



Heavy metals in phosphate fertilizers

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Heavy metals and human health

Of the 92 naturally occurring elements, approximately 30 metals and metalloids are potentially toxic to humans, namely: Be, B, Li, Al, Ti, V, Cr, Mn, Co, Ni, Cu, As, Se, Sr, Mo, Pd, Ag, Cd, Sn, Sb, Te, Cs, Ba, W, Pt, Au, Hg, Pb, and Bi.

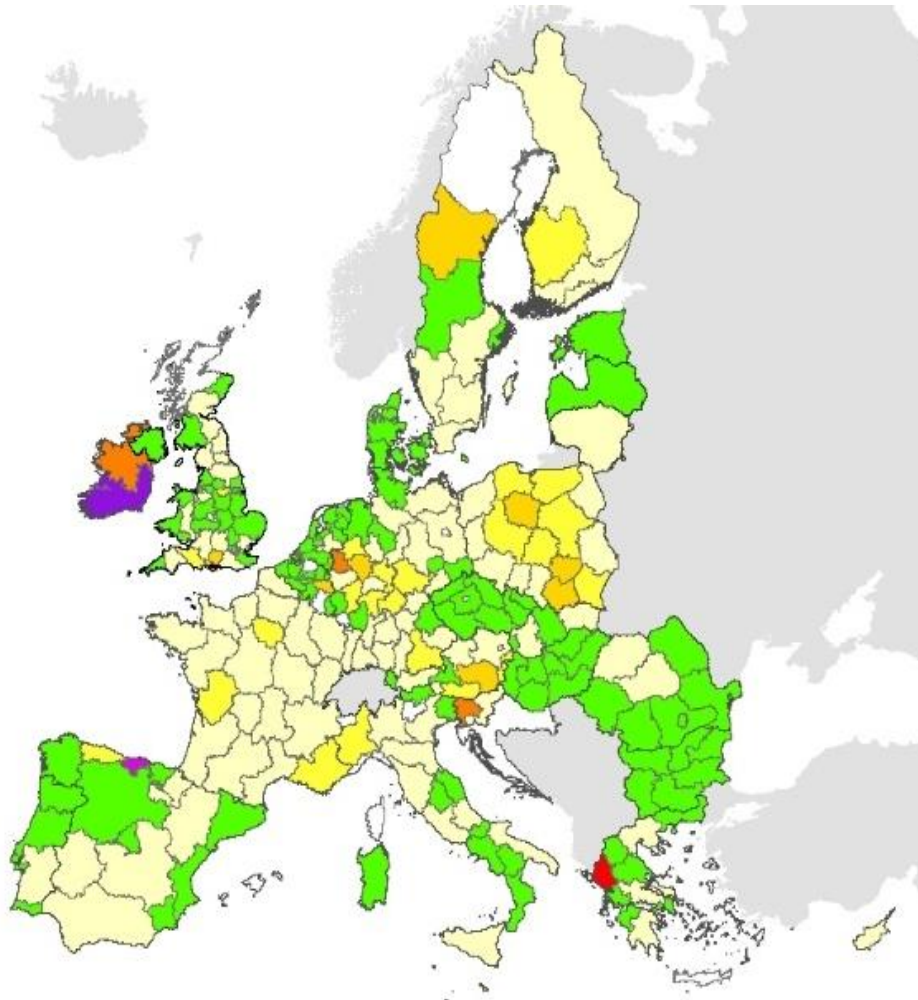
Heavy metals are **metallic elements** having an atomic weight > 40.04 (the atomic mass of Ca).

The most found and toxic heavy metals include **lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As)**.

Although toxicity and the resulting threat to human health of any contaminant are a function of concentration, the **chronic exposure** to heavy metals and metalloids at relatively low levels can cause adverse effects.

Morais *et al.*, 2012

Percentage of samples with cadmium (Cd) concentration above the threshold in agricultural land across EU



Data from the Land Use/Cover Area frame Survey (LUCAS) call for strict measures to prevent a further increase of Cd in the soil in many European regions.

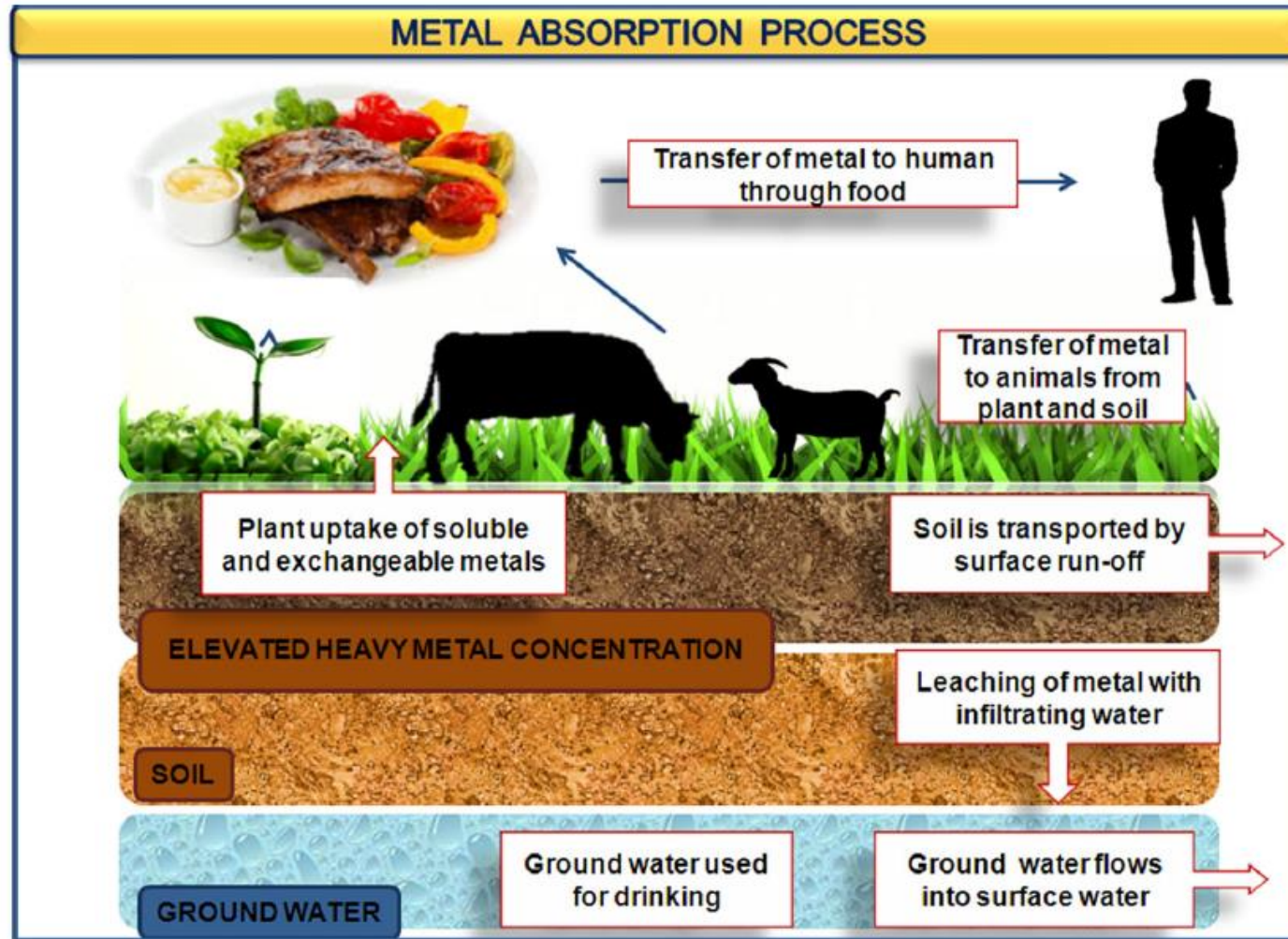
Threshold value = 1 mg Cd/kg.

Aqua regia (HCl+HNO₃) extraction for soil Cd (“pseudo-total” forms).

Tóth *et al.*, 2016



Transfer of heavy metals from soils to plants and humans



A. Singh and S.M. Prasad, 2019



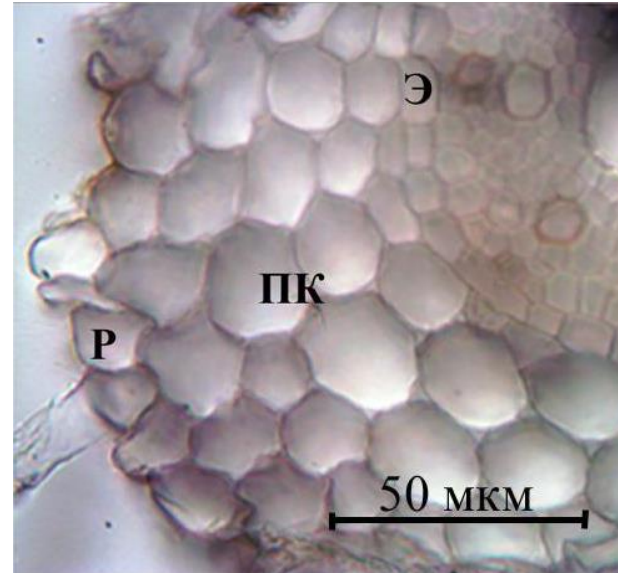
Cadmium accumulation by plants

“Normal” range of Cd in the aboveground plant parts is from 0.05 to 0.6 mg/kg DM, but toxic range is from **1.0 to 70 mg/kg DM**.

Cadmium has a high phytoaccumulation index because of its low adsorption coefficient and high soil-plant mobility.

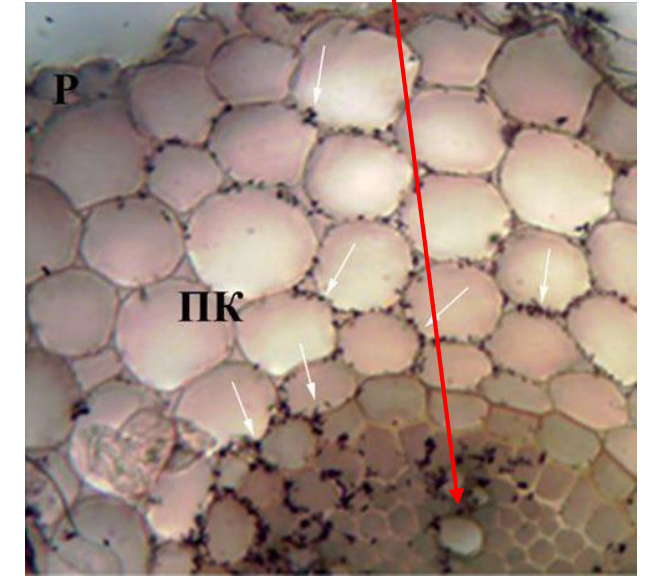
A. Kabata-Pendias and H. Pendias, 1989
M. Shahid *et al.*, 2017

Root cells of spring wheat



No added Cd

Dark points are Cd chelates



+ Cd

(total soil Cd = 10 ppm, i.e. 20x higher than the Maximum Allowable Concentration)

Z. Kuramshina and Yu. Smirnova, 2019



Environmental geochemical assessment of phosphate rock and fertilizer



Photo: Belousov et al., 2014

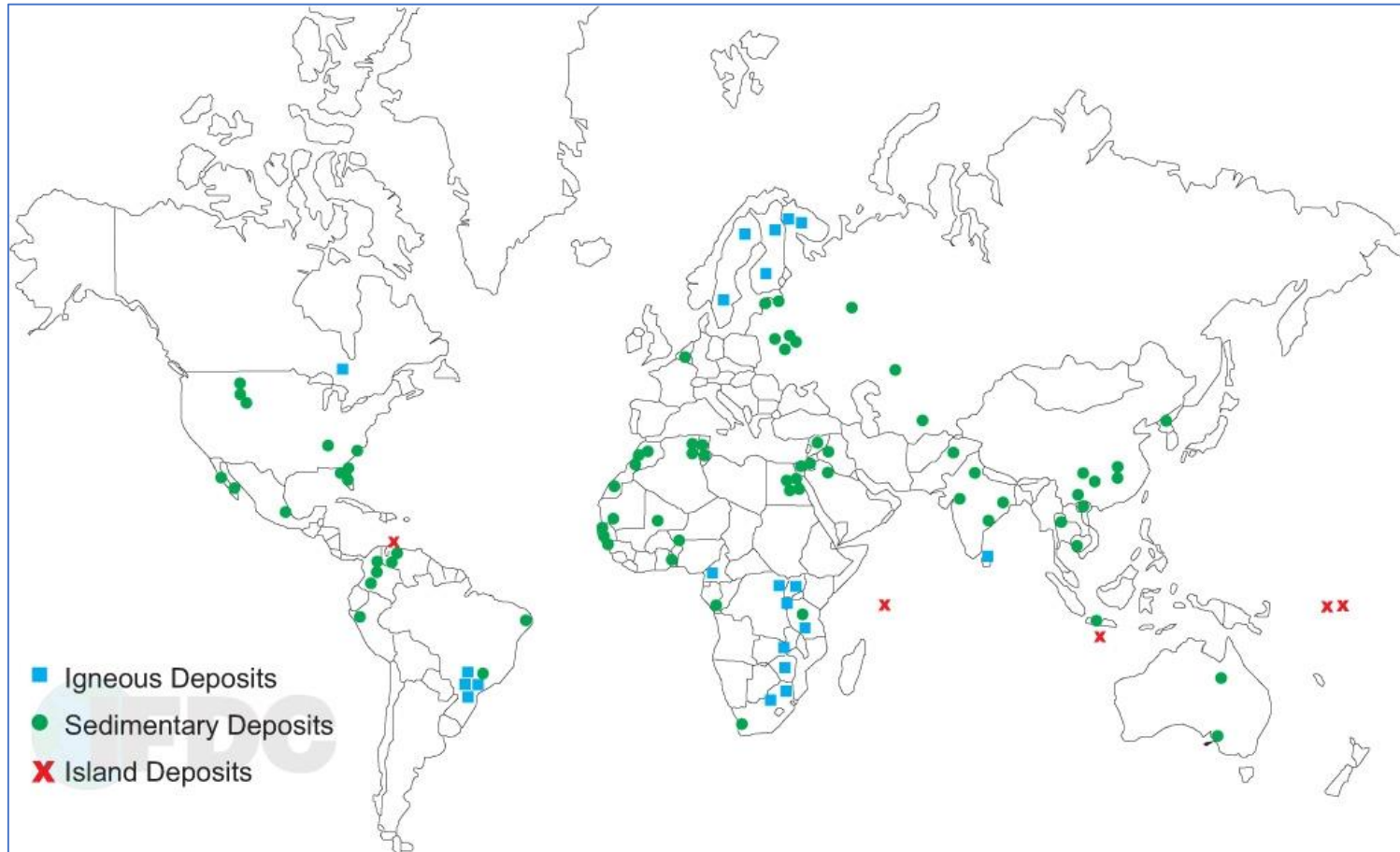
A number of non-essential elements is found in phosphate rocks throughout the world. These controlled elements include cadmium (Cd), fluorine (F), strontium (Sr), lead (Pb), arsenic (As), cobalt (Co), chromium (Cr), mercury (Hg), nickel (Ni), vanadium (V); radioactive thorium (Th), uranium (U), and yttrium (Y).

Non-essential elements that become a part of fertilizers have **combined environmental effects.**

Kiperman *et al.*, 1995



Sedimentary versus igneous phosphate rock



In the world, about 87% of mineral phosphate fertilizers are produced of sedimentary rock phosphate.

Sedimentary rock phosphate generally contains more heavy metals than apatites of igneous origin.

IFDC; Merkel *et al.*, 2006



Cadmium contents of phosphate rock of various origin (mg/kg)

Origin	Country	Deposit	Average Cd	Range
SEDIMENTARY	CHINA	Kaiyang	< 2	–
	ISRAEL	Zin	31	20–40
		Undifferentiated	24	20–28
		Arad	14	12–17
		Oron	5	–
	JORDAN	El-Hasa	5	3–12
	MOROCCO	Undifferentiated	26	10–45
		Bou Craa	38	32–43
		Khouribga	15	3–27
		Yousoufia	23	4–51
	SENEGAL	Taiba	87	60–115
	SYRIA	Khneifiss	3	–
	TOGO		58	48–67
	TUNISIA		40	30–56
UNITED STATES	Central Florida	9	3–20	
	North Florida	6	3–10	
	Idaho	92	40–150	
	North Carolina	38	20–51	
IGNEOUS	BRAZIL	Araxá	2	2–3
		Catalão	< 2	–
	SOUTH AFRICA	Phalaborwa	1	1–2
RUSSIA	Kola	1	< 1–2	



Photo: Belousov et al., 2014

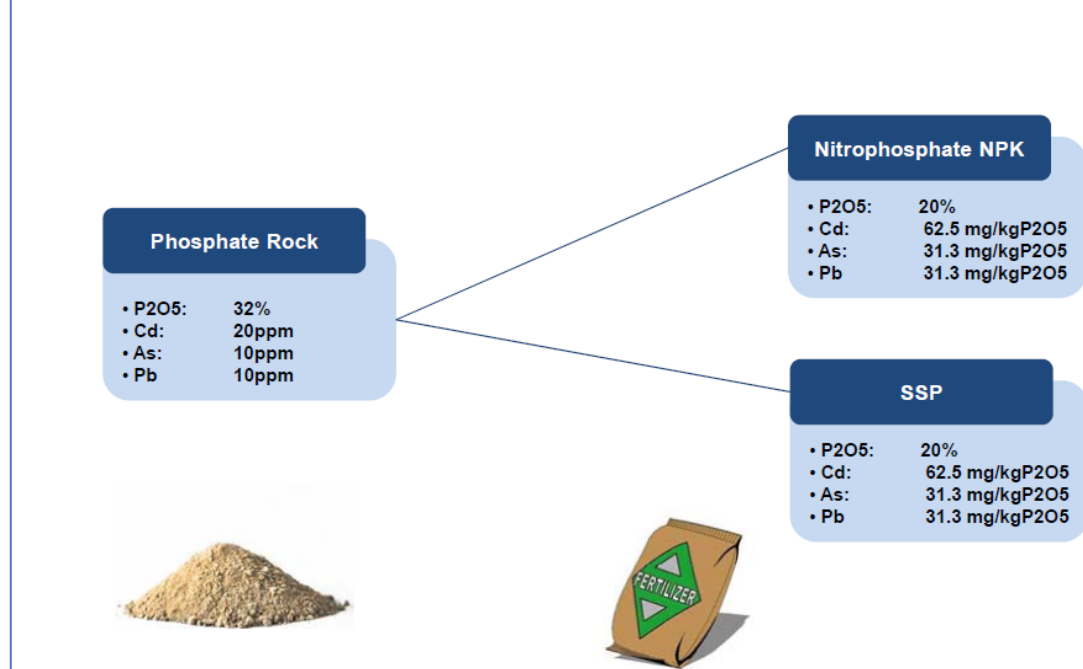
Igneous phosphate ore mined by PhosAgro in the Kola Peninsula has a low Cd content.

S.J. Van Kauwenbergh, 2001

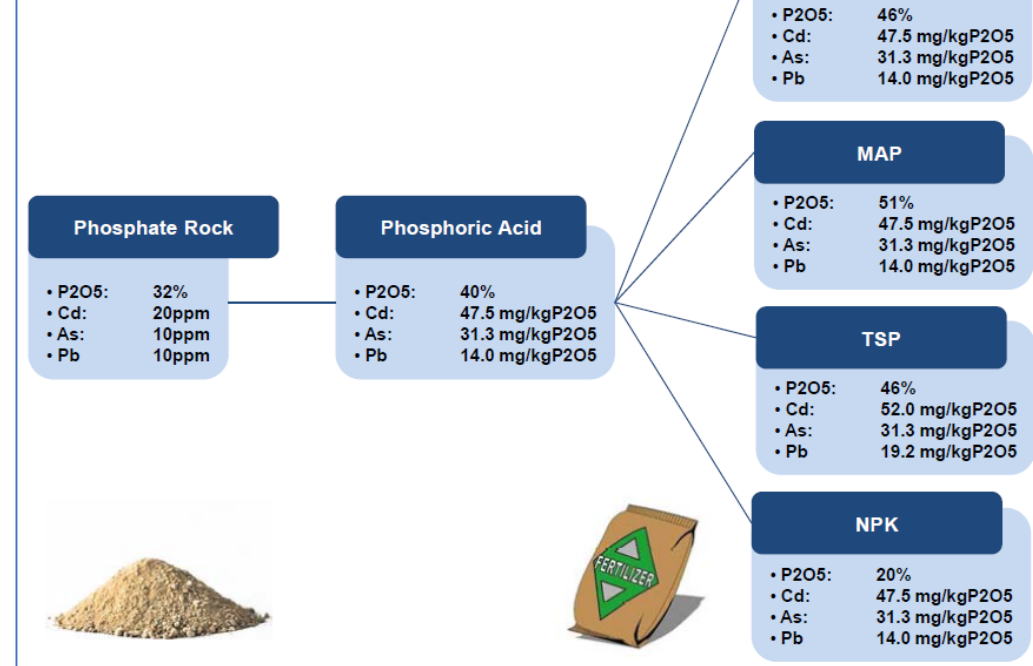


Heavy metal transfer from phosphate rocks to fertilizers

Pass-through rates of heavy metals from phosphate rock to Nitrophosphate NPKs and SSP



Pass-through rates of heavy metals from phosphate rock to phosphate fertilizers via phosphoric acid processes



With direct processing of phosphate rock to straight and complex fertilizers, there is no stage of phosphoric acid production.

In this case 100% of heavy metals are transferred to fertilizers.



How to calculate Cd concentration in fertilizer on P₂O₅ basis

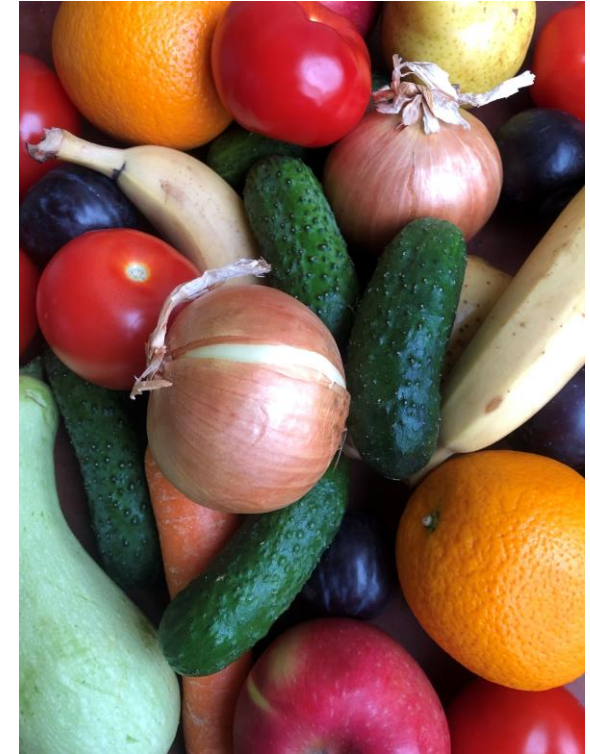
Cadmium, mg Cd/kg fertilizer	1
Percentage of P ₂ O ₅ in fertilizer	46
Cadmium, mg Cd/kg P ₂ O ₅	$\frac{1 \times 100}{46} = 2.2$





EU maximum levels for Cd in crop production

Plant-based products	Cd, mg/kg wet weight
Citrus fruits, pome fruits, stone fruits, table olives, kiwi fruits, bananas, mangoes, papayas and pineapples	0.02
Root and tuber vegetables (except radishes, tropical roots and tubers, parsley roots, turnips, beetroots, celeriac, horseradish, parsnips, and salsify). For potatoes, the maximum level applies to peeled potatoes	0.10
Leaf vegetables (except spinaches and similar leaves, mustard seedlings and fresh herbs)	0.10
Rice, quinoa, wheat bran and wheat gluten	0.15
<i>Triticum durum</i> (durum wheat)	0.18



Adopted from: COMMISSION REGULATION (EU) 2021/1323

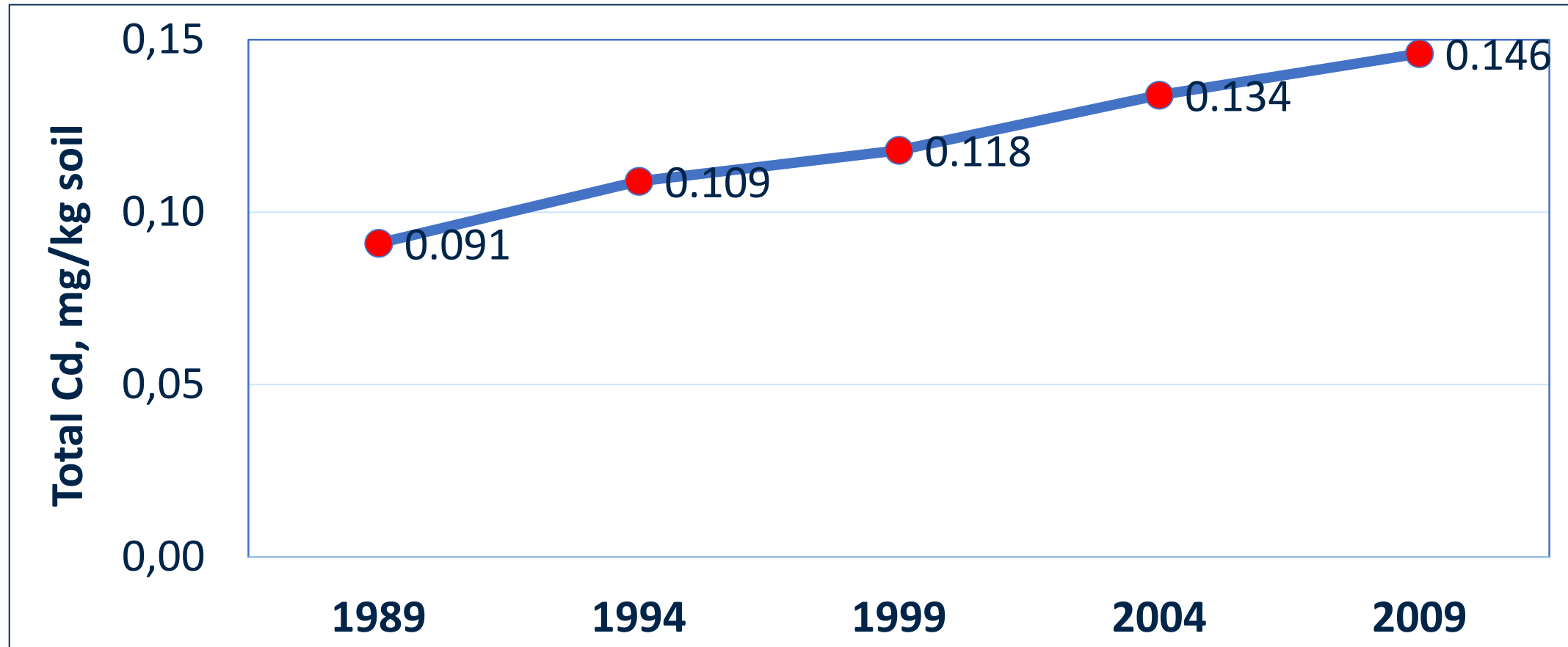


Estimating a weekly Cd intake: peeled potatoes as an example

Tolerable intake of Cd for most of the EU population (European Food Safety Authority)	mg Cd / kg body weight / week	0.0025
Tolerable Cd intake based on 70 kg body weight	mg Cd / week	0.175
EU maximum level of Cd in peeled potatoes	mg/kg wet weight	0.10
Safe quantity of peeled potatoes with maximum Cd levels	kg / week	1.75



Cadmium accumulation in soils from NP-fertilizers after 20 years



Calcaric fluvisol, Henan, China NP: superphosphate + urea

Wang *et al.*, 2014

Effect of MAP fertilizers with different Cd content on Cd concentration in wheat grain



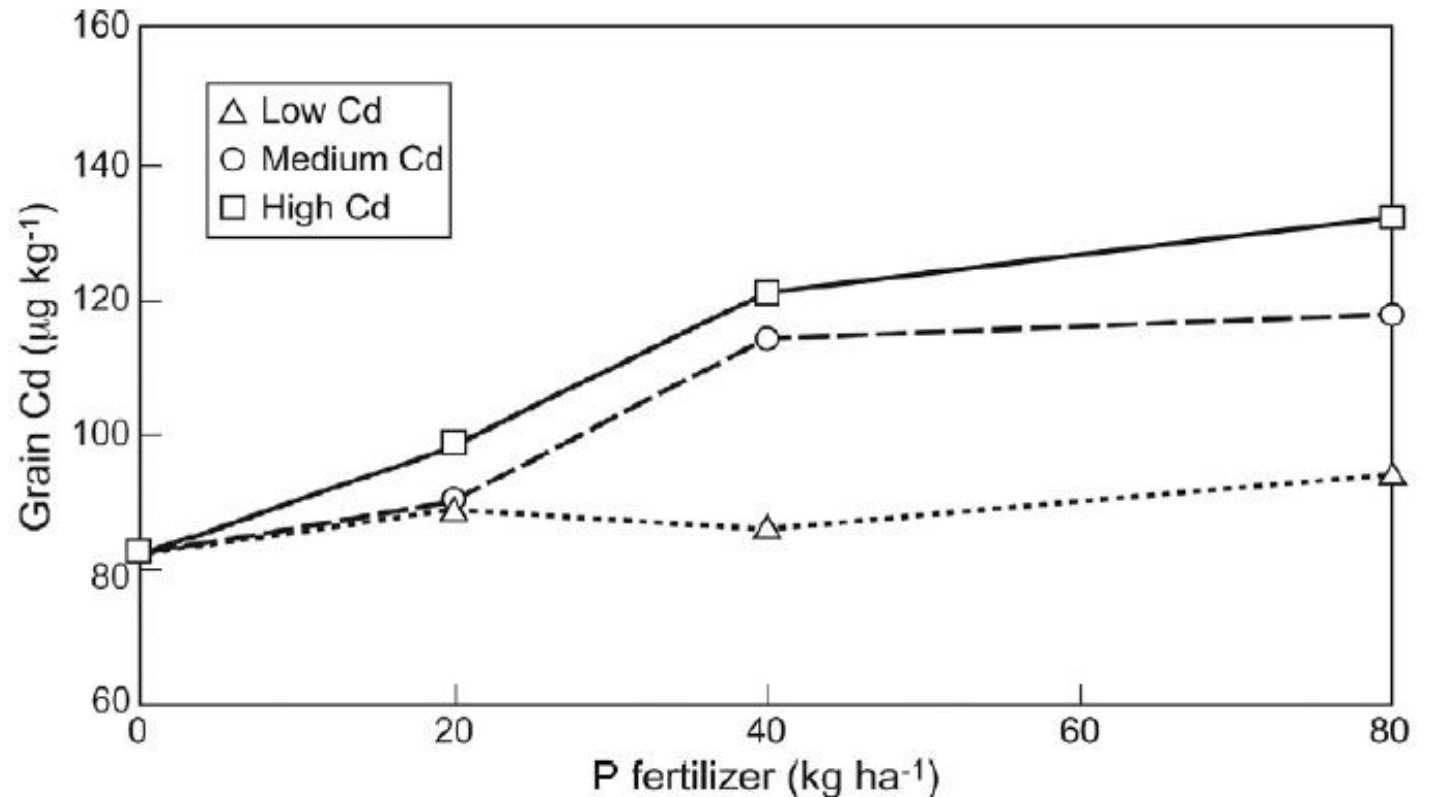
7 years of MAP application

Averaged over 6 locations on the Canadian prairies

Low Cd – 0.38 mg/kg

Medium Cd – 71 mg/kg

High Cd – 211 mg/kg



Grant *et al.*, 2013 (cited by: McLaughling *et al.*, 2021)



Thank you!