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Home work
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Proposed by: Dr Olfa Hentati

A Risk Assessment of Reusing Wastewater on Agricultural Soils

A Case Study on Heavy Metal Contamination of Peach Trees in Ouardanine, Monastir, Tunisia

State of art:
Tunisia is facing serious shortage of water resources, due to increasing water consumption and pollution of already existing water resources. Forecasts show an increase of fresh water demand due to industrial, urban and touristic development, mostly for agricultural purposes. Hence, it has become an imperative to develop additional water resources. Wastewater reuse is the other alternative in Tunisian national water resource strategy. But, the limiting factors are quality: pathogen content, salinity, sodicity, ion toxicity, trace element content and nutrients.

Region study:
This study applies to the wastewater collected by the wastewater treatment plant of Ouardanine, a small region situated just outside Monastir. The wastewater is used as the only irrigation water in a studied peach (*Prunus persica*) field in Ouardanine. Agricultural soils are fertilized by repeated sludge application from treatment plants.

Aims of the study and methodology:
The study is semi-qualitative and assesses the risk of reusing wastewater for irrigation in the peach field. The study is prospective and is aiming to describe future accumulation of hazardous heavy metals in the peaches. Thereafter, a dose-response relationship is established between the risks and the irrigation. The risk assessment will be limited to four heavy metals; cadmium (Cd), copper (Cu), lead (Pb) and zinc (Zn). Thus, heavy metal levels in soil water and then in peaches will be measured. The route of heavy metal exposure considered is only ingestion. Only risks of non-carcinogenic effects are considered. There are no Tunisian standards for heavy metal content in agricultural soils and in peaches; instead Swedish standards and regulations are used for comparison.

Physical Settings
The climate along Tunisia's coastal boarders is defined as Mediterranean. Geologically, the bedrock of the Monastir region consists of stratifications (1500m deep) from the middle to the end of the quaternary and tertiary geological time. The Ouardanine region is made of sedimentary rocks that are constantly exposed to erosion. Rocks in the area are fragile and are made from shale, charcoal, sandy clay, clayey sand and sandy rocks, which can contain remains of shells.
Vegetation is usually evergreen. No industries are known in the area.

1. Draw in a diagram the different steps to assess the risks of heavy metal accumulation.
2. What would be the different sources of heavy metals?

3. What are the different routes of exposure to heavy metals in and around the peach field? Draw the specific conceptual model for this site.

Result of water, soil and fruit analysis:

Table 1: General properties of the soil samples

Parameter	Value
Organic matter (g/Kg)	31.5
pH	8.404
Electric conductivity (µS/cm)	197
Salinity (g/Kg)	0
Granulometry	Clayey Silt / sandy silt / sandy clay

Table 2: Heavy metal levels in the water sample

Element	Value (mg/L) (Induced Coupled Plasma (ICP))	Tunisian standard (NT 106.03 1983: reused wastewater in agriculture) (mg/L)
Cd	0	0.01
Cu	0	0.5
Pb	0	1
Zn	0	5

Table 3: Total heavy metal levels in the soil samples and recommended limits given by Jordbruksverket (2007). (DM= dry matter)

Element	Mean (mg/kg DM)	Min (mg/kg DM)	Max (mg/kg DM)	Recommended limits (mg/kg DM)
Cd*	0,699	0,699	0,700	0,4
Cu	20,1	18,2	26,3	40
Pb	14,3	11,7	16,1	40
Zn	69,1	53,0	132	100

*For some samples the element is below detection limit for the ICP, i.e. <0, 6 mg/kg

Table 4: Heavy metal levels in the fruit samples (peaches) and recommended limits given by EG 1881/2006 (2006). (WM=Wet matter)

Element	Mean (mg/kg WM)	Min (mg/kg WM)	Max (mg/kg WM)	Recommended limits (mg/kg WM)
Cd**	<0,03	<0,03	<0,03	0,050
Cu	1,09	0,762	1,42	-
Pb*	0,291	0,267	0,306	0,1
Zn	1,14	1,00	1,28	-

*For some samples the element is below detection limit for the ICP, i.e. <0, 25 mg/kg

**For all samples the element is below detection limit for the ICP, i.e. <0, 03 mg/kg

4. Do the soil properties influence the bioavailability of heavy metals to plants? If yes, how? The plants' capacity to take up heavy metals is low or high?

5. Do the heavy metal concentrations found in the irrigation water, irrigated soils and peaches exceed published and recommended limits?

6. If you admit that 2% of total Zinc, 12% of total Cu, 11% of total Pb and 7-13% of total Cd are extractable in soil, calculate the theoretical extractable concentration of each metal. Could these results explain the undetectable levels of some metals by ICP?

Quantifying exposure: The average daily dose (ADD)

$$ADD = \frac{C \cdot IR \cdot ED \cdot EF}{BW \cdot AT \cdot 365}$$

C = Concentration of contaminant in the ingested food (mg/kg);
IR = Ingestion (Intake) rate (kg/day) = 0.00755 kg/day
ED=Exposure duration (years) = 70 years
EF = Exposure frequency (days/year) = 365
BW = body weight of the receptor (kg) = 70 Kg
AT = Averaging time (years) = ED = 70

7. Calculate the minimum, maximum and the mean of ADD of heavy metals in peaches, according to the equation above. For Cadmium consider the detection limit as the same concentration for min, max and mean of Cd concentration = 0.03 mg/Kg. Which metal has the lowest ADD?

Dose response Assessment

Rfd: reference dose = the highest dose that can be taken in every day without causing an adverse non-carcinogenic effect. AIC: acceptable chronic intakes values are presented in Table 5:

Table 5: Rfd and AIC values for the studied elements

Element	Rfd (mg/kg/day)	AIC (mg/kg/day)	Source
Cd	0,001		EPA U.S. (2009)
Cu	0,037	-	EPA U.S. (2009)
Pb	-	0,000686	Asante-Duah (1993)
Zn	0,3	-	EPA U.S. (2009)

Hazard Quotient :

The quantification of non-carcinogenic effects is measured by the hazard quotient (HQ). Expressed as the ratio between the dose resulting from exposure to the peaches from Ouardanine and the dose that is believed to be without risk of effects HQ is estimated by comparing the ADD with the Rfd or AIC. The HQ is calculated according to:

$$HQ = \frac{ADD}{Rfd}$$

8. Calculate the minimum, maximum and mean of hazard quotient (HQ) for eating peaches from the field for each metal. Which metal has the highest HQ?

The hazard index (HI) is estimated:

The summary of each element´s HQ becomes the hazard index (HI). A HI above 1.0 implies there is a risk for non-carcinogenic effects (toxicity). The probability tends to increase as the value of HI increases. The HI is calculated according to:

$$HI = \sum HQs = \{ADD_1 / Rfd_1 + ADD_2 / Rfd_2 + ... + ADD_i / Rfd_i\}$$

9. Calculate the minimum, maximum and mean HI including cadmium, and excluding it.

10. Is accumulation of heavy metals in plants a risk? Which metal would be stopped in soil-plant barrier, and which metal would be accumulated in the plant? If so, why could it be safe to eat peach even if it is irrigated with wastewater?

11. In the conditions and circumstances of this study, do you accept the risk? Should there be any restriction of the amount of water applied to the field, regarding heavy metals? What is the limiting contaminant?

Lexicon: Forecasts: previsions; Peaches: pèches; Shells: coquilles; Shale: shiste; Bedrock: roche mère; Charcoal: charbon; Clay: argile