Informational-Analytical Center for Risk Assessment of Food Chain,
Center for Ecological-Noosphere Studies,
National Academy of Sciences, Republic of Armenia

Heavy Metal Exposure Assessment in Mining Regions of Armenia

Meline Beglaryan

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Background

Environment

- Syunik is the major mining region of Armenia, which results pollution of environment;
- Heavy metals accumulate in agricultural soils and enter the food chain;
- Diet is one of the main exposure pathways to toxic trace elements.

Health

- Fruits and vegetables are considered to be essential part of healthy diet.
- Syunik's rural community population mostly consumes locally grown crops;
- Previous studies showed the occurrence of non-carcinogenic risk via fruits and vegetables consumption.

Kajaran Mine, the largest operating mine in Armenia.

Fruits and Vegetables in Diet

Fruits and vegetables grown under the impact of mining industry are also sold in the markets of adjacent urban areas.

DIET STUDY

- Individual-based approach
- Food frequency questionnaire **(FFQ)**

_____/_____/2017

Questionnaire N_____/____

Dear participant, the following survey is conducted by the Informational-Analytical Center for Risk Assessment of Food Chain of the Center for Ecological-Noosphere Studies of National Sciences of RA. The survey is designed to investigate the consumption of vegetables and fruits among Yerevan residents. When answering to the questions, please, be as honest as possible because your participation is highly important.

We would like to inform that the survey is ANONYMOUS, no personal data will be recorded and the results will be presented in a general format.

Block 1. Consumption data

1. How much and how often do you consume the following products?

Food type	Not consumed	Consumption frequency						Consumption portion (daily)
		1. Every day	2. 2-4 times a week	3. Once a week	4. 2-3 times a month	5. Once a month	Other	
1. Potato								
2. Bell Pepper								
3. Tomato								
4. Cucumber								
5. Carrot								
6. Eggplant								
7. Zucchini								
8. Green leafs								
9. Apple								
10. Plum								
11. Watermelon								
12. Muskmelon								

2. Where do you usually buy the following products?

Food type	Not consumed	Bazaar							Supermarket						Vegetable garden	Other	Mention the origin of food item, if possible
		1. GUM	2. Malatia	3. Nor Nork	4. Komitas	5. Shengavit	6. Erebuni	Other	1. Yerevan City	2. SAS	3. Ervika	4. Ver Zorq	5. TTFAK	Other			
1. Potato																	
2. Bell Pepper																	
3. Tomato																	
4. Cucumber																	
5. Carrot																	
6. Eggplant																	
7. Zucchini																	
8. Green leafs																	
9. Apple																	
10. Plum																	
11. Watermelon																	
12. Muskmelon																	

Block 2. Personal data

2.1 District: _____

2.2 Age: _____

2.3 Gender: ☐ 1) M. ☐ 2) F.

2.4 Education: ☐ 1) Higher ☐ 2) Vocational ☐ 3) Secondary

2.5 Occupation: ☐ 1)Employed ☐ 2) Unemployed

2.6 Number of family members: _____

2.7 Average monthly family income: ☐ 1) Up to 70.000 AMD ☐ 2) 71 150.000 AMD ☐ 3) 151 250.000 AMD ☐ 4) 251 400.000 AMD ☐ 5) 400.000 AMD and more ☐ 6) Refuse to answer

Investigated Food Items


Grape


Cabbage


Bean


Maize


Eggplant


Cucumber


Beet


Pepper


Plum


Fennel


Tomato


Onion bulb


Basil


Onion leaves


Carrot


Potato

FROM RURAL AREAS

Investigated Food Items


Dewberry


Cabbage


Bean


Potato


Cornel


Cucumber


Beet


Pepper


Eggplant


Zucchini


Tomato


Lettuce


Greens


Onion leaves


Carrot

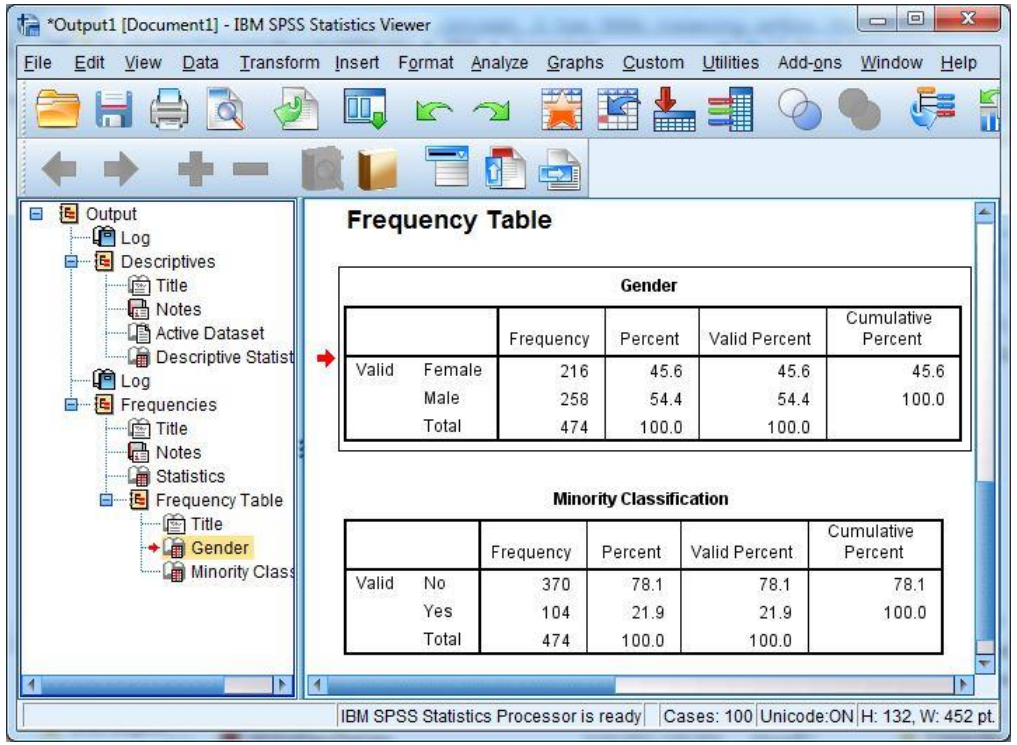
FROM KAPAN MARKETS

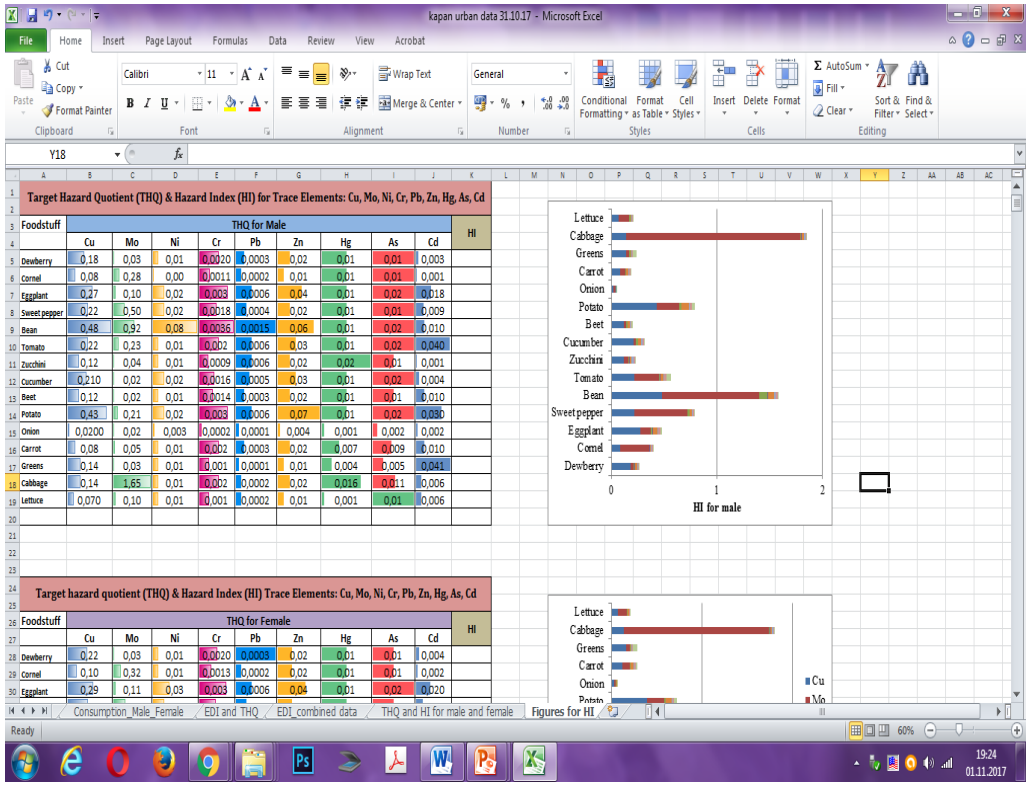
FOOD ANALYSIS

The concentration of ***Ni, Cr, Pb, As, Cd*** in commonly consumed fruits and vegetables were determined using the **atomic absorption spectrophotometer** (*AAS, Perkin Elmer Aanalyst 800*).

DATA ANALYSIS

Statistical analyses were carried out by Microsoft **Excel** and **SPSS** (SPSS Ins., Version 11).





Carcinogenic Risk (CR) Assessment

$$CR = EDI \times SF$$

EDI – Estimated Daily Intake

SF – Slope Factor

Trace element	Ni	Cr (VI)	Pb	Cd	As
SF *(mg/kg/day)*	1,7	0,5	0,0085	0,38	1,5

EDI (mg/kg/bw/day)

Estimated daily intake

$$EDI = (C \times IR \times EF \times ED) / (Bw \times AT)$$

C – concentration of trace element (mg/kg)

IR – ingestion rate (kg/day)

EF – exposure frequency (183 day/year, for potato 365 day/year)

ED – exposure duration (for female 69.7, for male 63.6)

Bw – body weight (for female 60 kg, for male 70 kg)

AT – which the dose is averaged (25550 days)

Limits

US EPA recommended the **SAFE LIMIT** for carcinogenic risk **below** 1 chance in a million lifetime exposure **($CR < 10^{-6}$).**

Threshold Risk Limit ($CR > 10^{-4}$) for cancer above 1 chance in 10,000 lifetime exposure where remedial measures are considerable.

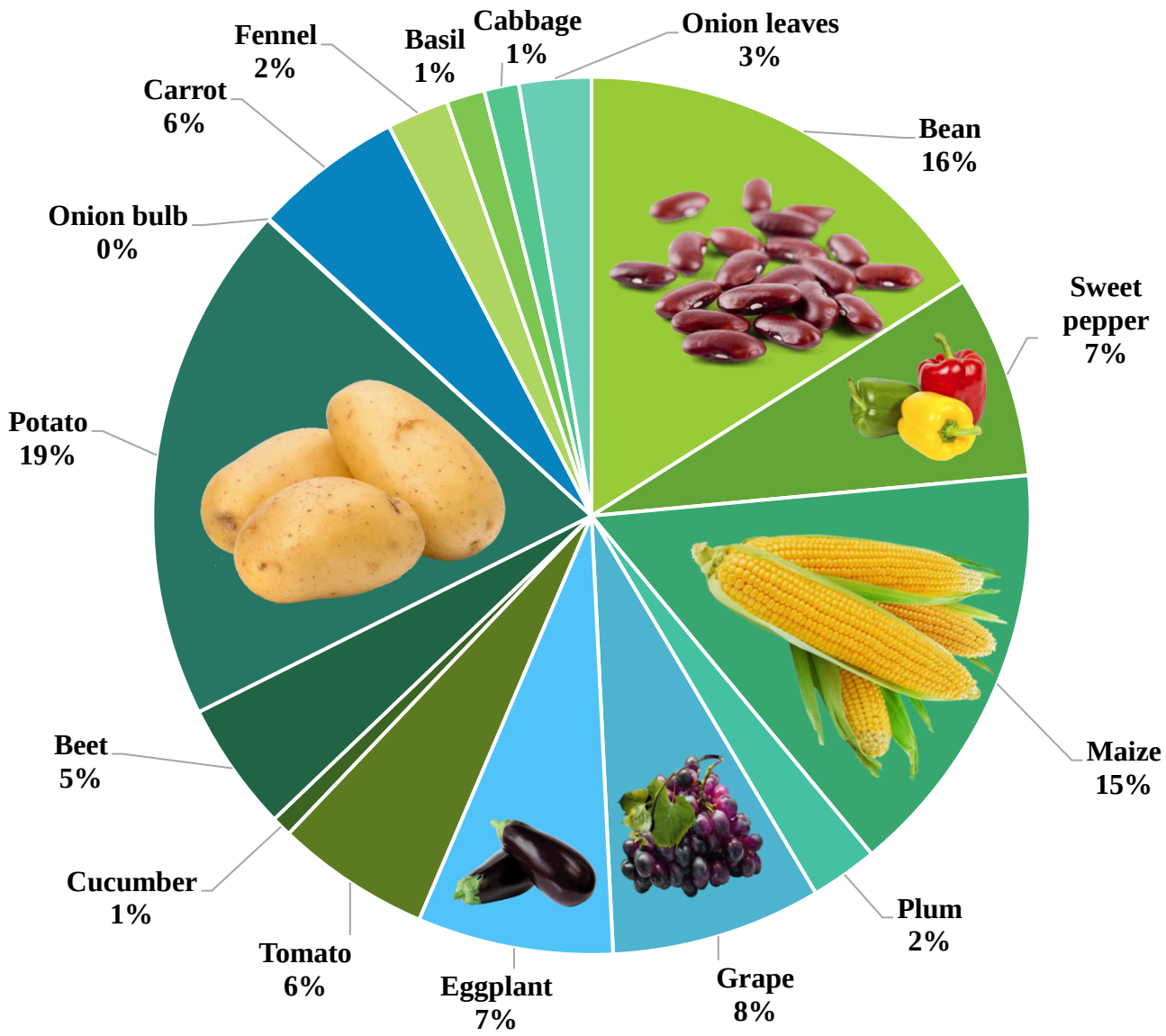
Moderate Risk Level ($CR > 10^{-3}$) is above 1 in 1000 where public health safety consideration is more important

(Tchounwou et. al 2014).


RESULTS

Carcinogenic risk of Ni

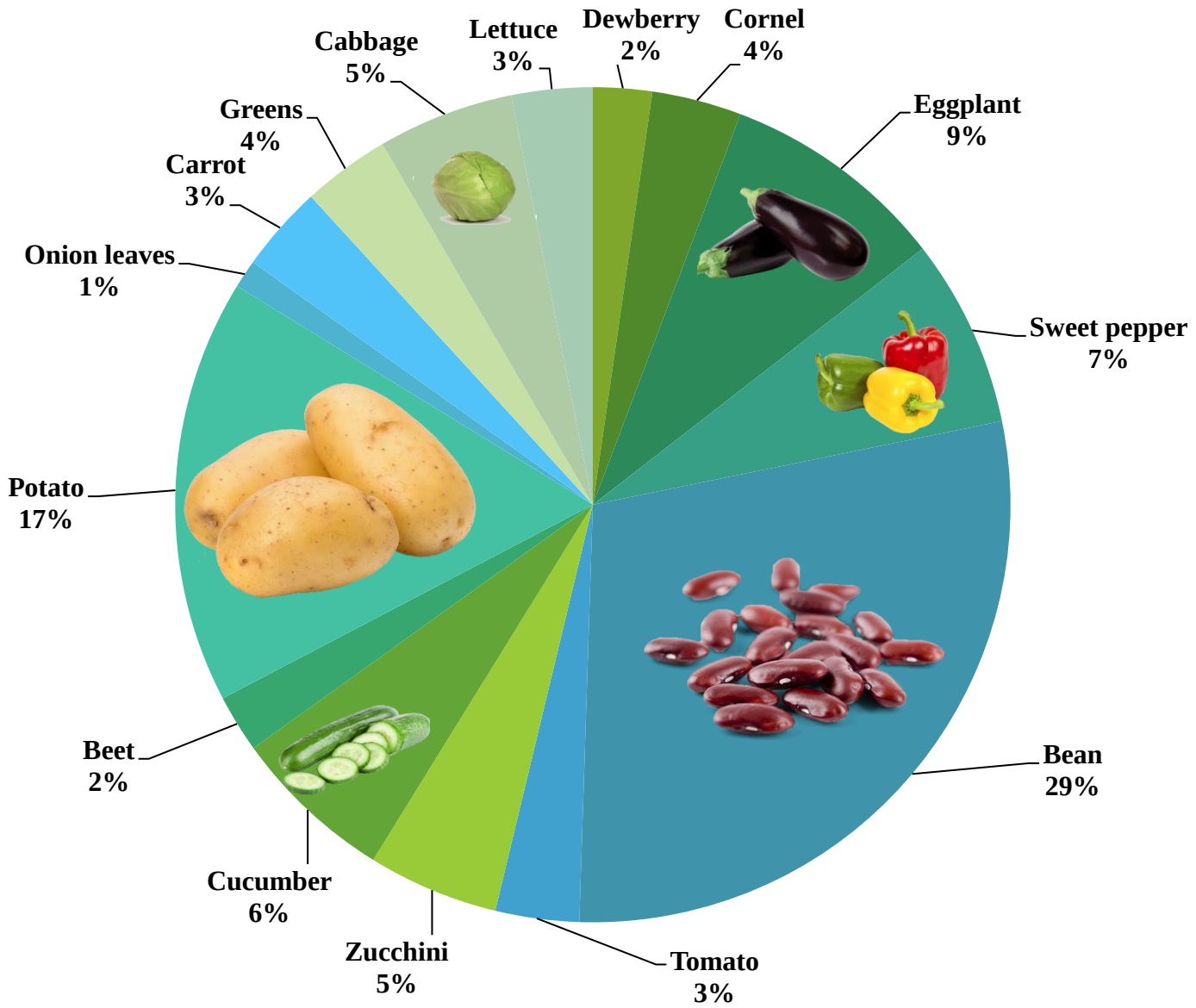
Foodstuff	Ni
Bean	1.14E-02
Sweet pepper	5.29E-03
Maize	1.09E-02
Plum	1.75E-03
Grape	5.48E-03
Eggplant	5.10E-03
Tomato	4.03E-03
Cucumber	5.25E-04
Beet	3.37E-03
Potato	1.36E-02
Onion bulb	4.03E-05
Carrot	3.91E-03
Fennel	1.62E-03
Basil	9.96E-04
Cabbage	9.05E-04
Onion leaves	1.88E-03
Total	**7.08E-02**



FOR RURAL POPULATION

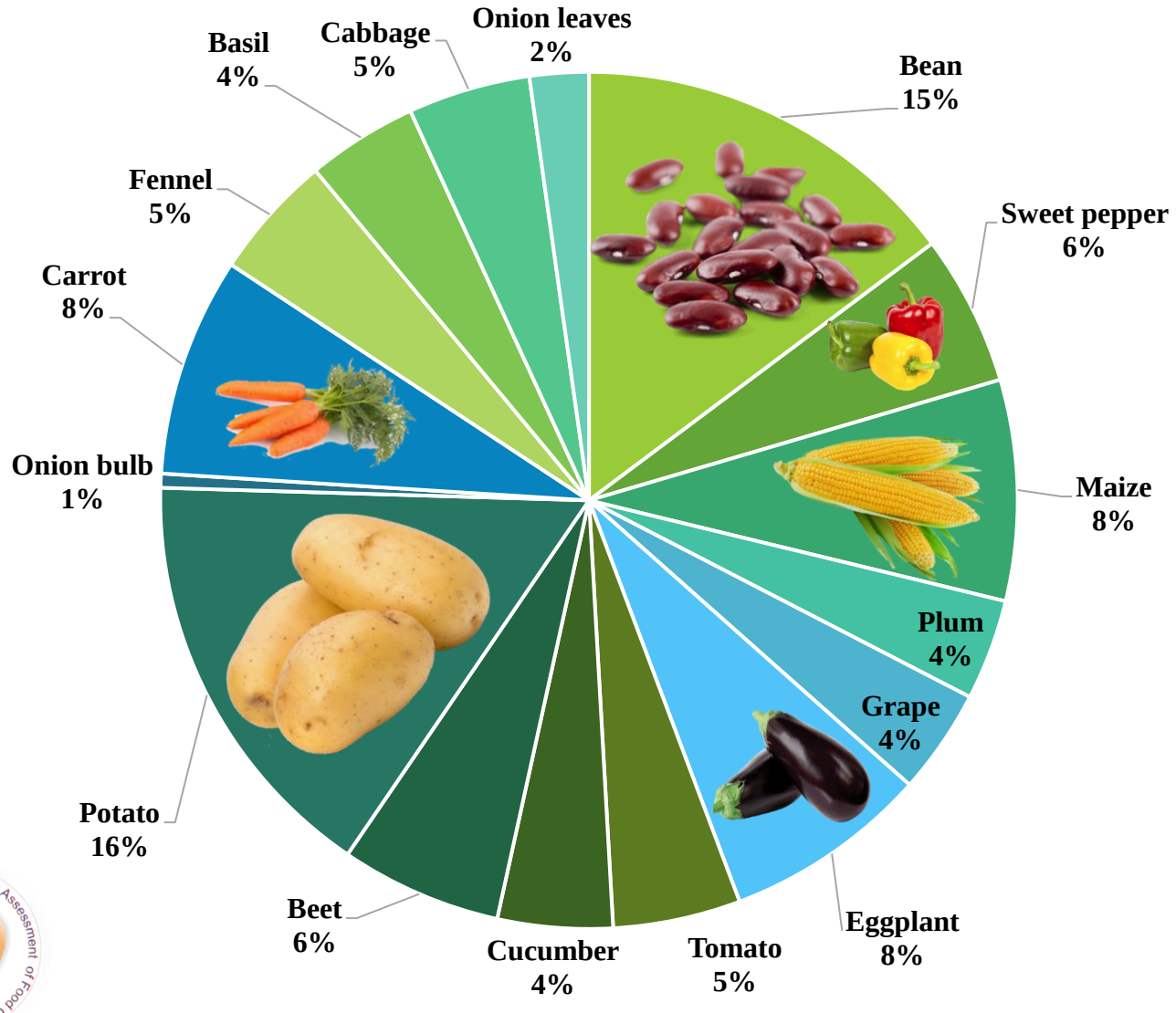
Carcinogenic risk of Ni

Foodstuff	Ni
Dewberry	9,78E-05
Cornel	1,49E-04
Eggplant	3,74E-04
Sweet pepper	3,13E-04
Bean	1,23E-03
Tomato	1,39E-04
Zucchini	2,17E-04
Cucumber	2,69E-04
Beet	9,56E-05
Potato	7,04E-04
Onion leaves	4,69E-05
Carrot	1,43E-04
Greens	1,45E-04
Cabbage	2,26E-04
Lettuce	1,34E-04
Total	4,28E-03



FOR KAPAN RESIDENTS

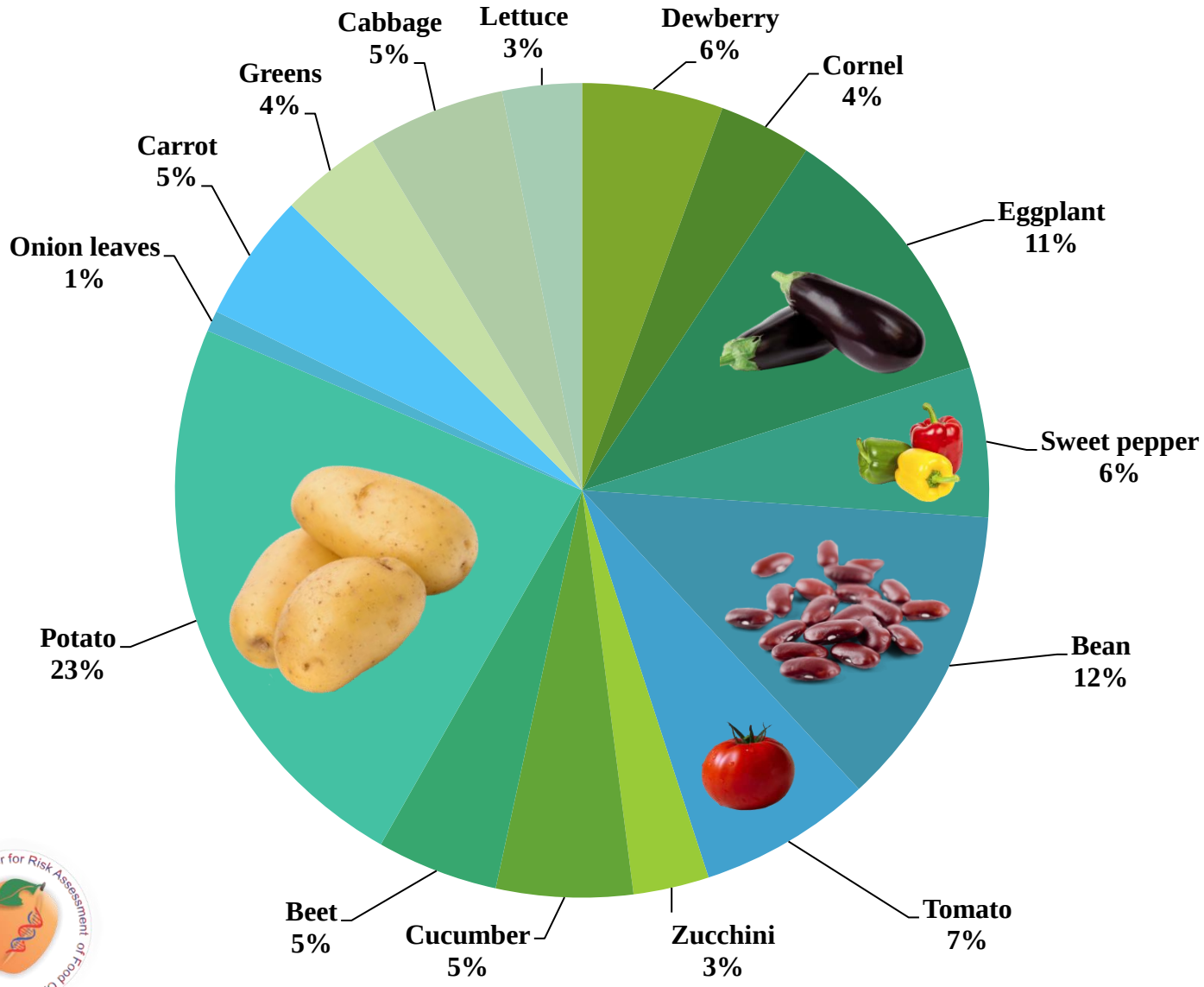
Carcinogenic risk of Cr



Foodstuff	Cr
Bean	4.13E-04
Sweet pepper	1.59E-04
Maize	2.33E-04
Plum	1.06E-04
Grape	1.11E-04
Eggplant	2.16E-04
Tomato	1.35E-04
Cucumber	1.21E-04
Beet	1.70E-04
Potato	4.46E-04
Onion bulb	1.48E-05
Carrot	2.31E-04
Fennel	1.32E-04
Basil	1.17E-04
Cabbage	1.29E-04
Onion leaves	6.23E-05
Total	2.80E-03

FOR RURAL POPULATION

Carcinogenic risk of Cr

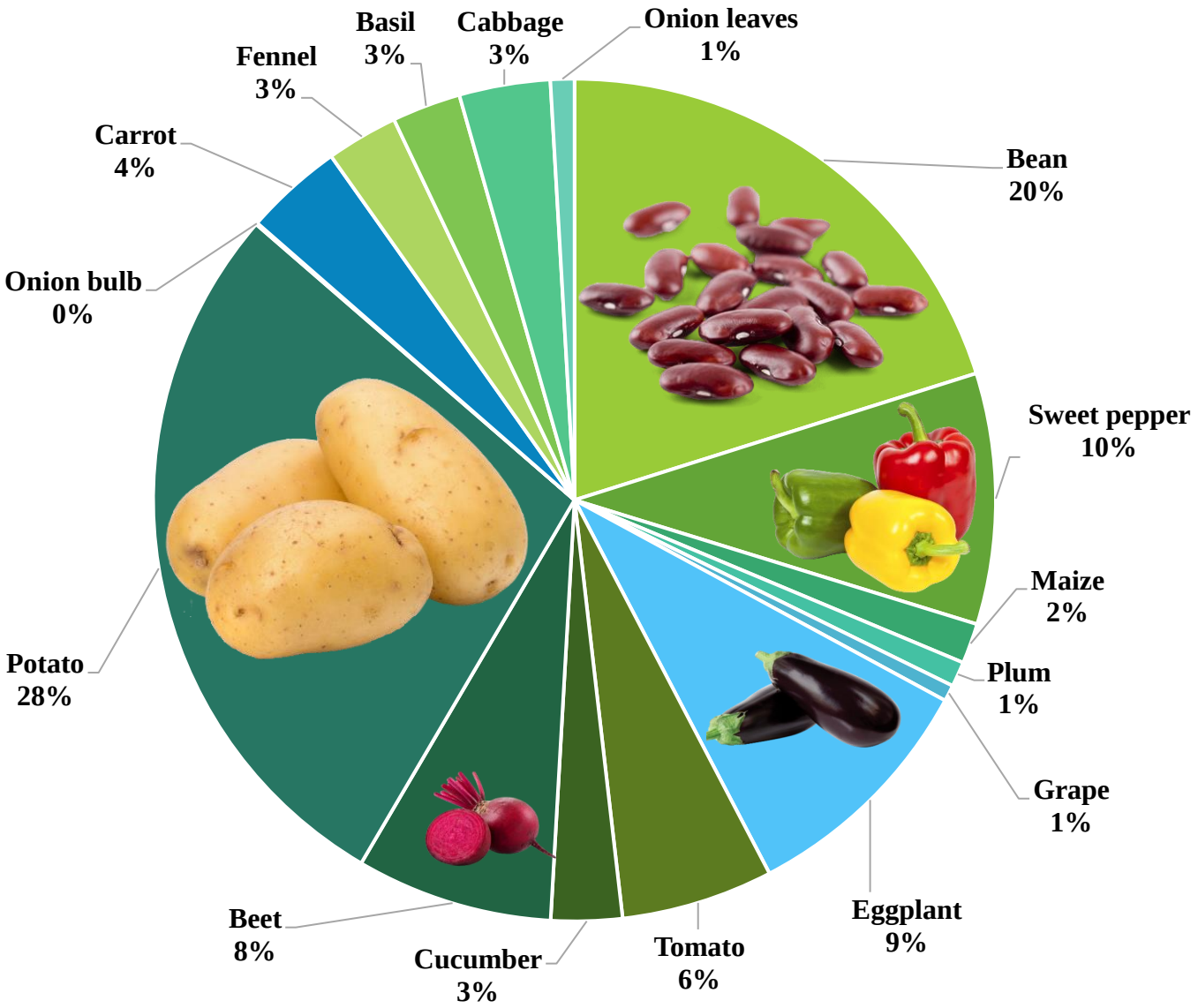


Foodstuff	Cr
Dewberry	1,15E-04
Cornel	7,55E-05
Eggplant	2,23E-04
Sweet pepper	1,22E-04
Bean	2,47E-04
Tomato	1,41E-04
Zucchini	6,18E-05
Cucumber	1,11E-04
Beet	9,90E-05
Potato	4,76E-04
Onion leaves	1,69E-05
Carrot	1,05E-04
Greens	8,33E-05
Cabbage	1,12E-04
Lettuce	6,49E-05
Total	2,05E-03

FOR KAPAN RESIDENTS

Carcinogenic risk of Pb

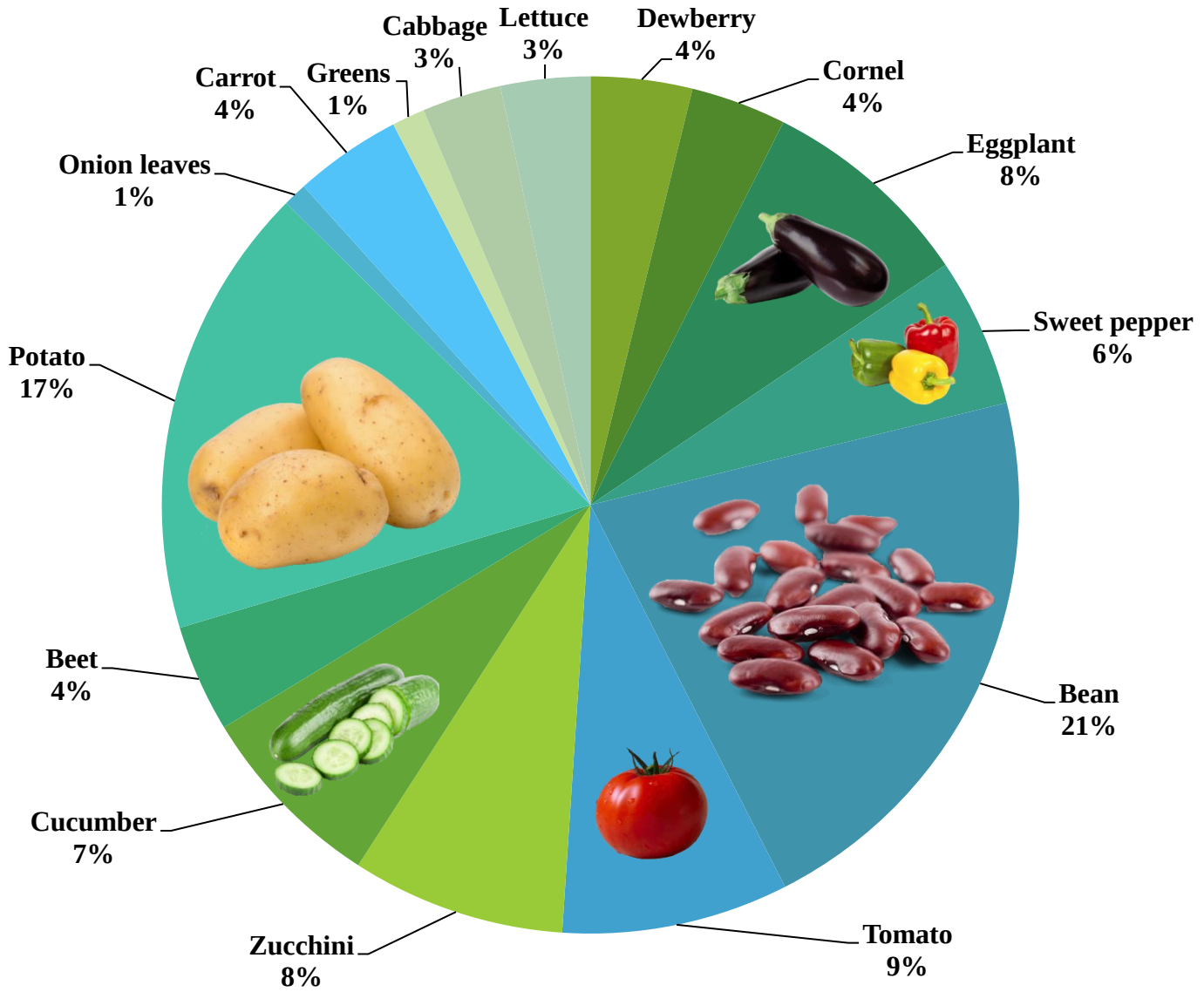
Foodstuff	Pb
Bean	**5.53E-06**
Sweet pepper	**2.64E-06**
Maize	4.24E-07
Plum	2.64E-07
Grape	1.71E-07
Eggplant	**2.60E-06**
Tomato	**1.60E-06**
Cucumber	7.50E-07
Beet	**2.07E-06**
Potato	**7.67E-06**
Onion bulb	1.76E-08
Carrot	**1.04E-06**
Fennel	7.56E-07
Basil	7.25E-07
Cabbage	9.60E-07
Onion leaves	2.52E-07
Total	**2.75E-05**



FOR RURAL POPULATION

Carcinogenic risk of Pb

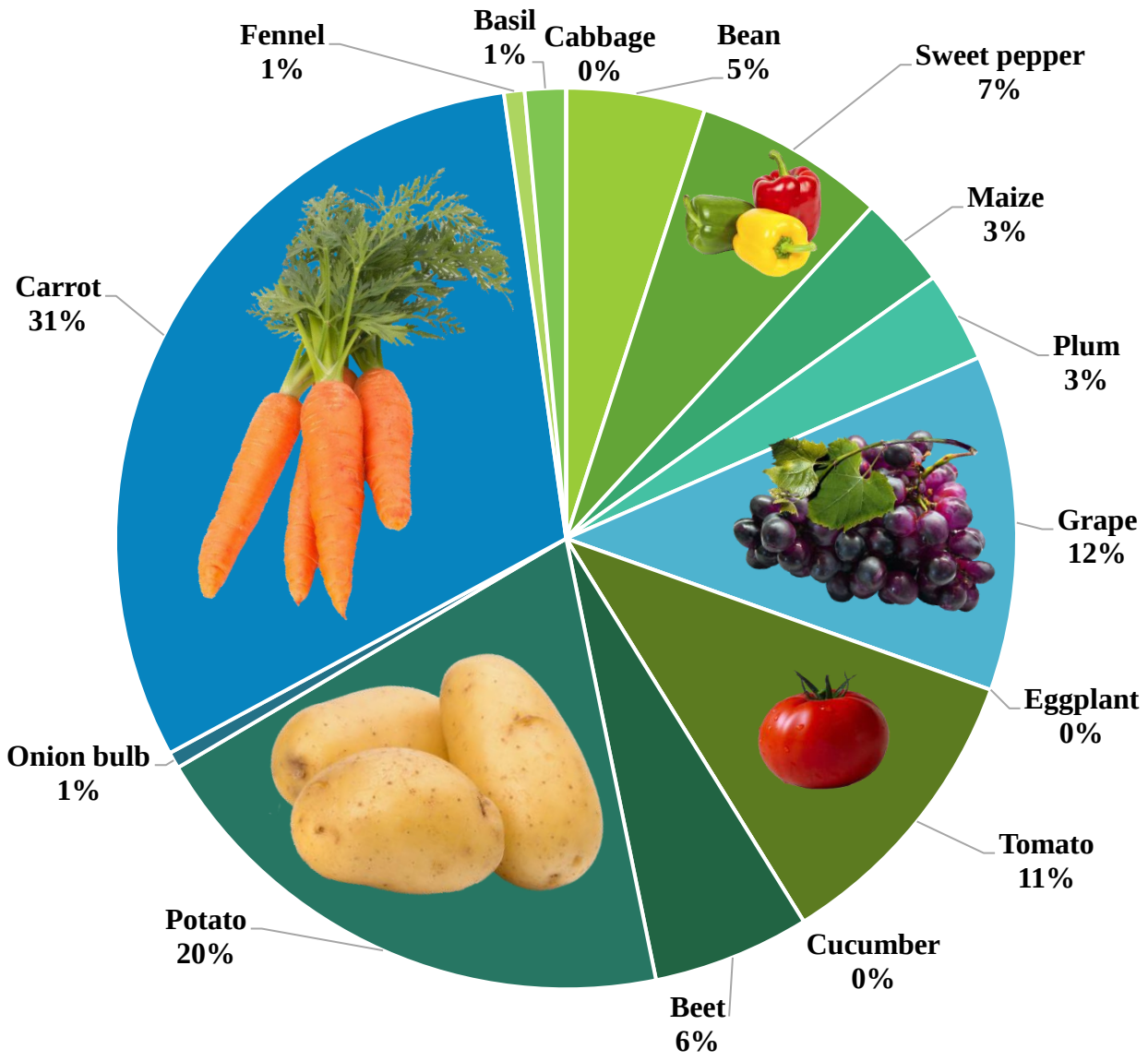
Foodstuff	Pb
Dewberry	3,57E-09
Cornel	3,36E-09
Eggplant	7,57E-09
Sweet pepper	5,25E-09
Bean	1,99E-08
Tomato	7,99E-09
Zucchini	7,52E-09
Cucumber	6,73E-09
Beet	3,78E-09
Potato	1,59E-08
Onion leaves	8,41E-10
Carrot	3,78E-09
Greens	1,16E-09
Cabbage	2,79E-09
Lettuce	3,15E-09
Total	9,33E-08



FOR KAPAN RESIDENTS

Carcinogenic risk of Cd

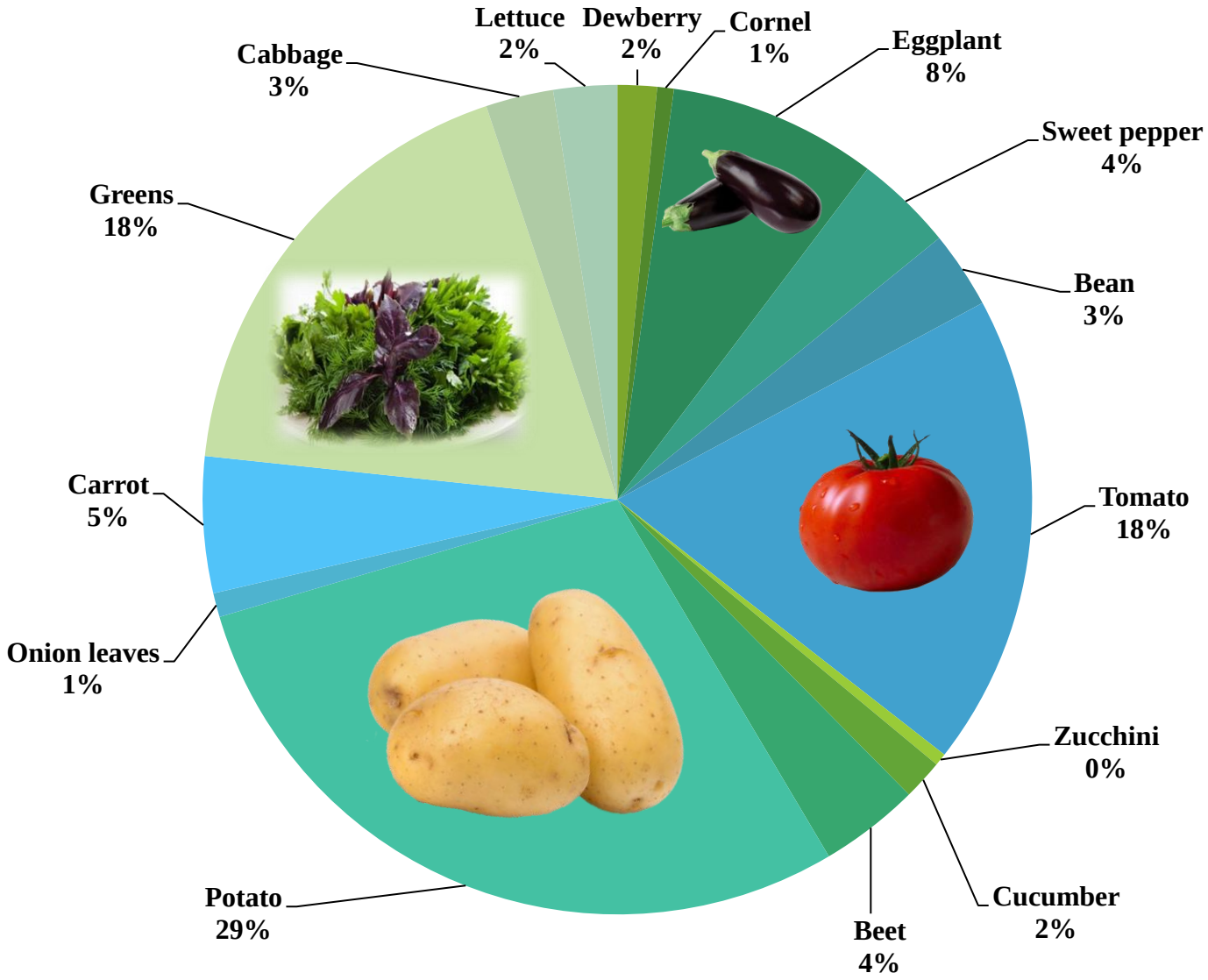
Foodstuff	Cd
Bean	9.51E-07
Sweet pepper	**1.31E-06**
Maize	6.32E-07
Plum	6.22E-07
Grape	**2.30E-06**
Eggplant	0.00E+00
Tomato	**2.05E-06**
Cucumber	0.00E+00
Beet	**1.08E-06**
Potato	**3.77E-06**
Onion bulb	1.13E-07
Carrot	**5.86E-06**
Fennel	1.41E-07
Basil	2.82E-07
Cabbage	0.00E+00
Onion leaves	0.00E+00
Total	**1.91E-05**



FOR RURAL POPULATION

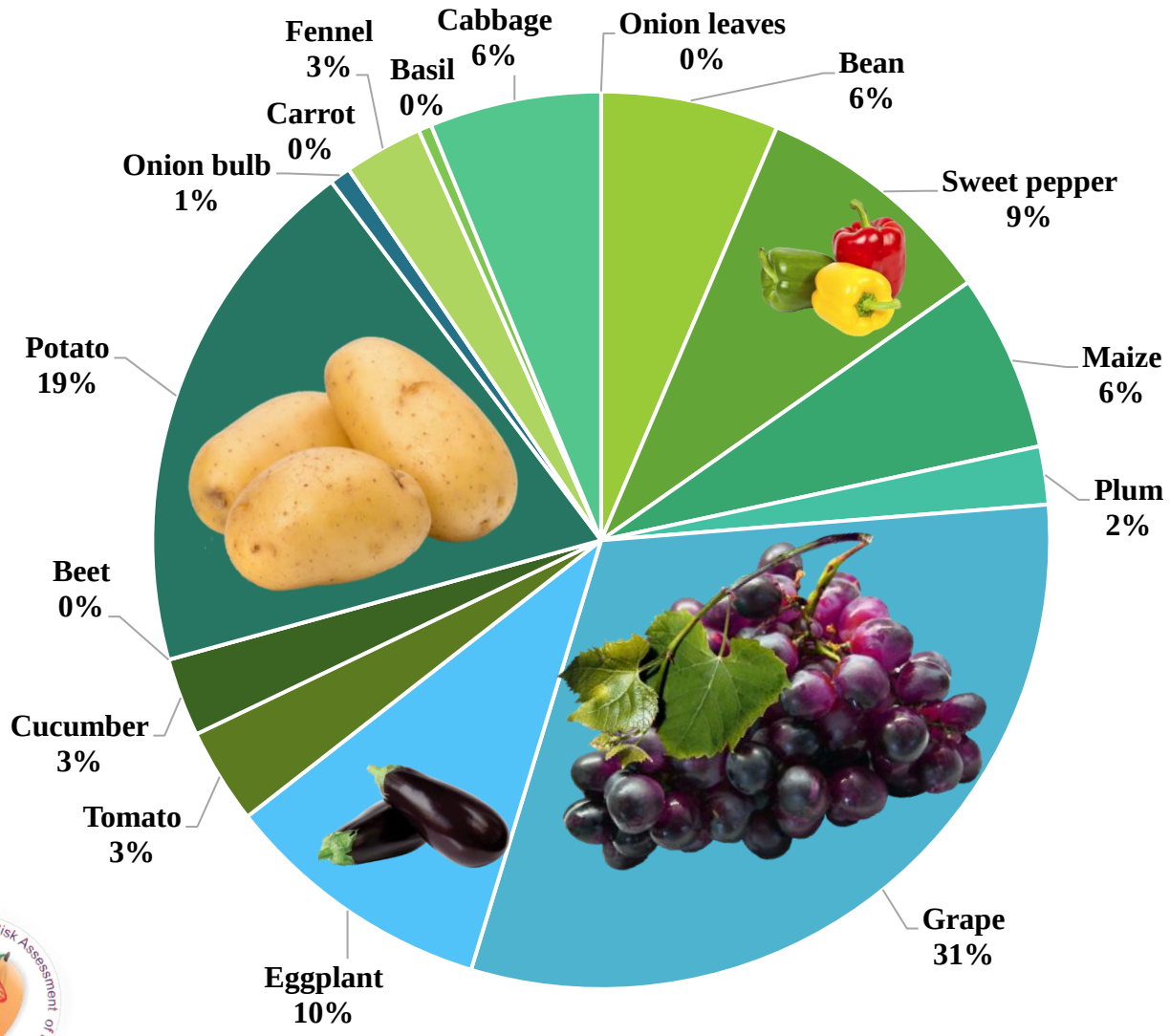
Carcinogenic risk of Cd

Foodstuff	Cd
Dewberry	5,97E-07
Cornel	2,53E-07
Eggplant	**3,16E-06**
Sweet pepper	**1,49E-06**
Bean	**1,17E-06**
Tomato	**7,16E-06**
Zucchini	1,88E-07
Cucumber	6,09E-07
Beet	**1,51E-06**
Potato	**1,13E-05**
Onion leaves	3,64E-07
Carrot	**2,07E-06**
Greens	**7,08E-06**
Cabbage	**1,03E-06**
Lettuce	9,64E-07
Total	**3,89E-05**



FOR KAPAN RESIDENTS

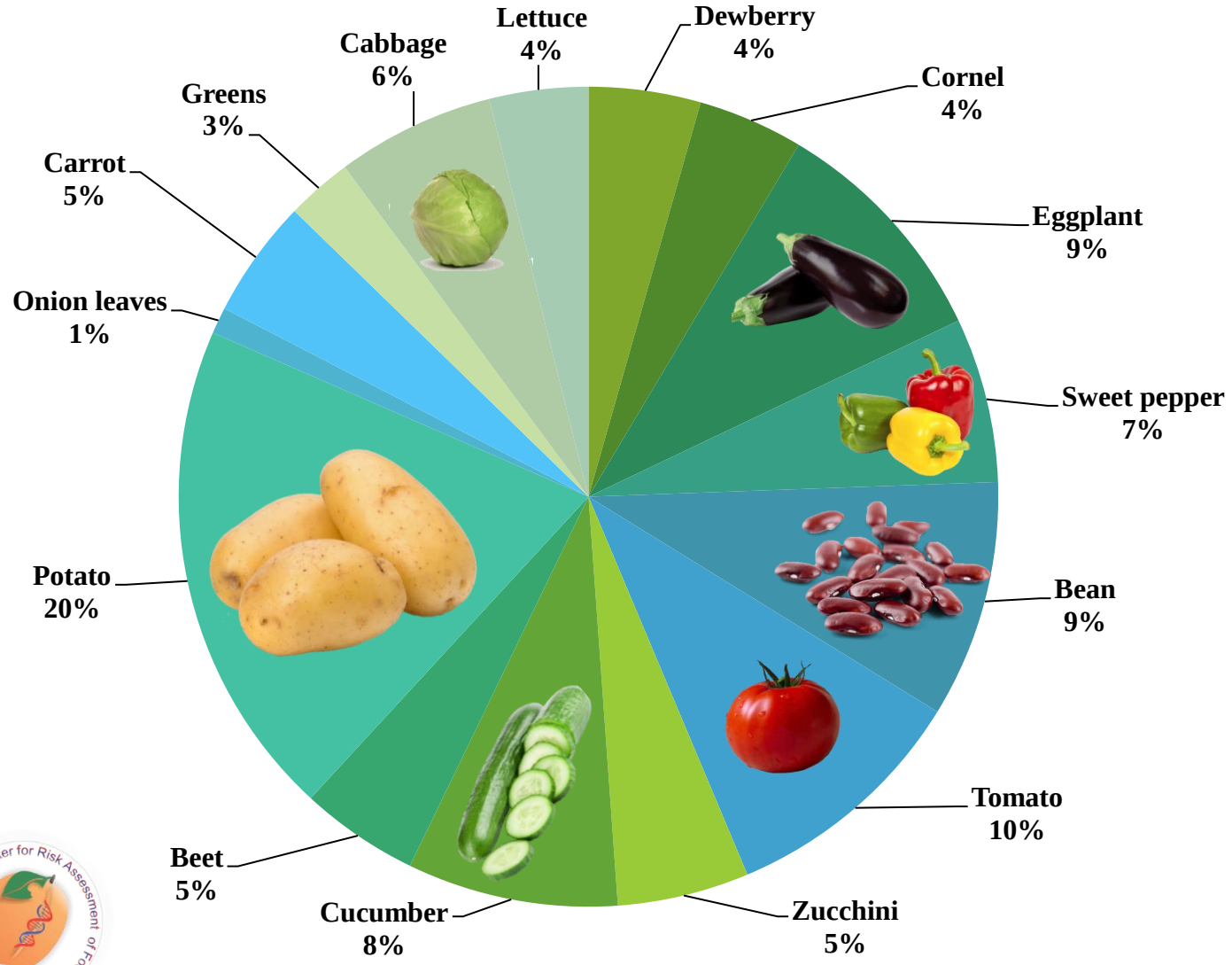
Carcinogenic risk of As



Foodstuff	As
Bean	7.51E-06
Sweet pepper	1.04E-05
Maize	7.49E-06
Plum	2.45E-06
Grape	3.63E-05
Eggplant	1.14E-05
Tomato	4.04E-06
Cucumber	3.31E-06
Beet	0.00E+00
Potato	2.23E-05
Onion bulb	8.90E-07
Carrot	0.00E+00
Fennel	3.34E-06
Basil	5.56E-07
Cabbage	7.26E-06
Onion leaves	0.00E+00
Total	**1.17E-04**

FOR RURAL POPULATION

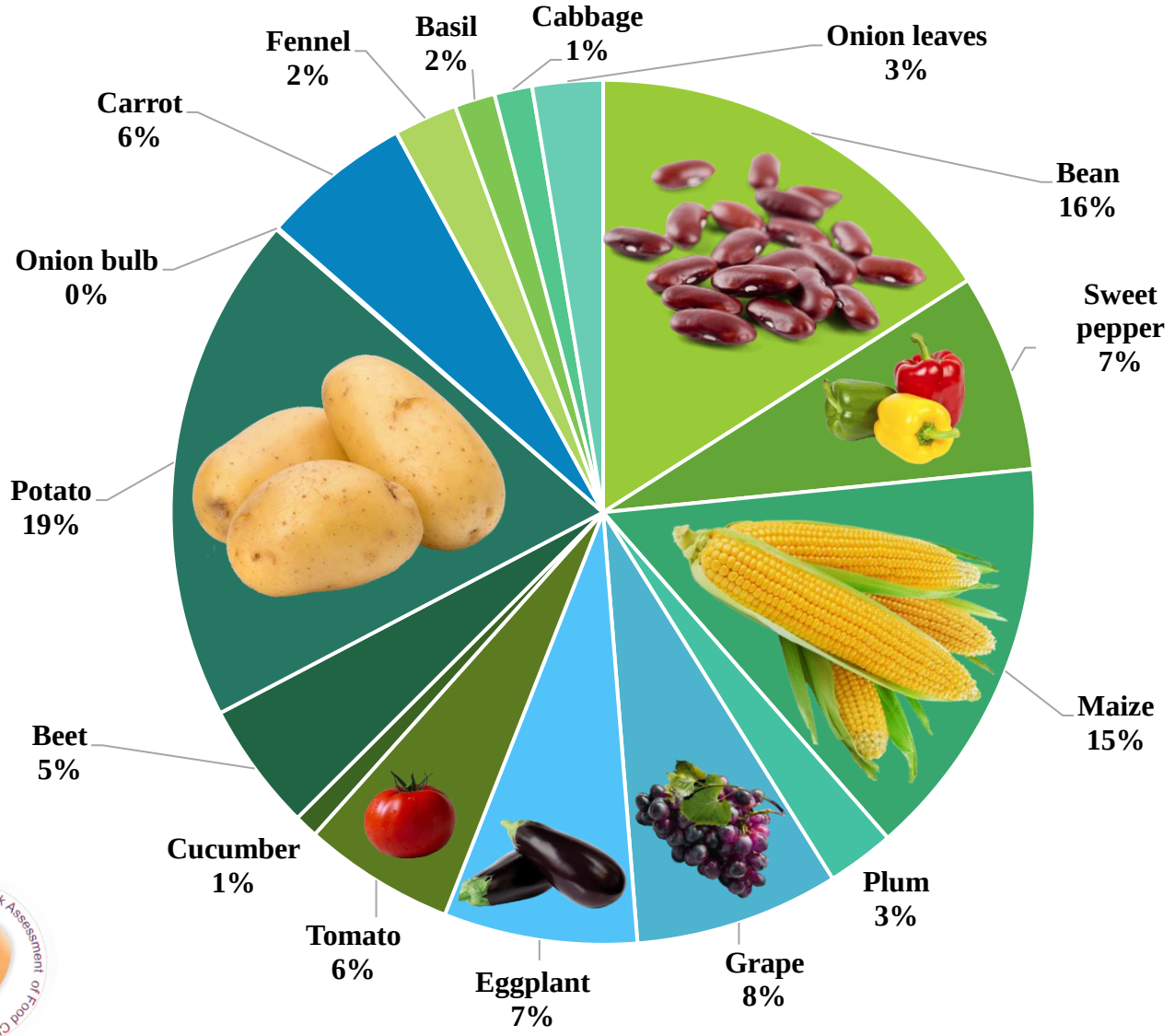
Carcinogenic risk of As



Foodstuff	As
Dewberry	1,66E-06
Cornel	1,56E-06
Eggplant	3,51E-06
Sweet pepper	2,44E-06
Bean	3,51E-06
Tomato	3,71E-06
Zucchini	1,95E-06
Cucumber	3,12E-06
Beet	1,76E-06
Potato	7,40E-06
Onion leaves	3,90E-07
Carrot	1,76E-06
Greens	9,76E-07
Cabbage	2,34E-06
Lettuce	1,46E-06
Total	3,76E-05

FOR KAPAN RESIDENTS

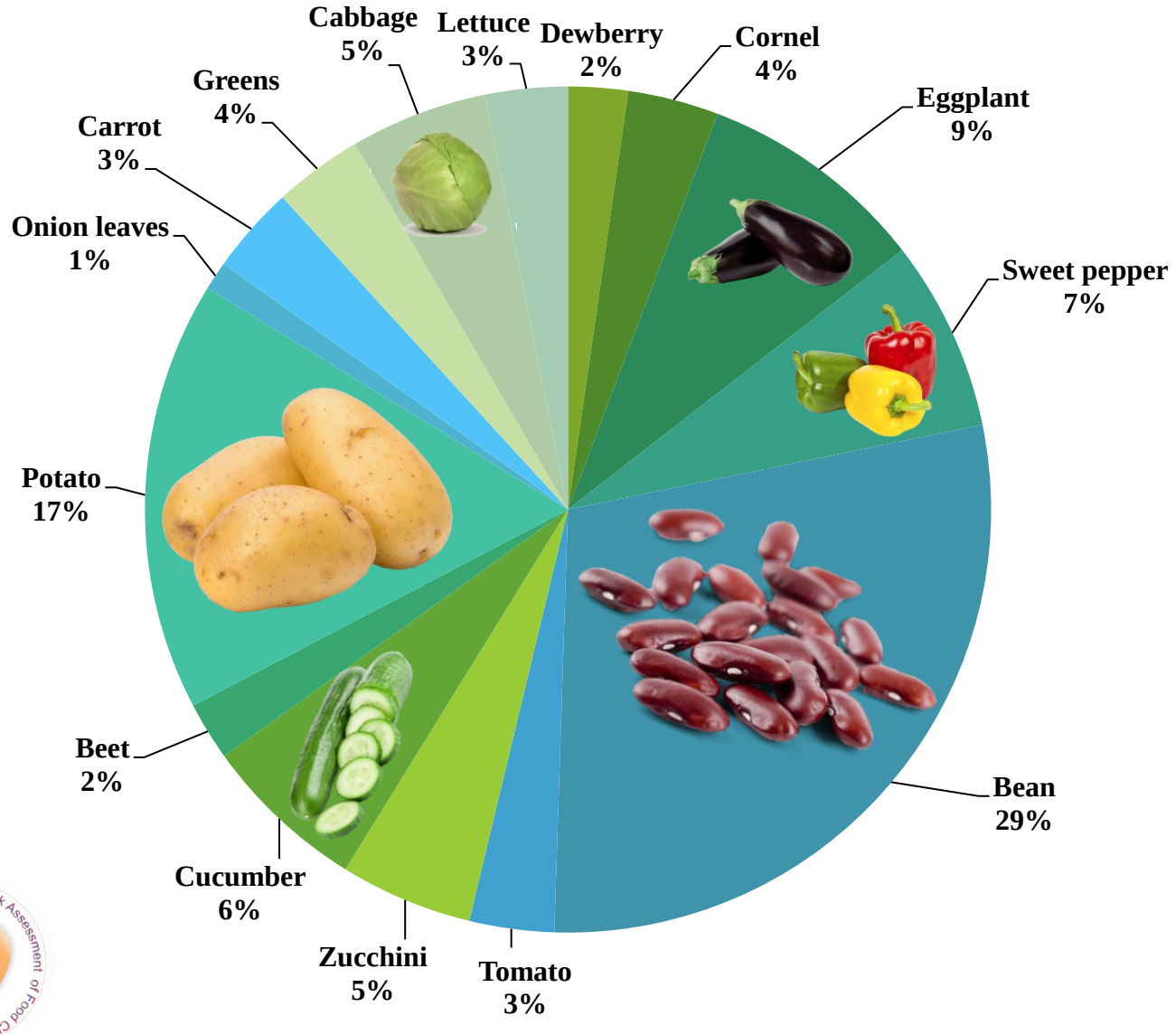
Total Carcinogenic Risk



Foodstuff	Σ
Bean	1.18E-02
Sweet pepper	5.46E-03
Maize	1.12E-02
Plum	1.86E-03
Grape	5.63E-03
Eggplant	5.33E-03
Tomato	4.17E-03
Cucumber	6.50E-04
Beet	3.55E-03
Potato	1.40E-02
Onion bulb	5.62E-05
Carrot	4.15E-03
Fennel	1.76E-03
Basil	1.11E-03
Cabbage	1.04E-03
Onion leaves	1.94E-03
Total	**7.37E-02**

FOR RURAL POPULATION

Total Carcinogenic Risk



Foodstuff	Σ
Dewberry	2,15E-04
Cornel	2,26E-04
Eggplant	6,04E-04
Sweet pepper	4,38E-04
Bean	1,48E-03
Tomato	2,91E-04
Zucchini	2,81E-04
Cucumber	3,84E-04
Beet	1,98E-04
Potato	1,20E-03
Onion leaves	6,46E-05
Carrot	2,52E-04
Greens	2,36E-04
Cabbage	3,41E-04
Lettuce	2,02E-04
Total	**6,41E-03**

FOR KAPAN RESIDENTS

SIMILIAR RESEARCHES

Science of the Total Environment 642 (2018) 864–878

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

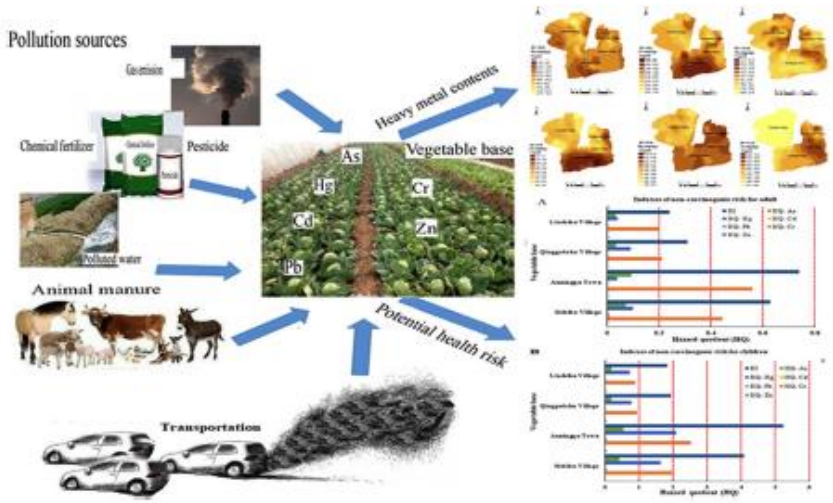
Pollution characteristics and health risk assessment of heavy metals in the vegetable bases of northwest China

Rukeya Sawut [a,c], Nijat Kasim [a,c], Balati Maihemuti [a,b,c,*], Li Hu [e], Abdugheni Abliz [c,d], Abdusalam Abdujappar [a,c], Miradil Kurban [a]

HIGHLIGHTS

- A comprehensive heavy metal pollution and health risk assessment of agricultural soil was conducted.
- Soils of the examined vegetable bases were more seriously polluted by heavy metals than was groundwater.
- Heavy metal pollution in soil leads to high health risks to the public, especially children.
- Major pollution sources affecting the vegetable bases, such as transportation, agricultural activities and stock farming.

GRAPHICAL ABSTRACT



Study strongly suggests that the vegetable base soil quality should be periodically investigated, and an **urgent and systematic study** should be conducted on vegetables growing in the contaminated soils.

In addition, effective measures should be adopted to control heavy metal pollution in the study area, and strong and efficient actions should be taken to decrease the human health risks (non-carcinogenic or cancer risk) caused by heavy metals resulting from unreasonable agricultural activities and surrounding industrial plants.

SIMILIAR RESEARCHES

Chemosphere 152 (2016) 431–438

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Presence of heavy metals in fruits and vegetables: Health risk implications in Bangladesh

Nazma Shaheen [a, *], Nafis Md. Irfan [a], Ishrat Nourin Khan [a], Saiful Islam [a], Md. Saiful Islam [b], Md. Kawser Ahmed [c]

A B S T R A C T

The presence of toxic heavy metals such as As, Cd, Pb, Cr, Mn, Ni, Cu, and Zn in nationally representative samples of highly consumed fruits and vegetables was determined by inductively coupled plasma mass spectrometry (ICP-MS). Their concentrations exceeded the maximum allowable concentration (MAC) set by FAO/WHO for Pb in mango and Cd in tomato among the analyzed fruits and vegetables. Pb content in mango was found to be six times higher than the safe limit at production level. Health risks associated with the intake of these metals were evaluated in terms of estimated daily intake (EDI), and carcinogenic and noncarcinogenic risks by target hazard quotient (THQ) and hazard index (HI). EDI values of all the metals were found to be below the maximum tolerable daily intake (MTDI). The THQs of all metals were <1, suggesting no health hazards for adult population. However, total THQs of Mn and Cu were >1 through consumption of all vegetables, indicating significant health risks. HI was found to be <1 (0.825) for consumption of fruits; however, it was >1 (3.727) for vegetable consumption, suggesting adverse health effects from vegetable consumption only. The total carcinogenic risk (CR) of As was below the threshold level (10^{-6}) and 9.82E-05 for Pb, suggesting no potential CR from As consumption, but indicating the risk of Pb-induced carcinogenesis. The findings of this study reveal the health risks associated with the consumption of heavy metals through the intake of selected fruits and vegetables in adult population of Bangladesh.

The **total carcinogenic risk (CR)** of As was below the threshold level (E-06) and **9.82E-05 for Pb**, suggesting no potential CR from As consumption, but indicating the **risk of Pb-induced carcino-genesis**.

The findings of this study **significantly contribute to the field of food safety**, considering the health risk for Bangladeshi population.

SIMILIAR RESEARCHES

Special Issue on Urban Environmental Toxins: Public Exposure and Health Risk Management

Journal of INTERNATIONAL MEDICAL RESEARCH

Journal of International Medical Research
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Heavy metal contamination in soils and vegetables and health risk assessment of inhabitants in Daye, China

Jun Yang[1,2]*, Silu Ma[1,2]*, Jingcheng Zhou[1,2], Yongwei Song[1,2] and Fei Li[1,2]

Abstract

Objective: This study was performed to evaluate the state of heavy metal contamination in soil and vegetables and assess the health risk of inhabitants in the mine-affected area and area far from the mine (reference area) in Daye, China.

Methods: The heavy metal concentrations in soil and vegetable samples were detected by inductively coupled plasma mass spectrometry. Residents' exposure parameters were obtained through a questionnaire survey. A health risk assessment model recommended by the United States Environmental Protection Agency was used to evaluate the residents' risk of oral exposure.

Results: The copper, lead, cadmium, and arsenic concentrations in soil and in vegetables were higher in the mine-affected area than in the reference area. The health risk of residents in the reference area was within the acceptable range (hazard index < 1, carcinogen risk $< 10^{-4}$). In the contaminated area, however, the mean hazard index was 2.25 for children and 3.00 for adults, and the mean carcinogen risk was 4.749×10^{-4} for children and 0.587×10^{-4} for adults.

Conclusions: Potential health risks exist for inhabitants near the mine area. Cadmium and arsenic should be paid more attention as risk sources.

The **CR** contribution rate of different heavy metals for residents in both the contaminated and reference areas showed **the order of As > Cd > Pb.**

From a health risk perspective, the **environmental quality standards and food safety standards** of some heavy metals may **need to be improved.**

SIMILIAR RESEARCHES

ELSEVIER

Available online at www.sciencedirect.com
ScienceDirect
Journal of Geochemical Exploration 96 (2008) 223–230

JOURNAL OF GEOCHEMICAL EXPLORATION
www.elsevier.com/locate/jgeoexp

Heavy metal contamination and health risk assessment in the vicinity of the abandoned Songcheon Au–Ag mine in Korea

Hye-Sook Lim [a], Jin-Soo Lee [b], Hyo-Taek Chon [a,*], Manfred Sager [c]

Abstract

The objective of this study is, firstly, to investigate the contamination levels and dispersion patterns of As and heavy metals, secondly, to estimate the bioaccessible fraction of the metals in soil and crop plant and, finally, to assess the risk of health effects on the residence in the vicinity of the abandoned Songcheon Au–Ag mine, Korea. Samples of tailing, soil, crop plant and water were collected around the mine site. After appropriate preparation, all samples were analyzed for As, Cd, Cu, Pb and Zn by ICP-AES and ICP-MS. Elevated levels of As and heavy metals were found in tailing. Mean concentrations of As in agricultural soil higher than the permissible level. Especially, maximum levels of As and Hg in farmland soil were up to 626 mg/kg and respectively. The highest levels in crop plant were 33 mg As/kg and 3.8 mg Pb/kg (in green onion root), 0 226 mg Zn/kg (in lettuce root), 16.3 mg Cu/kg (in sesame leaves). The concentration of heavy metals in le those in grains and stalk. Vegetables grown on the contaminated soil were rich in As and heavy met and Zn in most stream waters which are used for drinking water around the mine area wer vels regulated in Korea. Maximum levels of As, Cd and Zn in stream waters were 0.71 mg respectively. These results indicate that mine tailings can be the main contamination sources of e soil–water system of the mine site. The average of estimated human-bioaccessible fraction in soil was 3% As, 40% Cd, 15% Cu, 31% Pb and 21% Zn, and that in simulated small intestine 12% As, 2.2 % Pb and 1.2% Zn. The highest value of human-bioaccessible fraction of metal in farmland soil was 85% timated human-bioaccessible fraction of plant was up to 97% for Cd in simulated stomach, and to 51% for Pb small intestine. The highest human-bioaccessible fractions were found in Chinese cabbage (in stomach) and p ves (in small intestine). The average human-bioaccessible fraction in plants were 47% As, 70% Cd, 62% Cu, 0% 62% Zn in simulated stomach and 22% As, 7% Cd, 27% Cu, 9% Pb and 23% Zn in simulated small intestine. Th HQ (hazard quotient) value of the mine site was 16, and especially, the HI (hazard index) value of only As was 15. The carcinogenic risk of the mine site was 2.7E−03. This value means the probable possibility that about 3 cancer patients among 1000 people happen. Carcinogenic risk exceeded in the generally accepted range of E−04 to E−06.

The **carcinogenic risk** of the mine site was **2.7E−03**. This value means the probable possibility that about **3 cancer patients among 1000 people** happen.

Carcinogenic risk exceeded in the generally accepted range of 1E−04 to 1E−06.

SIMILIAR RESEARCHES

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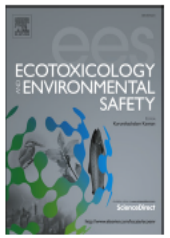


Pollution and health risk assessment of heavy metals in agricultural soil, atmospheric dust and major food crops in Kermanshah province, Iran

Shahab Ahmadi Doabi[a,*], Mahin Karami[b], Majid Afyuni[a], Mojgan Yeganeh[c]

A B S T R A C T

A total of 167 samples of agricultural soil, atmospheric dust and food crops (wheat and maize) were collected, and four heavy metals, including Zn, Cu, Ni, and Cr, were analyzed for their concentrations, pollution levels and human health risks. The mean heavy metal contents in the agricultural soil and atmospheric dust were exceeds background values and lower than their IEQS (Iranian Environmental Quality Standard) with an exception of Ni. A pollution assessment by Geo-accumulation Index (I_{geo}) showed that the pollution levels were in the order of Ni > Cu > Cr > Zn for agricultural soils and Ni > Cu > Zn > Cr for atmospheric dust. The Ni levels can be considered "moderately to heavily contaminated" status. The human health risk assessment indicated that non-carcinogenic values were below the threshold values (1), and main exposure pathway of heavy metals to both children and adults are ingestion. The carcinogenic risks values for Ni and Cr were higher than the safe value (1×10^{-6}), suggesting that all receptors (especially wheat) in Kermanshah province might have significant and acceptable potential health risk because of exposure to Ni and Cr. The carcinogenic risk for children and adults has a descending order of Ni > Cr, except for wheat. These results provide basic information on heavy metal contamination control and human health risk assessment management in the Kermanshah province.

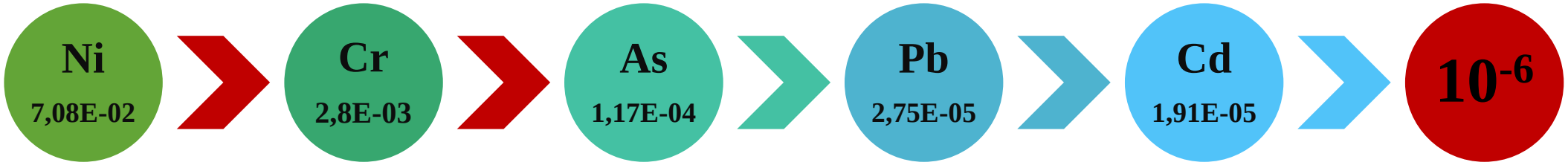
The **carcinogenic risks values for Ni and Cr were higher than the safe value (1E−6),** suggesting that in Kermanshah province might have significant and acceptable potential health risk because of exposure to **Ni** and **Cr**.

Children are likely under a higher health risk than adults, especially where the **carcinogenic risk is higher than 1E−4, indicating that children may be facing the threat of serious carcinogenic risk over a lifetime**.

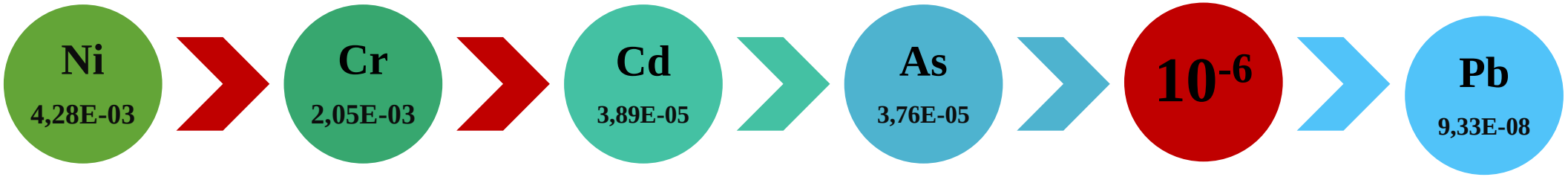
These findings indicate that more consideration ought to be paid to HM contamination of food crops in Kermanshah province.

Conclusions

- Each of studied trace elements poses significant level of carcinogenic risk through fruits and vegetables consumption.
- Total carcinogenic risk values for investigated trace elements in Syunik **rural** communities showed a decreasing order of **Ni > Cr > As > Pb > Cd > 10^{-6}**.



- Total carcinogenic risk values for investigated trace elements in **Kapan** showed a decreasing order of **Ni > Cr > Cd > As > 10^{-6} > Pb**.



- Among investigated fruits and vegetables **potato, bean** and **maize** were considered the most hazardous.

Recommendations

- It is recommended that intense consumption of vegetables and fruits growing in contaminated areas should be avoided.
- Appropriate risk management actions are needed.
- Implementation of Good Agricultural Practices (GAP).
- A more comprehensive assessment of the dietary exposure of trace elements is needed that would take into account many other exposure pathways (i.e. inhalation or dermal pathways) in order to ensure the safety of the population living under the impact of mining industry.

Publications

Biological Trace Element Research
https://doi.org/10.1007/s12011-018-1522-8

Dietary Exposure Assessment of Potentially Toxic Trace Elements in Fruits and Vegetables Sold in Town of Kapan, Armenia

Davit Pipoyan[1] · Meline Beglaryan[1] · Stella Stepanyan[1] · Nicolò Merendino[2]

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Abstract
Fruits and vegetables grown under the impact of Armenia's mining industry are widely sold in markets of adjacent towns. As the share of fruits and vegetables in Armenians' diet is significant, the present study aims to assess the dietary exposure of potentially toxic trace elements through the intake of fruits and vegetables sold in Kapan town, located in the biggest mining region of Armenia. The concentrations of Cu, Mo, Ni, Cr, Pb, Zn, Hg, As, and Cd in 15 types of fruits and vegetables were determined. Non-carcinogenic and carcinogenic risks were assessed. Although the estimated daily intakes of trace elements for each studied food item did not exceed health-based guidelines values, in case of the combined consumption of fruits and vegetables estimated cumulative daily intakes exceeded reference doses for Cu and Mo. Moreover, carcinogenic risk for the majority of fruits and vegetables exceeded the EPA recommended risk level of 10^{-6}, indicating adverse health effect to local population. The outcomes of this study can serve as a basis for further research that will consider many other exposure pathways (i.e., inhalation or dermal pathways) in order to ensure the safety of the residents living under the impact of mining industry.

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Risk Assessment of Population Exposure to Toxic Trace Elements via Consumption of Vegetables and Fruits Grown in Some Mining Areas of Armenia

Davit Pipoyan, Meline Beglaryan, Lara Costantini, Romina Molinari & Nicolò Merendino

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Exposure assessment of potentially toxic trace elements via consumption of fruits and vegetables grown under the impact of Alaverdi's mining complex

Davit Pipoyan, Meline Beglaryan, Liana Sireyan & Nicolò Merendino

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meline.beglaryan@cens.am

+374 94 50 54 80
+374 10 55 30 81

Web: https://www.cens.am/ FB: web.facebook.com/cens.armenia