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Copper and nickel accumulation and translocation in leafy vegetables irrigated with metal-containing effluents.

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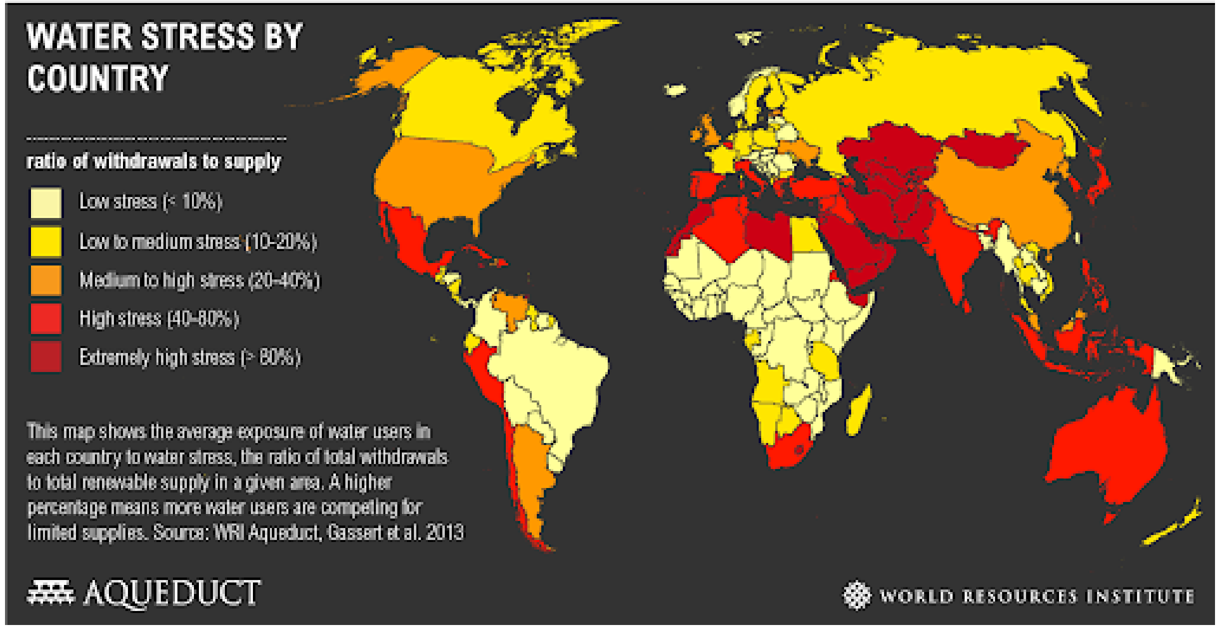
Dongguan

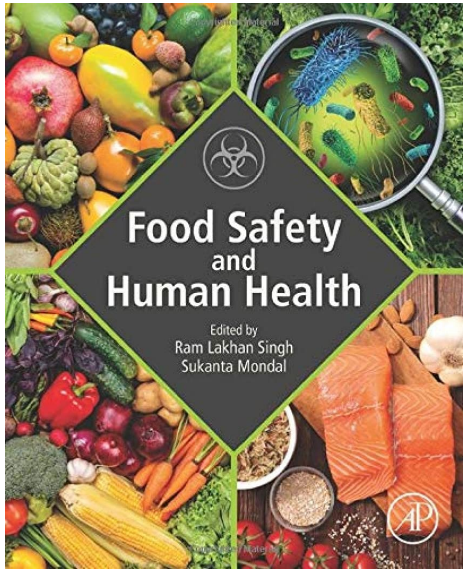
Practice of wastewater irrigation

About 8% of the total land area is irrigated by wastewater worldwide (2/3 – Asia)



Irrigation with wastewater

Soil contamination and accumulation of heavy metals both in agricultural soil and crops



Leafy vegetables

- According to the Food and Agriculture Organization (FAO), harvested area for the main leafy vegetables has increased by more than 200% over the past decades, also due to the growing number of health-conscious consumers.

- Green leafy vegetables are considered as natural caches of nutrients for human beings as they are a rich source of vitamins, such as ascorbic acid, folic acid, tocopherols, b-carotene, and riboflavin, as well as minerals such as iron, calcium, and phosphorous.

- They also contain an enormous range of bioactive health-promoting compounds such as antioxidants and antimicrobial agents, which provide health benefits beyond basic nutrition.

- Among the vegetables, the leafy ones demonstrate the highest accumulation capacity of different metals due to higher translocation and transpiration rates.

The essentiality and toxicity of Cu and Ni in plants

Cu

+

- Significant role in cell wall metabolism, photosynthesis, respiration, carbohydrate metabolism, chlorophyll biosynthesis, and oxidative phosphorylation.
- An optimal Cu concentration is a prerequisite for the activities of numerous enzymes, mostly for neutralizing oxidative stress response in plants.

−

- Reduced overall growth;
- Enhanced antioxidant activity;
- Decreased pigment production;
- Chlorosis, necrosis;
- Reduced nutrient absorption;
- Reduced root growth.

Ni

+

- Ni is an important constituent of many enzymes.
- Ni also participates in different metabolic reactions.
- Ni deficiency reduces growth, causes senescence, and disturbs the N assimilation and uptake of Fe in plants.

−

- growth retardation, chlorosis, decrease in the mass and length of roots;
- loss of cell turgor, degradation of cell walls;
- High Ni content in soil can lead to decreased concentrations of macronutrients such as phosphorus and potassium in plant tissues.

Many studies have assessed the human health risks associated with the consumption of vegetables irrigated with wastewater.

Problems

- Content of metals in irrigation wastewater?
- Features of metals distribution in roots and edible parts of vegetables?
- Daily intake of leafy vegetables?
- Maximum permissible concentration of metals in vegetables?

Aims

- to assess the accumulation of Cu and Ni in soil and different parts of lettuce (*Lactuca sativa*), green onion (*Allium fistulosum* L.), arugula (*Eruca vesicaria*) and chard (*Beta vulgaris* var. cicla) grown on soils irrigated with industrial effluents;
- to estimate Cu and Ni bioaccumulation and translocation in different parts of vegetables;
- to calculate the estimated daily intake and target hazard quotient of Cu and Ni through intake of wastewater-irrigated vegetables

Laboratory experiment

2 industrial effluents

Cu	Ni
(1.3 mg/L)	(7.7 mg/L)
≈ 7 MPC	≈ 38 MPC

*Maximum permissible concentration (MPC) of metal in irrigation water

The plants were irrigated with effluents during 6 weeks.

4 Plants

Lettuce

Onion

Chard

Arugula

Elemental accumulation in soils, leaves and roots of plants

Measurement of element concentrations with ICP-OES

The vegetables are an important part of human’s diet. That’s why the ability of plants to accumulate metals from soil and translocate it from the roots to the aboveground part of the plant was estimated using the bioconcentration factor and translocation factor.
Also, the potential health risks associated with their intake was estimated.

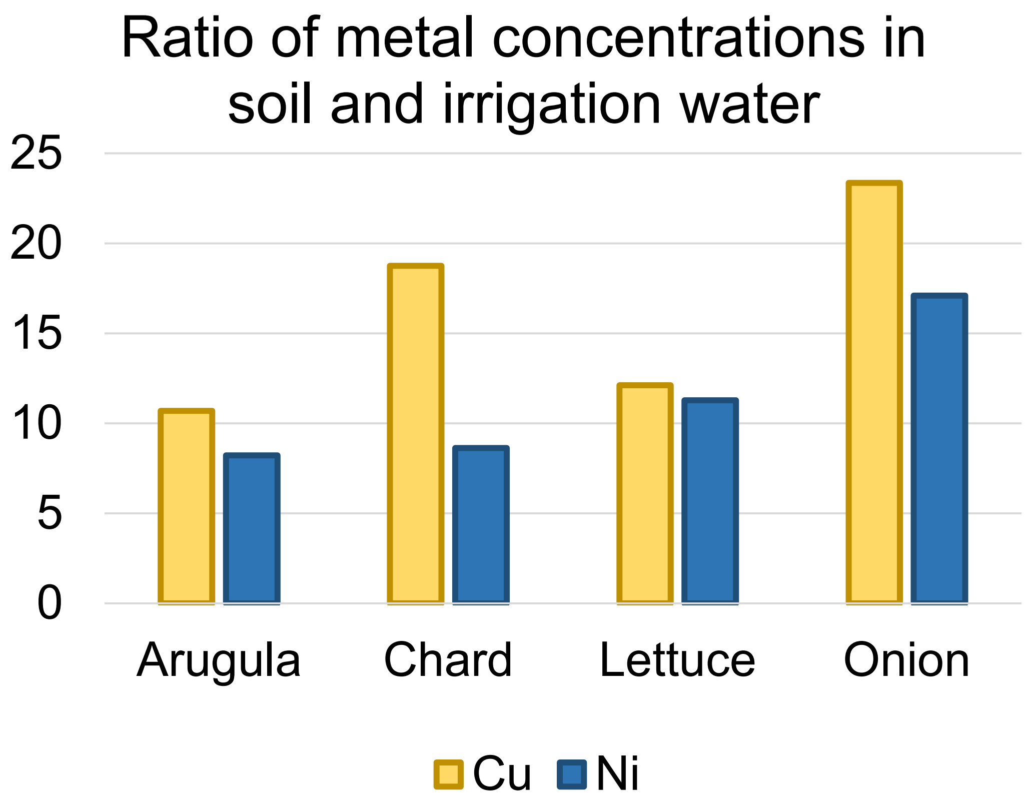
Features of metal accumulation in plants

- Bioconcentration factor (BCF)
- Translocation factor (TF)

Human health risks

- Estimated daily intake of metals (EDI)
- Target hazard quotient (THQ)

Cu and Ni accumulation in soil



Ni concentrations in the soil during cultivation of **all vegetables** exceeded the established permissible concentration of the metal in the soil.

Under vegetable cultivation	Cu	Ni
	mg/kg	
Arugula	13.9±2.51	62.9±0.60
Chard	24.4±16.7	66.0±0.69
Lettuce	15.7±10.1	86.4±0.82
Onion	30.4±8.23	131±0.38
US EPA	20	50

Cu and Ni accumulation in roots

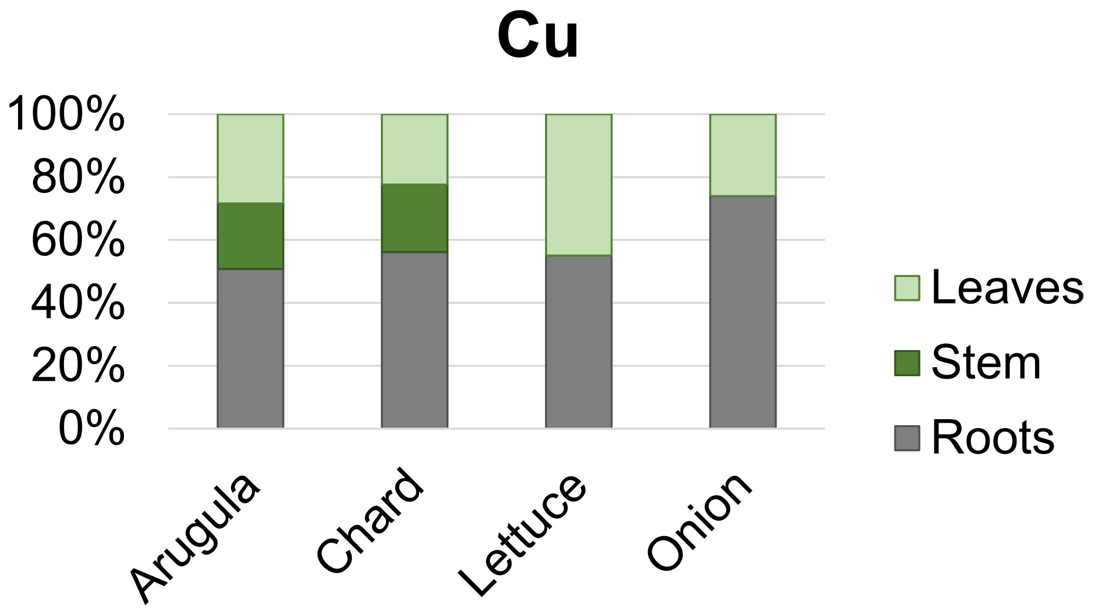
Bioconcentration factor (BCF) = C (roots) / C (soil)

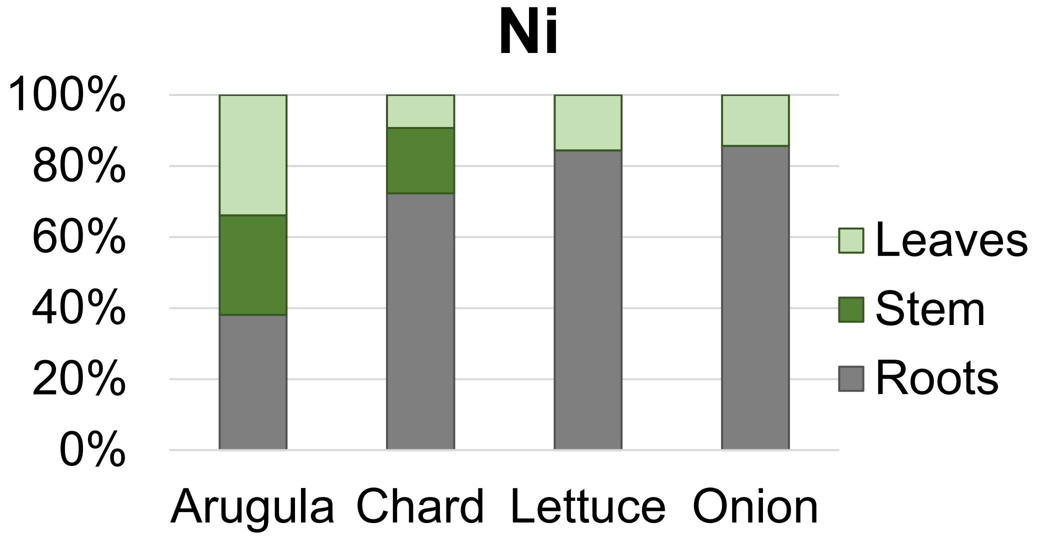
Effluent	Bioconcentration factors			
	Arugula	Chard	Lettuce	Onion
Cu	**0.8**	**1.0**	0.7	0.6
Ni	0.3	**0.9**	**1.5**	0.4

Lettuce actively accumulated Ni (BCF > 1) from the soils.

For **chard**, high values of BCF were also obtained for both metals.

Cu translocation in lettuce, onion, chard and arugula





TF = C (leaves) / C (roots)

Effluent	Translocation factors			
	Arugula	Chard	Lettuce	Onion
Cu	0.5	0.4	**0.8**	0.4
Ni	**0.8**	0.2	0.2	0.2

Chard and onion showed a low capacity to transfer copper and nickel from underground to above-ground plant parts.

Arugula and **lettuce** were the exceptions with the values of the TF of 0.8 for Ni and Cu, respectively.

Cu and Ni content in the edible part of plants (mg/kg dry weight)

Element	Arugula 	Chard 	Lettuce 	Onion 	Vegetables (FAO/WHO standards)
Cu	5.10±1.09	**9.79**±0.27	**8.34**±1.24	5.93±0.37	40
% of the total content	*49*	*44*	*45*	*26*	
Ni	**16.8**±2.21	11.4±3.11	**24.1**±5.34	9.43±2.31	10
% of the total content	*62*	*28*	*16*	*14*	

Estimated daily intake of Cu and Ni through consumption of contaminated vegetables (μg/kg - day)

$$\mathrm{EDI} = \frac{C_{metal\ conc} \times C_{factor} \times D_{food\ intake}}{B_{average\ weight}}$$

- $C_{metal\ conc}$ - Cu and Ni concentration in edible part of vegetables (mg/kg dry weight);
- C_{factor} - the conversion factors of 0.05 - 0.08 were used for different vegetables;
- Daily intake of arugula/chard/lettuce/onion – 0.04 kg/day;
- The average body weight for an adult was considered as 70 kg

Intake	Plants	Cu	Ni
EDI	Arugula	0.23	0.77
	Chard	0.40	0.47
	Lettuce	0.26	0.74
	Onion	0.17	0.26
Safe daily dietary intake	Food	29-43 (Adults) 7.1-10 (Infants)	20

Target hazard quotient (THQ), developed by USEPA (United States Environmental Protection Agency) fits well for the purposes of non-carcinogenic health risk assessment. If the THQ is < 1 then no non-carcinogenic health effects are expected.

THQ for all leafy vegetables and elements analyzed were < 1

Conclusions

- The concentration of Ni in the soil during the cultivation of all vegetables exceeded the established permissible concentration of the metal in the soil by 1.2 - 2.6 times.

- **Lettuce** actively accumulated Ni in the roots (BCF > 1) and translocated it to the green part.
- **Chard** also showed high BCF values for both metals, but low capacity to transfer copper and nickel from underground to above-ground plant parts.
- **Arugula** was characterized by the ability to actively accumulate Cu (BCF=0.8) and weak translocation of Cu to the green part. The opposite pattern was found for Ni.
- **Onion** was characterized by weak accumulation and translocation capacity with respect to both metals.

- The highest concentrations of Cu were determined in **chard** and **lettuce**. The concentration of Cu in all vegetables was below the established maximum permissible level.
- The highest concentrations of Ni were determined in **lettuce.** Concentrations of Ni in arugula and lettuce were higher than the established maximum permissible level.

- The obtained values of EDI were one or two order of magnitude lower than the safe daily dietary intake established for nickel and copper. THQ for all leafy vegetables and elements

Thank you for attention!