2024). Foliar application of Zn fertilizers seems to be an alternative without increasing the level of toxicity.

Key Findings

- Wastewater-irrigated citrus in Sargodha contains Cd (0.010-0.063 mg kg^{-1}), Cr (0.015-0.293 mg kg^{-1}), Fe (6.691-11.342 mg kg^{-1}), and Mn (0.366-0.667 mg kg^{-1}), with the highest amounts in sewage-irrigated soils (Ugulu et al., 2024).
- Elemental composition in *Citrus sinensis* varies in different tehsils, with Zn levels related to irrigation and fertilizers (Ghani et al., 2017; Saleem et al., 2024).
- Soil-to-fruit transfer factors indicate substantial Cu, Zn, Fe, and Mn uptake from contaminated sources (Khan et al., 2023).
- Health risks persist despite permissible soil/fruit levels, as HRI >1 signals chronic exposure threats (Khan et al., 2024).

Table 1: Comparative assessment of toxic metals in wastewater and freshwater irrigated citrus in consort with WHO safe limits

Metal	Wastewater-Irrigated Citrus (mg kg^{-1})	Freshwater-Irrigated Citrus (mg kg^{-1})	Safe Limit (WHO)
Cd	0.010-0.063 *(Ugulu et al., 2024)*	<0.010	0.003
Cr	0.015-0.293 *(Ugulu et al., 2024)*	0.015	0.05
Fe	6.691-11.342 *(Ugulu et al., 2024)*	6.691	20
Zn	0.321 *(Saleem et al., 2024)*	0.032	100

Table 2: Health related toxic metals in *Citrus limetta* and *Citrus sinensis* irrigated by wastewater

Metal	*Citrus sinensis* (Wastewater)	*Citrus sinensis* (Fresh)	*Citrus limetta* (Wastewater)	*Citrus limetta* (Fresh)	WHO Limit
Cd	0.063	0.010	0.045	0.012	0.05
Cr	0.293	0.015	0.210	0.020	0.05
Fe	11.342	6.691	10.500	7.200	10.0
Mn	0.667	0.366	0.580	0.400	2.0

Sources: Ugulu et al., (2024); Khan et al., (2023).

Policy Implications

Sargodha's citrus export trade, worth millions of dollars, is at risk if wastewater is not treated, as it may lead to rejection in other countries due to metal contaminants (Ghani et al., 2017; Khan et

al., 2024). Health implications arising from consuming food with metals may affect the health infrastructure of Punjab province if it leads to an increase in non-communicable diseases (Ugulu et al., 2024). This is where the need to monitor water and soil is felt, as per the Pakistan Environmental Protection Act (1997), and fertigation is a technique that can help without compromising crop yield (Boaretto et al., 2024).

Policy Recommendations and Scientific Solutions

Regulate Irrigation: Impose blending of wastewater with freshwater in 50:50 proportion and restrict its application only to non-edible crops; monitor and regulate through Punjab's Agriculture Department (Khan et al., 2024).

Wastewater Treatment: Install primary/secondary treatment plants at industrial effluent outlets to decrease metals by 70-90% (Khan et al., 2014).

Soil Remediation: Use organic amendments and Zn nanoparticles to immobilize metals in the soil; encourage phyto-extraction with hyperaccumulator plants (Saleem et al., 2024).

Fertilizer Optimization: Use foliar Zn fertigation in place of soil application to reduce toxicity uptake by plants (2-5 kg ha^{-1}) (Boaretto et al., 2024).

Monitoring Framework: Develop a GIS-based quarterly monitoring framework with thresholds set at HRI values in Citrus Valley (Khan et al., 2023).

Farmer Incentives: Provide subsidies on drip irrigation systems and certified seeds; train farmers through extension services (Ugulu et al., 2024).

Conclusion and Future Thrusts

Transfer of toxic metals through wastewater irrigation is a sustainability threat to Citrus Valley, but it can be prevented with appropriate policies. In the future, more research should be conducted on the effects of multi-metal interactions, climate-resilient remediation, and policy impact assessments to promote food security.

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