

# Minerals and trace elements in food and diet

## Mineral elements in food

**Definition:** chemical elements contained in the ash of the foodstuff (matter remaining after total oxidation of organic compounds)

**Ash content** – used as an approx. indicator of the total content of mineral elements

**Origin** of mineral elements in food:

- naturally occurring food components
- contaminants
- additives

## Classes of mineral elements

### According to content

- major elements  
(content > 100 mg/kg)  
(Na), K, Mg, Ca, Cl, P,  
(S)
- trace elements

### According to significance

- essential elements  
major + Fe, Zn, Cu, Mn,  
(Ni, Co), Cr, Si, (Mo, B),  
Se, I, F
- toxic elements  
Pb, Cd, Hg, As
- non-essential elements

### Total amount of some elements in an adult human body

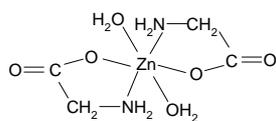
Ca	1000-1500 g	Fe	3-5 g	Ni	10 mg
P	420-840 g	Zn	1.5-3 g	Cr	5 mg
K	140-180 g	F	0.8-2.5 g	V	<1-20 mg
S	140 g	Si	1.4 g	I	10-30 mg
Cl	70-110 g	Cu	100-180 mg	Se	10-20 mg
Na	70-100 g	Mn	10-20 mg	Co	1-1.5 mg
Mg	24-40 g	Mo	5-10 mg	Cd	5-30 mg

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104														

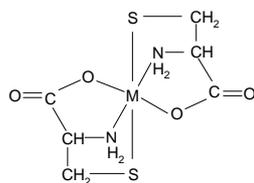
58 Ce	59 Pr	60 Nd	61 Pr	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

## Compounds of metals

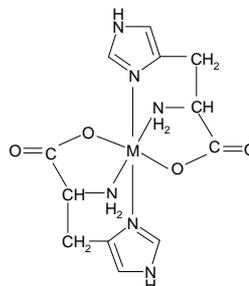
examples of amino-acids chelates:



Zn(Gly)<sub>2</sub>

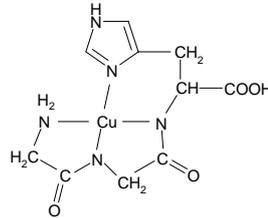
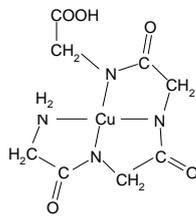


M(Cys)<sub>2</sub>

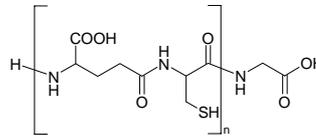
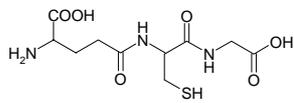


M(His)<sub>2</sub>

Examples of metal-peptide complexes:



Metal-binding peptides of plant origin  
*phytochelatines* (peptides derived from *glutathione*)



*Glutathione*

$\gamma$  Glu-Cys-Gly

*Phytochelatins*

$(\gamma$  Glu-Cys) $_n$ Gly

Metal-binding polypeptides in animal tissues

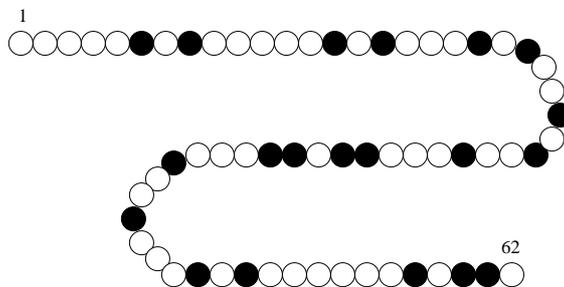
*metallothioneins* (MT)

occurrence: liver, kidney, intestinal wall, pancreas, brain

structure: peptide chain containing 60-63 AA, 20 Cys

$M_r$ : 6000-8000

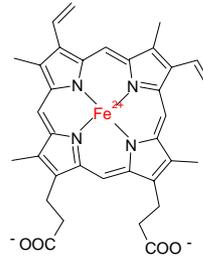
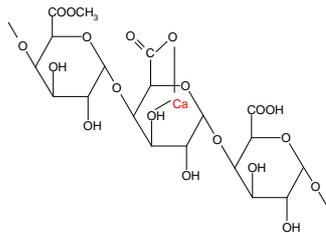
a molecule of MT can bind up to 7 atoms of Cd, Zn, Cu...



Schematic AA sequence of mammalian MT: ● is Cys, ○ is other AA than Cys

## Other compounds of metals:

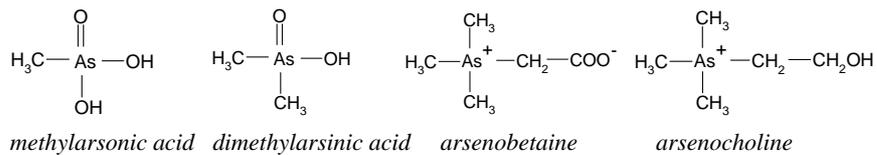
- complexes with organic acids (*citric, tartaric, phytic etc*)
- insoluble salts of organic acids (*calcium oxalate, ferric phytate*)
- complexes of polysaccharides (*pectin*)
- metalloporphyrins (*chlorophylls, hem*)



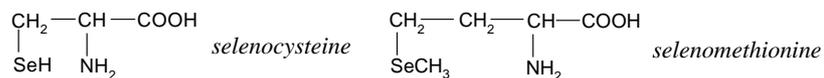
- organometallics  
( $\text{MeHg}^+$ ,  $\text{Me}_2\text{Hg}$ ,  $\text{Et}_4\text{Pb}$ ,  $\text{Bu}_4\text{Sn}$ ,  $\text{Bu}_3\text{SnX}$ )

## Compounds of metalloids and non-metals

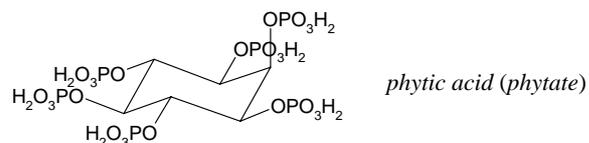
- arsenic compounds



- selenium containing amino-acids



- phosphorus compounds



## Sodium and potassium

### Biochemical roles

- maintaining of osmotic pressure
- activation of enzymes :  $\alpha$ -amylase (Na)
- effect on muscle activity

### Metabolism

- rate of absorption approx. 90 %
- excretion in urine and sweat (Na)

### Contents in foodstuffs

- Na: from tens mg/kg to units %
- K: from thousands mg/kg to units %

### Recommended dietary intakes

- Na: 0.5 to 2.4 g/day (2.4 g Na is equivalent to 6 g NaCl)
- K: 2 g/day

## Magnesium and calcium

### Biochemical roles

- enzymes activation (Mg – phosphatases, kinases)
- effect on muscle activity (Ca – activation of myosin)
- regulatory functions
- blood coagulation (Ca – fibrinogen  $\rightarrow$  fibrin transformation)
- building up bones

### Absorption

- Mg absorption 40-50 % (decreased by phytic acid)
- Ca absorption 2-70 % (decreased by phytic acid, oxalic acid, increased by proteins)

## Magnesium and calcium

### Occurrence in food

- Mg: hundreds mg/kg to thousands mg/kg (higher content in food of plant origin)
- Ca: hundreds mg/kg to thousands mg/kg (higher content in milk and dairy products)

### Recommended dietary intakes

- Mg 300-350 mg/day (adults), 70-200 mg /day (children), 450 mg/day (pregnant women and nursing mothers)
- Ca 800 mg/day (adults), 400-500 mg /day (children), 1200 mg /day (teenagers, pregnant women and nursing mothers)

## Phosphorus

### Biochemical roles

- energy storage (ATP)
- activation of substrates in enzyme-catalysed reactions
- activation of enzymes
- regulatory functions (cAMP, enzyme co-factors)
- building up biological structures (bones, bio-membranes)

### Absorption

- absorption rate 50-70 % (low absorption of P bound in phytic acid)
- effect of Ca – optimum Ca/P ratio: from 1:1 to 2:3

# Phosphorus

## Occurrence in food

- chemical compounds: phytic acid (high content in cereals, legumes, nuts), other organic phosphates, inorganic phosphates, phosphoric acid
- content: hundreds mg/kg (vegetable, fruit) to thousands mg/kg (dairy products, egg yolk, cereals, legumes)

## Recommended dietary intakes

- adults: 1200 mg/day
- children: 300-800 mg/day

# Iron

## Biochemical roles

- oxygen transport (hemoglobin)
- oxygen storing in muscle tissue (myoglobin)
- constituent of enzymes (catalase, peroxidase, cytochroms etc)

## Absorption

- absorption rate 5-15 % (30-60 % in the state of deficiency)
- better availability of hem containing iron compounds
- non-hem iron forms:
  - **reduced bio-availability** in the presence of phytic acid, plant phenolic compounds (tannins from tea) and some types of dietary fibre
  - ascorbic acid, organic acids, amino-acids (His, Lys, Cys) and sugars **increase iron bio-availability**
- effect of iron valency:  $Fe^{2+} > Fe^{3+}$

## **Iron**

### **Occurrence in food**

- total Fe content: units to hundreds mg/kg
- high Fe content: kidney, liver, egg yolk, tea leaves, legumes
- low Fe content: fish, poultry, vegetables (except spinach), fruit
- very low Fe content: milk, dairy products
- Fe-enriched food: infant formulas (addition of ferrous fumarate)

### **Recommended dietary intakes**

- 10 mg (men), 12 mg (boys)
- 15 mg (girls and women), 30 mg (pregnant women)
- 6-10 mg (children)

## **Zinc and copper**

### **Biochemical roles**

- catalytic activities: metalloenzymes
- Cu affects metabolism of Fe

### **Absorption**

- absorption rate: Zn approx. 30 %, Cu 25-70 %
- proteins and amino-acids increase Zn bio-availability
- phytic acid decreases Zn bio-availability
- ascorbic acid decreases Cu bio-availability

### **Occurrence in food**

- Zn content: units to tens mg/kg
- Zn-rich food: cheese, liver, legumes, cereals
- Cu content: units mg/kg or lower
- Cu-rich food: liver, legumes, mushrooms

## Zinc and copper

### Recommended dietary intakes

Group	Zn (mg/day)	Cu (mg/day)
Men	15	1.5-3
Women	12	1.5-3
pregnant	15	1.5-3
nursing	16-19	1.5-3
Children	5-10	0.4-2

## Iodine

### Biochemical roles

constituent of thyroid gland hormones (thyroxine, triiodothyronine)

### Metabolism

- absorption rate 100 %
- 60 µg/day is fixed in thyroid gland, excess is excreted in urine

### Occurrence in food

- sea fish: hundreds µg/kg to units mg/kg
- milk, dairy products tens to hundreds µg/kg
- other food: units to tens µg/kg

### Recommended dietary intakes

- 150 µg/day (adults)
- 175 µg/day (pregnant women), 200 µg/day (nursing women)
- 40-50 µg/day (babies), 70 µg/day (toddlers), 90-120 (children)

## Selenium

### Biochemical roles

- constituent of glutathioneperoxidase
- participation in metabolism of iodine

### Metabolism

- absorption rate 50-100 %
- urinary excretion

### Occurrence in food

- strongly depends on Se content in soil, water etc.
- higher Se content (tens  $\mu\text{g}/\text{kg}$  to units  $\text{mg}/\text{kg}$ ): sea fish, liver, kidney, wholemeal cereals

### Recommended dietary intakes

- 70  $\mu\text{g}/\text{day}$  (men)
- 55  $\mu\text{g}/\text{day}$  (women), 65-75  $\mu\text{g}/\text{day}$  (pregnant and nursing women)
- 20-30  $\mu\text{g}/\text{day}$  (toddlers and children),
- 40-45  $\mu\text{g}/\text{day}$  (teenagers)