



Composition of the mother's milk III. Macro and micro element contents. A review

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Abstract. The authors have analysed macro and micro element contents of the mother's colostrum and mother's milk in comparison with the newest publications. Calcium contents of the mother's milk varied in most of the studies between 84 and 462, while phosphorus contents varied from 17 and 278 mg/dm³. The amount of both calcium and phosphorus increased during lactation, but none of these elements was affected by calcium and phosphorus level of the serum, the vitamin supply, age and smoking. Average magnesium concentration of the mother's milk is 30 mg/dm³, which is not affected by age, vitamin D supply, lactation and diabetes, and even the magnesium supply increases the first day only the magnesium contents of the milk. Sodium contents of the colostrum decreases from 400 mg/dm³ to 150 mg/dm³, potassium contents from 600–700 mg/dm³ to 400–550 mg/dm³, chloride contents from 600–800 mg/dm³ to 400–500 mg/dm³ in the mature milk.

Some of the micro elements occur bonded in protein in the milk, which increase the efficiency of the absorption. Iron contents of mother's

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milk were found in extreme cases between 0.04–1.92 mg/dm³, on average 0.40 mg/dm³, which is not affected by the environment, the mother's nutriment, the iron intake and the contraceptive preparations. Its absorption from the mother's milk is extraordinarily favourable, therefore even a low iron contents are sufficient to satisfy the needs of the babies. Copper contents of the mother's milk vary between 0.03–219 mg/dm³, on average 0.350 mg/dm³. The effect of lactation on the copper contents is controversial, and it appears that the copper contents are not influenced by either the nutriment or the copper intake. Its major part is bonded to protein, therefore its absorption is very favourable. Zinc contents of the mother's milk were measured to be between 0.15–5.41 mg/dm³, it is difficult to specify an average value due to variations of order of magnitude. Similarly, there are extreme values obtained for the manganese contents 0.8–21.5 µg/dm³, which can be explained by the different manganese intake of the mothers, or by extreme manganese burden of the environment.

Out of the other micro elements, the authors analyze the chromium, nickel, cobalt, molybdenum, selenium, iodine and silicon contents of the mother's milk, while among toxic trace elements cadmium, lead and mercury contents. Amount of latter ones in the mother's milk is affected by smoking, the polluted urban air, exhaust gas of the motor vehicles, the polluted environment and by the number of amalgam fillings. Cadmium contents of the mother's milk were measured to be between 0.07–3.8 µg/dm³, but in an extremely polluted urban environment it reached even the value of 24.6 µg/dm³. Even more extreme values were measured for the lead, as its concentration ranged from a couple of tenths to 350 µg/dm³. Lead contents were increased mainly by the polluted urban air, however, its amount decreased after the unleaded fuels have been widely used. Mercury contents of the mother's milk were affected mainly by the number of amalgam fillings and the surface of the fillings. Its amount varied from 0.10 to 6.86 µg/dm³.

1 Macro elements

1.1 Calcium, phosphorus

Khatir Sam et al. [58] measured calcium content of Sudanese mothers to be 388 mg/dm³. Bocca et al. [11] determined calcium content of 60 mothers from different areas of Italy, aged between 19 and 40 years, by high-performance liquid chromatography and inductively coupled plasma emission spectrophotometry, and measured it to be 306 µg/cm³. Based on the measurements a close positive correlation was found between the calcium and magnesium con-

tent.

Dorea [29] analyzing calcium and phosphorus content of mother's milk examined between 1950 and 1999 – based on the works of 169 authors – established that the calcium content varied between 84–462 mg/dm³ (on the average 252 mg/dm³), while phosphorus content between 17–278 mg/dm³ (average value 143 mg/dm³). Average calcium/phosphorus ratio was 1.7, with extreme values 0.8 and 6.0. In this study the effect of childbirth at young age, duration of the pregnancy, state of underfeeding of the mother, physical burden, various metabolic diseases, different nationality, lactation state, time of separation, milk amount, sampling techniques, environmental differences, social-cultural differences, smoking habits, nutrition, calcium and vitamin D supplementation and contraceptives taken for a long time, on the mother's milk, was specially treated. It was concluded that with the exception of youth motherhood and some metabolic diseases no environmental or other factor did have an effect on the calcium and phosphorus content of the mother's milk.

Shores et al. [86] examined calcium, copper, magnesium, manganese, phosphorus and zinc content as well as middle-chain fatty acid content (capric, lauric and miristic acid) of milk of 33 Fulani mothers, and recorded age, height, body mass of the mothers and number of children. After sampling the samples were stored at –20 °C until the analyses. Calcium content was measured to be 263 mg/dm³, while phosphorus content to be 165 mg/dm³. No relationship could be established between middle-chain fatty acids and calcium content.

According to Emmett and Rogers [34] calcium content of mothers of different nationality increases during the lactation from 28 mg/dm³ in the colostrum to 34 mg/dm³ in the ripe milk, while phosphorus content from 14 mg/dm³ to 16 mg/dm³. Hunt et al. [52] examined calcium content of the mother's milk during first four weeks of the lactation and established that it reduced from 7.01 µmol/dm³ to 6.68 µmol/dm³.

Picciano [77] examined calcium and phosphorus content of the mother's milk and experienced that these components are independent of the serum concentration, although Greer et al. [46] established a weak positive relationship between the mother's calcium-intake and calcium content of the milk. In the course of the lactation phosphorus content of the mother's milk decreased from 147 mg/dm³ in the third week of lactation to 107 mg/dm³ till week 26 of lactation; calcium content decreased from 259 mg/dm³ to 248 mg/dm³. In his opinion nutrition of the mother does not affect concentration of these elements.

Yamawaki et al. [97] examined macro and micro element composition of milk of mothers from different areas of Japan by an inductively coupled plasma emission spectrophotometer. The milk samples were collected from around 4000

women in different date of lactation (day 1 to day 365), in summer between July and September, and in winter between December and March, respectively, from around 4000 women in different date of lactation (day 1 to day 365). From each mother around 50 cm³ milk was collected in the part of the day between two nursings, the samples were stored in a deep-freeze until the analysis. Along with the sampling, data were collected on smoking habits, vitamin supply, birth-weight of the newborn and on breast position (left or right). The samples were arranged into four groups based on the obtained information: Group A (3170 sample): mothers aged below 40 years, non-smokers, who took vitamin supplementation, and with babies with birth-weight of 2.5 kg or more. Group B (630 sample): age of women and birth-weight of the babies were the same like in group A, but the mothers smoked regularly, took vitamin supplementation, and received drug treatment during lactation. Group C (30 sample): the only difference from group A was that the mothers were older than 40 years. Group D (200 sample): except birth-weight of the babies (less than 2.5 kg) this group was identical with group A. Between the formed groups no significant difference was found regarding calcium and phosphorus content of the mother's milk. It was established that concentration of phosphorus and calcium in the milk is higher in the winter months than in the summer (phosphorus: 14.6–15.3 mg/100 cm³; calcium: 23.7–26.2 mg/100 cm³), the lactation does not affect the concentration of these components, however.

Honda et al. [49] examining calcium and phosphorus content of the mother's milk, drew 68 mothers, aged between 19 and 38 years, into the experiment, who lived in the non-industrial region of Japan. More than 70% of them was a housewife, and they did not differ significantly from each other in nourishment and state of health. Comparing calcium and phosphorus content of the milk according to the age the mothers, it was established that calcium content of milk of mothers older than 35 years was higher than that of mothers below 35 years (344.4 mg/dm³, 326.4 mg/dm³), in the phosphorus content there was no significant difference (191.6 and 188.6 mg/dm³) between the two groups. No significant difference could be established in case of both elements, either for mothers with the first childbirth or for those with several childbirths (calcium: 327.8; 330.4 mg/dm³, phosphorus: 183.9; 194.5 mg/dm³).

1.2 Magnesium

Shores et al. [86] measured magnesium content of milk of Fulani mothers to be 31.2 mg/dm³. No relationship could be established between middle-chain fatty acids of milk and magnesium content. Butte et al. [12] established signif-

icant difference in the magnesium content of the precolostrum and colostrum, while others could report no such a significant difference. The high magnesium content in the precolostrum is connected presumably with the fact that magnesium is necessary for the formation of the bone's minerals. As ash content of the mother's milk decreases continuously during the lactation, similar changes should occur also in the magnesium content. However, according to Carias et al. [14] as well as Tanzer and Sunel [90] magnesium content of the mother's milk increases slightly in the first six months of lactation. According to Emmett and Rogers [34] magnesium content of milk of mothers with different nationality does not change with the lactation, it is 30 mg/dm³ on the average. According to Picciano [77] magnesium content of the mother's milk increases from 29.0 mg/dm³ measured in week 3 of lactation to 33.0 mg/dm³ till week 26 of the lactation.

According to Hunt et al. [52] magnesium content of the mother's milk increases during the first four weeks of lactation from 1.18 mmol/dm³ to 1.36 mmol/dm³, according to Atkinson et al. [6] and Itriago et al. [55] it decreases, whereas according to Allen et al. [2] and Carrion et al. [15] it shows no substantial change in the first phase of the lactation. In the further part of lactation – in connection with the change of the ash content – a minimal change occurs in the magnesium content.

Yamawaki et al. [97] measured the average magnesium content of milk of mothers from different areas of Japan to be 2.7 mg/100 cm³. It was established that during lactation the magnesium content decreased from 3.2 to 2.5 mg/100 cm³, but does not change significantly seasonally (2.6–2.7 mg/100 cm³).

Dorea [31] in a comparative study examining the magnesium content of the precolostrum, the transitional milk and the ripe milk, came to the conclusion that the colostrum and the precolostrum contribute considerably to the satisfaction of the needs of the children born prematurely. Magnesium content of the precolostrum does not differ significantly from that of the ripe milk due to the great variations in the mean values.

According to Fransson and Lönnerdal [42], major part of the magnesium content of the mother's milk is attached to the protein fractions with lower molecular weight and proteins, respectively (53.6%), and only a very small portion of it can be found in the milk fat (1.8%) and fat micelles (0.8%). Magnesium content was measured on the average to be 31 mg/dm³, with extreme values of 15 and 64 mg/dm³, and in 75% of the examined cases it did not reach 35 mg/dm³.

Coni et al. [20] taking magnesium content of the mother's milk 28.0 mg/kg

established that 90% of it is linked to low molecular weight protein fractions.

According to Huang et al. [51] as well as Hua et al. [50] circumstances influencing the mother's metabolism do not affect secretion of magnesium. Magnesium metabolism is affected by changes in the insuline production due to which concentration of the intracellular magnesium increases.

Bitman et al. [10] established that magnesium content of 48.6 mg/dm^3 of milk of diabethic mothers did not change significantly from that of control mothers. Even galactosemie did not affect significantly the milk comparison [38]. During the early pregnancy mineralization of the baby's bones can be disturbed [18] and Lipsman et al. [65] established that magnesium content of teenager mothers is lower than that of older mothers. Bocca et al. [11] measured magnesium content of the mothers milk to be $0.030 \mu\text{g/cm}^3$ and established that its concentration in the milk of mothers older than 30 years is higher than in that of younger mothers.

According to Honda et al. [49] magnesium content of milk of Japanese mothers older than 35 years is lower than that of mothers aged below 35 years (32.2 mg/dm^3 and 34.7 mg/dm^3). No significant difference could be found between the milk of mothers with the first childbirth and that of mothers with more childbirth (35.1 and 33.6 mg/dm^3). Number of children [63], state of underfeeding [81] and social position [43] have no significant effect on the composition of the mother's milk. Similarly, loss of magnesium due to physical efforts did not affect magnesium content of milk [37]. Regional differences, the countryside or urban environment did not affect magnesium content of the milk [19, 76] comparing magnesium content of milk of mothers living in various countries (Guatemala, Hungary, Niger, Philippines, Sweden, Zaire) established that there was a substantial difference between the different countries (22.6 and 34.2 mg/dm^3).

According to Karra and Kirksey [56] magnesium content of milk of the American mothers significantly increase in the first three months of lactation despite unchanged magnesium-intake. Magnesium deficiency does not occur either in the developing or in the developed countries, therefore there are no data on the effect of the food's magnesium deficiency on the magnesium content of the milk. Independently of the daily magnesium consumption there was no significant difference in the magnesium content between the milk of the Egyptian (386 mg/day), the American ($361\text{--}410 \text{ mg/day}$) and the Nepalese mothers (353 mg/day) [57, 70]. The vegetarian lifestyle can affect the magnesium content of the milk, because from the vegetarian foods magnesium is utilized worse [36]. Comparing the magnesium content of milk of vegetarian and non-vegetarian mothers it was experienced that beside the same magne-

sium intake magnesium content of the vegetarian mothers was 27.5 mg/dm^3 , whereas that of non-vegetarian mothers 31.1 mg/dm^3 . On the other hand, Dagnelie et al. [24] reported that magnesium content of milk of those who consumed macrobiotic diet was lower (31.1 mg/dm^3) than that of pantophage ones (35.8 mg/dm^3). It seems that the components supporting the incorporation of minerals into the bones, e.g. vitamin D, do not influence the magnesium content of the milk. Magnesium content of milk of mothers taking vitamin D was measured to be $21.6\text{--}22.8 \text{ mg/dm}^3$, whereas that of mothers not taking vitamin D to be $20.9\text{--}25.5 \text{ mg/dm}^3$ [89]. Steroid hormones do not have an influence on the magnesium content of the milk, even though they were taken for a long time before the pregnancy [72].

Some reported magnesium decreasing effect of contraceptives taken during the lactation, while others denied these results, which may be explained by the hormone preparations taken in different doses. Comparing the magnesium content of milk of the group treated with hormones and the control group, it can be established that in case of the control group there was no significant difference according to the lactation, on the contrary, in case of ones taking hormone preparation magnesium content of the milk significantly decreased. After the childbirth, magnesium content of mothers who received a magnesium sulfate therapy was 64 mg/dm^3 24 hours after the start of the treatment, in comparison with the concentration of 47.7 mg/dm^3 of the control group. One day after the treatment, however, there was no difference in the magnesium concentration of either the serum or the colostrum between the two groups [21]. The high-calcium diet did not affect the magnesium status and the absorption of magnesium [95]. For newborns with very low body weight absorption of magnesium was around 86% [6, 66]. According to [66] the increasing concentration of calcium can have a negative effect on the absorption of magnesium, however, several claim the opposite.

1.3 Potassium, sodium, chlorine

According to Emmett and Rogers [34] sodium content of milk of mothers of different nationality decrease during the lactation from 47 mg/dm^3 measured in the colostrum to 15 mg/dm^3 in the ripe milk. Picciano [77] measured sodium content of the foremilk to be $300\text{--}400 \text{ mg/dm}^3$, which decreased in the ripe milk to $120\text{--}250 \text{ mg/dm}^3$. Honda et al. [49] measured the sodium content in the milk of Japanese mothers older than 35 years to be 371.5 mg/dm^3 , while for mothers under 35 years to be 345.9 mg/dm^3 . A few difference could be established between the milk of mothers with the first and several childbirths

(373.3 and 327.3 mg/dm³).

Yamawaki et al. [97] measured the average sodium content of milk of mothers from different areas of Japan to be 13.5 mg/100 cm³. During the lactation sodium decreased from 32.7 mg/100 cm³ to 13.9 mg/100 cm³, its concentration was higher in the summer months than in winter (13.8–13.2 mg/100 cm³). According to Picciano [77] potassium content of the mother's milk decreases during the lactation from 600–700 mg/dm³ to 400–550 mg/dm³ in the ripe milk.

Honda et al. [49] measured the potassium content in the milk of Japanese mothers older than 35 years to be 678.3 mg/dm³, while for mothers under 35 years to be 727.8 mg/dm³. There was a significant difference between the milk of mothers with the first and several childbirths (738.3 and 701.6 mg/dm³).

Yamawaki et al. [97] measured average potassium content of mother's milk to be 47.0 mg/100 cm³, which decreased during the lactation from 72.3 mg/100 cm³ to 46.6 mg/100 cm³. It was established that its concentration was higher in winter than in the summer (45.5 and 48.5 mg/100 cm³). Khatir Sam et al. [58] measured chloride content of milk of Sudanese mothers on the average to be 328 mg/100 cm³, and its potassium content to be 738 mg/dm³. Picciano [77] measured the chloride content of the mother's milk in the foremilk to be 600–800 mg/dm³, which value decreased in the ripe milk to 400–450 mg/dm³. Yamawaki et al. [97] measured the average chloride content of milk of mothers from different areas of Japan to be 35.19 mg/100 cm³ that was not affected by the lactation, however it was higher in the summer's months than in winter (38.7 and 33.1 mg/100 cm³).

2 Micro elements

2.1 Connection between micro elements and milk protein fractions

Remy et al. [79] determined macro and micro element content of the human precolostrum by inductively coupled plasma emission technique connected to size-exclusion chromatography and linked mass spectrometer. They analyzed the composition of the precolostrum that was taken from mothers bearing in the week 28 and 32 of the pregnancy in the first month of the lactation. Milk samples taken directly after the childbirth, then on the day 6, 14 and 28 of the lactation were examined. Lead, sulfur, chromium, manganese, iron, cobalt, copper, zink, bromine, selenium, iodine and aluminium content of the milk samples was determined. It was established that the whey protein

fraction of the mother's milk is extremely rich in sulfur, which is due to the high molecular weight sulfur-containing proteins, and low molecular weight substances (glutathione, taurine). Similarly to the sulfur, it was established for all the above macro and micro elements, to what whey protein fraction is attributed their presence.

According to the examinations milk of mothers with premature childbirth differs substantially from the milk replacing preparations in the respect that the different macro and micro elements to what protein fractions are attached. It was also confirmed that the precolostrum is extremely rich in high molecular weight proteins linked to metals, and this is also true to the colostrum and the transitional milk. Amount of the metal-bonding, high molecular weight fractions decreases during the lactation, at the same time the amount of the low molecular weight metal-bonding fractions increases along with the time elapsed after the childbirth. This is very important because absorption of the essential micro elements depends extremely on that in what form they are present in the mother's milk, that is, how the protein modifies utilization of the micro elements. The attention is drawn to that beyond determination of the micro element content it can be also important to know in what form – e.g. linked to proteins – they occur, especially when it is about nourishment of babies born prematurely.

2.2 Iron

Arnaud and Favier [4] examined copper, iron, zinc and manganese content of colostrum and transitional milk of French mothers. From 82 breast-feeding mothers 143 samples were taken; out of the mothers 67 lived in Grenoble, 15 in the neighbourhood. Income, age, number of children, body mass before and at the end of the pregnancy of the mothers were examined. Milk samples were collected between the first and seventh day after the childbirth. During the sampling it was taken care of reducing the contamination with trace elements to the minimum. The sampling was carried out between 9 and 11 a.m.; before the sampling by the hands the breasts were washed with distilled water, then the samples taken were cooled down to -10°C . Iron concentration of the samples was determined by electrothermal atomic absorption spectrophotometer. It was established that although to the sampling and the storage of the samples special attention was paid, great differences were obtained between the individual samples, for which various physiological and non-physiological factors can be responsible. Trace element concentration of the colostrum is high, and adequately satisfies the micro element needs of the newborns. Due to the low

milk amount in the first days the newborns require more micro elements in the milk, by which the higher concentration can be explained. It was established that the environment does not have an influence on the iron content of the mother's milk. No relationship was found between age of mother as well as number of children and iron content of the mother's milk. Examining sex and birth weight of the newborn was found no significant relationships. Iron content of samples taken directly after the childbirth decreased from $14 \mu\text{mol}/\text{dm}^3$ to $7 \mu\text{mol}/\text{dm}^3$ until day 4 of the lactation, then remained at a constant level.

Khatir Sam et al. [58] measured iron content of milk of Sudanese mothers to be $0.56 \text{ mg}/\text{dm}^3$. The mothers used hand pump for the sampling, by which they could take around 100 cm^3 milk per person. The examinations were done by neutron activation analysis and X-ray spectrometer.

Dorea and Miazaki [32] examined the effect of contraceptives on the iron and copper content of the mother's milk for 54 Brazilian mothers. The contraceptive tablets contained 0.15 mg levonorgestrel and 0.03 mg ethynyl estradiol each; and active ingredient of the minipill tablets was 0.35 mg norethidron. Examined blood and milk samples were taken before and after of the treatment with contraceptives. Half of the 54 mothers took the hormone preparation and the other half of them was the control group. When evaluating the results social position of the mothers, number of children, duration of the earlier lactation, type of the contraceptive, duration of the application and the age of the mothers were taken into consideration. It was established that on the iron content of the mother's milk the lactation had only a negligible effect, and also the contraceptives did not have a significant influence on the iron content of the mother's milk during first six months of the lactation. Recently, the contraceptives taken in tablet form have been widely used, changing the hormone level of the blood serum, they affect the mineral metabolism [68, 74]. According to Milman et al. [69] and Andrade et al. [3] the hormones have considerable effect on the iron metabolism and reduction of the iron loss due to menstruation. Contraceptives containing oestrogen increased the iron loss the body without influencing its absorption. Despite this, Kirksey et al. [59] established that the contraceptives did not have an influence on the iron content of the milk in the long run.

Al-Awadi and Srikumar [1] examined trace element of milk of 34 Kuwaiti and non-Kuwaiti breast-feeding mothers and established that iron content of the milk of the Kuwaiti mothers was significantly higher ($0.43 \text{ mg}/\text{dm}^3$) than that of the non-Kuwaiti ones ($0.33 \text{ mg}/\text{dm}^3$). The milk sample was taken before the nursing in the morning, iron content of the milk was determined by atomic absorption spectrophotometer and it was tried to find a relationship

between the protein and iron content of the milk during the lactation. It was established that the high protein content of the milk is connected with the high concentration of the trace elements, from which it was concluded that the high protein content had a considerable effect on the concentration of the examined elements within this on that of iron and its biological utilization. Bocca et al. [11] measured iron content of milk of Italian mothers to be $0.650 \mu\text{g}/\text{cm}^3$ and found a positive relationship between the iron and manganese content.

According to Picciano [77] iron content of the mother's milk in the early phase of the lactation first increases ($0.5\text{--}1.0 \text{ mg}/\text{dm}^3$), then it stabilizes in the ripe milk at around $0.4 \text{ mg}/\text{dm}^3$ and it appears that its concentration is not affected by the mother's food. It was reported that the iron content of the mother's milk utilized extremely well, the absorption mechanism has not been clarified yet in every respect, however. Under similar circumstances from the mother's milk iron utilizes five times better than from cow's milk. One-third of the iron content of the mother's milk is attached to the lipid fraction, one-third can be found in the aqueous phase and approx. 10% of it is linked to the casein. The immunologically important iron-binding lactoferrin binds approx. 20–30% of the iron, and to this is the extreme good utilization of the iron is attributed despite thermal degradation of lactoferrin, but this has no effect on the iron absorption. Also the higher plasma iron concentration of babies fed with mother's milk can be explained by this.

According to Cumming et al. [22]; Fransson and Lönnerdal [41, 43]); Hirai et al. [48] the iron is bonded mainly to the low molecular weight peptides (18–56%), the fat micelles (15–46%) and the lactoferrin (16–40%). Concentration of the main metal transporting proteins decreases with the advance of the lactation, but with the decrease of the lactoferrin the iron concentration of the milk does not change.

According to Dorea [30] iron concentration of the colostrum and the foremilk is significantly higher, and they also claim that the mother's iron reserves do not play a role in the iron content of the mother's milk. Feeley et al. [35] observed significant decrease with the advance of the lactation, on the contrary according to Arnaud et al. [5] there is no significant change in the iron content of the milk during the lactation, and also according to Emmett and Rogers [34], as well as Al-Awaidi the iron content remains at a constant level ($0.07 \text{ mg}/\text{dm}^3$) with the advance of the lactation. Celada et al. [17] established that the iron content of the mother's milk is independent of the lower iron reserves caused by the increasing number of pregnancy, as well as of the concentration of the serum ferritin and transferrin. No significant difference was found in the iron content of the mother's milk, even then when

the mother was iron deficient, when she consumed too much iron, or she had a normal iron status. Iron supplementation of such an extent, which significantly increased the iron content of the blood, did not affect the iron content of the mother's milk [5, 99]. On the contrary, Fransson [39] reported that iron content of milk of anaemic Indian women was higher than that of mothers with higher haemoglobin level. The iron secretion in the milk gland takes place in a very specific way, and it appears that it absolutely does not depend on that of the other macro and micro elements.

Balogun et al. [7] measured the iron concentration of milk of different mothers to be between 10 and 25 mg/kg. From the animal experiments would be concluded that the mother's iron-intake increases the iron content of the milk, for the human there is no proof for this mechanism, however. It appears that a one-time high iron containing mineral intake does not have an influence on the composition of the mother's milk. Many studies prove that there is no difference in the iron content of the mother's milk when different nutritional habits are compared in the same cultural circle, and also there is no difference between the vegetarians, the non-vegetarians and the different nationalities [36, 78]. In Brasil and the United States, during whether the pregnancy or the lactation the food was completed with iron, this did not affect the iron content of the milk [28, 98].

Zapata et al. [98] also reported that a daily iron supplementation of 40 mg increased the total iron-binding capacity, but did not have a significant effect on the iron content of the mother's milk. It was established that an iron supplementation of 100 and 200 mg a day, respectively, did not influence the iron content of milk of Nigerian mothers in the last six months of the pregnancy. Today it appears to be clear that the iron reserve of the body does not influence the transfer from the blood serum into the milk. Despite that there is a significant difference in the fat content of the foremilk and the ripe milk, and there is a relationship between the fat and iron content, some claim that the iron content of the foremilk and the ripe milk differs significantly, while others say it does not. Despite that the iron content of the mother's milk varies in extreme cases between 0.04–1.92 mg/dm³, it appears that in case of breast-fed babies no iron deficiency is expected in the first six months of the lactation. The iron reserve of the newborn's liver balances the lack for the mother's milk [27]. During the first four months the mineral-intake of the babies fed with mother's milk decreases significantly, but as the utilization of the iron from the mother's milk is very high, the feeding with mother's milk completely satisfies the requirements of the growth at this age [13]. Although with advancing lactation the iron intake decreases, it completely satisfies the

needs compared to children fed with baby food preparation.

Krachler et al. [60] measured iron content of transitional and ripe milk of 27 mothers be on the average $380 \mu\text{g}/\text{dm}^3$ by a traditional ICP-MS (inductively coupled plasma emission – mass spectrometry) technique.

Santos da Costa et al. [83] examining the micro element content of colostrum of 50 Brazilian mothers from the first day of the lactation till the fourth day, determined the iron, copper and zinc content. By the whole reflexion X-ray fluorescence analysis the iron content of the colostrum was measured to be $1.72 \text{ mg}/\text{dm}^3$. The applied analytical technique was proven to be suitable for the determination of the trace element content of the colostrum, as by a simple measurement it makes possible a multi-element analysis and it does not require preliminary concentration of the sample.

Domellöf et al. [26] examined the iron, zinc and copper content of milk of 191 Swedish and Honduran mothers, as well as the relationship between the mineral status of the mother. The milk samples were collected for nine months, and also the zinc and copper content of the plasma as well as in connection with the iron status the haemoglobin, plasma ferritin, soluble transferrin receptors and zinc porphirin amount were determined. It was established that the iron content of the milk of the Honduran mothers was significantly lower ($0.21 \text{ mg}/\text{dm}^3$) than that of the Swedish mothers ($0.29 \text{ mg}/\text{dm}^3$). The iron content was in a positive relationship with the energy content of the food. It was concluded that the iron content of the milk was not affected by the mineral status of the mother during the period of nine months after the child-birth, therefore it was assumed that iron got in the milk gland by some active transport. Iron content of the milk decreased during the breast-feeding.

Hunt et al. [53] studying the iron content of milk of mothers with premature childbirth and with normal bearing time between the first and twelfth week of the lactation established that in the milk of mothers bearing at normal time the iron content decreased from $355 \mu\text{g}/\text{dm}^3$ to $225 \mu\text{g}/\text{dm}^3$, while in case of mothers with premature from $406 \mu\text{g}/\text{dm}^3$ to $287 \mu\text{g}/\text{dm}^3$.

Leotsinidis et al. [62] examined the toxic and essential trace elements of the mother's milk and factors influencing the composition of the mother's milk. Into the experiment 180 Greek mothers were drawn, who gave birth to healthy babies. Based on a questionnaire the food consumption of the mothers was precisely gauged, during which information relating to 22 different foodstuffs was collected. Age, height of the mothers, body mass before and after the pregnancy, smoking habits, marital status, qualification, occupation, number of children and food supplementation consumed during the pregnancy were recorded. Milk samples of $10\text{--}20 \text{ cm}^3$ were taken by the hand into polyethylene

pots previously treated with nitric acid and autoclaved at 150 °C for 3 hours, then the samples were stored at -20 °C until the analysis. The iron content was determined by flame atomization atomic absorption spectrophotometer and it was established that this decreased during the lactation. 34% of the mothers taking part in the experiment smoked during the pregnancy, and almost each of them consumed some kind of food supplementation. Between the data relating to the mothers and the iron content of the milk (431 µg/dm³) there was no significant relationship. Decrease of the iron content is closely connected with the lower protein and fat content of the transitional and ripe milk, as it is well-known that half of the iron content is bonded to the protein fractions, whereas the other half of it can be found in the fat. Iron content of the mother's food did not influence the milk composition, from which it can be concluded that the iron is getting in the milk gland by active transport. It was come to the conclusion that although the micro elements of the mother's milk contribute to different extent to the satisfaction of the baby's needs, supplementation of the mother's milk with micro elements is not necessary.

Yamawaki et al. [97] measured the average iron content of milk of mothers from different areas of Japan to be 119 µg/100 cm³. It was established that the iron increases during the lactation from 110 µg/100 cm³ to 180 µg/100 cm³, and that its concentration is higher in the winter's months than in the summer (129; 108 µg/100 cm³).

Shashiraj et al. [85] analyzing the relationship between the iron and lactoferrin concentration of the mother's milk as well as the mother's hemoglobin and iron status established that on the first day after the childbirth the iron content of the mother's milk was between 0.86–0.89 mg/dm³, which decrease to 0.33–0.34 until week 14 of the lactation, and to 0.26–0.27 mg/dm³ until month six of the lactation. In the same period the concentration of lactoferrin is 12.02–12.91 g/dm³; 5.84–6.68 g/dm³ and 5.85–6.37 g/dm³.

2.3 Copper

Khatir Sam et al. [58] measured copper content of milk of Sudanese mothers to be 34.8 mg/dm³. According to Balogun et al. [7] copper concentration of the different mother's milks is between 1.7 and 5.9 mg/kg. Turan et al. [92] determined copper content of colostrum of 30 Turkish middle-class mothers by electrothermal atomic absorption spectrophotometer. For the digestion of the samples and to remove the fat wet ashing was applied. Copper content of the colostrum was measured to be 278 µg/dm³.

According to Dorea [30] copper content of the colostrum and the foremilk

is significantly higher, while according to others it completely corresponds to that of the ripe milk. Feeley et al. [35] observed a decrease with advancing lactation in the copper content of the milk. Arnaud and Favier [4] examining copper content of colostrum and transitional milk of French mothers by atomic absorption spectrophotometer established that copper content of samples taken directly after the childbirth was $17 \mu\text{mol}/\text{dm}^3$, which decreased on the second day to $13 \mu\text{mol}/\text{dm}^3$, while between the fourth and seventh day remained at a constant level. The lactation state had no significant effect on the copper concentration. It was also established that the copper content was significantly affected by the nutrition of the mothers. According to Emmett and Rogers [34] copper content of milk of mothers of different nationality ($0.05 \text{ mg}/\text{dm}^3$) does not change during the lactation. According to Picciano [77] the copper content of the mother's milk in the early phase of the lactation is $0.5\text{--}0.8 \text{ mg}/\text{dm}^3$, which stabilizes in the ripe milk at a concentration value of $0.4 \text{ mg}/\text{dm}^3$. It appears that the food of the mother does not influence its concentration.

Rossipal and Krachler [80] examined content of 19 trace elements of 79 milk samples taken from 46 healthy mothers between day 1–293 of the lactation. Barium, beryllium, bismuth, cadmium, cobalt, caesium, copper, mercury, lanthanum, lithium, manganese, molybdenum, lead, rubidium, antimony, tin, strontium, thallium and zinc content was determined not only in the course of the lactation but also during the nursing. In the case of the copper content a decrease was reported during the lactation. Concentration of the copper in the colostrum (day 1–3) is $549 \mu\text{g}/\text{dm}^3$; in the transitional milk (day 42–60) $241 \mu\text{g}/\text{dm}^3$; whereas in the ripe milk (day 97–293) $148 \mu\text{g}/\text{dm}^3$. After the suckling the concentration of the copper increased even up to 60%.

Leotsinidis et al. [62] examining the composition of the mother's colostrum, transitional milk and ripe milk established that concentration of the copper increased in the course of the lactation. The average copper concentration was measured to be $368 \mu\text{g}/\text{dm}^3$. Between body mass of the mothers and copper content of the milk there was only a little relationship. Although consumption of rice and potato increase the copper content, food of the mother affects it to a small extent.

Yamawaki et al. [97] measured the average copper content of milk of mothers from different areas of Japan to be $35 \mu\text{g}/100 \text{ cm}^3$. It was established that the lactation does not influence the copper content of the mother's milk, however, its concentration is higher in the summer months than in the winter (36 ; $34 \mu\text{g}/100 \text{ cm}^3$).

Hunt et al. [53] investigating the copper concentration of milk of mothers

with premature childbirth and with normal bearing time established that it decreases significantly between week 1 and week 12 of the lactation, in the milk of mothers bearing at normal time from $651 \mu\text{g}/\text{dm}^3$ to $361 \mu\text{g}/\text{dm}^3$, whereas in case of mothers with premature childbirth from $542 \mu\text{g}/\text{dm}^3$ to $425 \mu\text{g}/\text{dm}^3$. According to Salmenpera et al. [82] the copper content of the serum is bonded almost entirely to the celluloplasmin but this does not influence the copper uptake of the milk gland. No increase of the copper content in the mother's milk was found even in such extreme cases where copper content of the blood serum considerably increased due to disease. Although intravenous copper injection increased copper content of the blood serum of the bearing mothers, but did not affect substantially copper concentration of the colostrum [71]. It seems therefore that the mechanism relating to the copper taking place in the milk gland are not affected by the serum copper concentration. The copper secretion in the milk gland takes place in a very specific way and it appears that it does absolutely not depend on that of the rest of the macro and micro elements. Partition of the copper between the different protein fractions of the mother's milk appears to be independent. 15–20% of the copper content of the mother's milk can be found in the fat micelle membrane [67], whereas 20–25% is bonded the copper-containing protein celuloplasmin [64, 96]. Concentration of the major metal transporting proteins reduces with the advance of lactation.

There is no data available regarding whether decrease of the concentration of the copper-containing proteins have an effect on the milk's copper content in the first month of lactation. From the animal experiments would be concluded that the mother's copper-intake increases the copper content of the milk, for the humans there is no proof for this mechanism, however. It appears that a one-time high copper-containing mineral intake does not have an influence on the composition of the mother's milk. Many studies prove that there is no difference in the copper content of the mother's milk when different nutritional habits are compared in the same cultural circle, and also there is no difference even between the vegetarians, the non-vegetarians and the different nationalities [36, 78]. Lipsman et al. [65] reported that Nepalese women consumed foods with significantly higher copper content than the American ones, in the comparison of milk no significant difference could be found, however. Despite this, in the United States milk of the Spanish women contains significantly less copper than that of other nationality. It was established that a copper supplementation of 100 and 200 mg/day in the last six months of the pregnancy did not influence the copper content of the milk of Nigerian mothers. Experiments in Ethiopia and India proved that there can be differences in the milk's copper content between the different ethnical groups [40, 25].

It was also reported that babies of underfed mothers consumed milk with lower copper content, but the experiments show that the copper content of the mother's food does not influence the milk's copper concentration, in fact low or high copper supplementation does not have an effect on it [16]. Oral copper supplementation significantly increases the serum copper level, however, neither the copper concentration of the serum nor the extent of the supplementation have an effect on the copper content of the mother's milk. Today it appears obvious that even the body's copper reserve does influence the transfer from the blood serum into the milk. The oestrogen-containing contraceptives increased the body's copper lost without influencing its absorption. Despite this Kirksey et al. [59] by the examination of the contraceptives in the long run established that they did not affect the copper content of the milk, although they decreased the copper content of the serum in case of mothers, who took contraceptives prior to the pregnancy.

According to Dorea and Miazaki [32] the contraceptives do not affect the copper content of milk of Brazilian mothers in the first six months of lactation. It was established that the copper content in the mother's milk significantly decreased during the lactation. Despite that copper content of the mother's milk varies in extreme cases between 0.03–2.19 mg/dm³, in case of babies fed with mother's milk in the first 6 months of the lactation no copper deficiency is expected. Copper reserve of the newborn's liver balances the lack for mother's milk [27]. Although with advancing lactation the copper intake decreases, the mother's milk still completely satisfies the requirements of the breast-fed babies in comparison with children fed with baby food preparations.

Bocca et al. [11] measured copper content of milk of Italian mothers to be 0.370 µg/cm³ and established that the copper content is significantly higher in case of mothers living in town and there is a close negative relationship between the copper and zinc content. Al-Awadi and Srikumar [1] examined copper content of milk of Kuwaiti and non-Kuwaiti breast-feeding mothers and established that this was significantly higher in case of the Kuwaiti mothers (0.71 mg/dm³) than in case of the non-Kuwaiti mothers (0.59 mg/dm³). Irrespective of the mother's nationality the copper content of the milk decreased between month 6 and 12 of the lactation. Santos da Costa et al. [83] measured copper content of the colostrum of Brazilian mothers to be 0.54 mg/dm³.

Honda et al. [49] measured the copper content of mothers older than 35 years to be 263.0 µg/dm³, while that of mothers under 35 years to be 312.6 µg/dm³. No significant difference was found in the milk of mothers with the first and several childbirth. According to Domellöf et al. [26] copper content of milk of Honduran mothers is significantly lower (0.12 mg/dm³) than that of Swedish

mothers (0.16 mg/dm^3). Between the energy intake and copper content of the mother's plasma no significant relationship was found and it was concluded that during the nine months' period after the childbirth the mother's mineral status did not influence the copper content of the milk.

Shores et al. [86] measured the mother's milk's copper content to be $399 \text{ } \mu\text{g/dm}^3$, and analyzed the capric (0.28); lauric (9.10) and miristic acid content (12.5%) of the milk fat. Significant relationship was found between the copper content and the amount of the three fatty acids. According to the authors the relationship between the copper and the middle-chain fatty acids can be explained by the fact that in the milk gland a copper-containing enzyme is necessary for the synthesis of the C10–C14 fatty acids or the middle-chain fatty acids are capable of bonding the copper in a special way.

Coni et al. [20] analyzed content and absorption of some trace element of milk of 30, healthy mothers living in Torino. During sampling care was taken to avoid contamination of the samples. The ripe milk samples were taken in the second month of the lactation from mothers who were taught the careful and precise sampling. The sampling was done by hand using talkum-free rubber gloves, then the approx. 10 g of mother's milk was stored in polyethylene pots. After appropriate sample preparation the analyses were carried out by quadrupole inductively coupled plasma emission mass spectrometry. A copper content of $552 \text{ } \mu\text{g/kg}$ was obtained. Beyond determining the micro elements it was also examined to what protein fractions the substances of interest are bonded in the milk. In order to determine this, the milk protein fractions were divided into five fractions using size-exclusion chromatography. The first fraction contained proteins with molecular weight above 2000 kDa (α -, β -, κ -casein), the second fraction proteins between 2000–500 kDa (immunoglobulins), the third fraction were of 500–100 kDa (human serum albumin, lactoferrin), the fourth fraction contained fractions between 100–2 kDa (α -lactalbumin), and fraction five contained fractions with molecular weight below 2 kDa (proteose-pepton, free amino acids). It was established that copper occur in the first and second, as well as in the fourth and fifth fraction in the same concentration. The final conclusion was that the specific ligands being in the mother's milk, like proteins and enzymes of different molecular weight, were in a close relation with the trace elements, increasing their biological utilization.

2.4 Zinc

Arnaud and Favier [4] examined zinc content of the colostrum and transitional milk of French mothers by flame atomic absorption spectrophotometer and established that it increased from $130 \mu\text{mol}/\text{dm}^3$ measured on the first day to $180 \mu\text{mol}/\text{dm}^3$ on the second day, then continuously decreased till the fourth day of the lactation, and on the day 7 became constant at $80\text{--}90 \mu\text{mol}/\text{dm}^3$. The zinc content exhibited a maximal value on day 2.

Emmett and Rogers [34] established that the zinc content of milk of mothers of different nationality showed only a little change during the lactation ($0.6\text{--}0.3 \text{ mg}/\text{dm}^3$). Rossipal and Krachler [80] measured the zinc content of the colostrum to be $4.7 \text{ mg}/\text{dm}^3$, that of the transitional milk to be $0.56 \text{ mg}/\text{dm}^3$ and that of the ripe milk to be $0.38 \text{ mg}/\text{dm}^3$. According to Picciano [77] the mother's milk contains around $4\text{--}12 \text{ mg}/\text{dm}^3$ zinc that decreases till month 6 of the lactation to $1.1 \text{ mg}/\text{dm}^3$, till month 12 to $0.5 \text{ mg}/\text{dm}^3$. It appears that the mother's food does not influence the concentration of these elements. It was also reported that the zinc content of the mother's milk was extremely well utilized in the organism of the newborn.

Yamawaki et al. [97] measured the average zinc content of milk of mothers from different areas of Japan to be relatively high, $145 \mu\text{g}/100 \text{ cm}^3$. It was established that during the lactation the zinc content decreased from $475 \mu\text{g}/100 \text{ ml}$ to $177 \mu\text{g}/100 \text{ cm}^3$, and it was higher in the winter's months than in the summer (159 ; $132 \mu\text{g}/100 \text{ cm}^3$).

Hunt et al. [52] examining the zinc concentration of the mother's milk established that in case of a healthy childbirth it decreased between the first and fourth month of the lactation from $0.04 \mu\text{mol}/\text{dm}^3$ to $0.02 \mu\text{mol}/\text{dm}^3$. Hunt et al. [53] in the course of another investigation examining the zinc concentration of milk of mothers having premature childbirth and mothers bearing at normal time established that between week 1 and 12 of the lactation it decreased significantly in the most cases, in the milk of mothers bearing at normal time from $4060 \mu\text{g}/\text{dm}^3$ to $1190 \mu\text{g}/\text{dm}^3$, whereas in that of mothers having premature childbirth from $5970 \mu\text{g}/\text{dm}^3$ to $1270 \mu\text{g}/\text{dm}^3$.

Frković et al. [45] measured the zinc content of the mothers milk to be $4.98 \pm 2.53 \text{ mg}/\text{dm}^3$. Comparing age of mothers, environment of the home, smoking habits it was experienced that zinc content of milk of mothers under 25 years was higher than that of mothers above 25 years, however, in case of the other parameter no difference was found. Honda et al. [49] measured the zinc content of milk of mothers older than 35 years to be $5.41 \text{ mg}/\text{dm}^3$, while that of mothers under 35 years to be $5.90 \text{ mg}/\text{dm}^3$. In case of mothers having the

first childbirth this value was significantly higher ($6.27 \mu\text{g}/\text{dm}^3$) than in case of mothers having more childbirth ($5.36 \mu\text{g}/\text{dm}^3$). Bocca et al. [11] measured the zinc content of milk of Italian mothers to be $2.72 \mu\text{g}/\text{cm}^3$. Evaluating the results based on the age of the mothers it was established that the zinc content was the higher in the milk of mothers under 30 years.

Khatir Sam et al. [58] measured zinc content of milk of Sudanese mothers to be $1.64 \text{ mg}/\text{dm}^3$. According to Al-Awadi and Srikumar [1] the zinc content in the milk of the Kuwaiti mothers is significantly higher ($3.2 \text{ mg}/\text{dm}^3$) than in the non-Kuwaiti ones ($2.4 \text{ mg}/\text{dm}^3$). Between month 6 and 12 of the lactation independent of the nationality the zinc content decreased in the mother's milk. Shores et al. [86] measured the zinc content of the mother's milk to be $2.93 \text{ mg}/\text{dm}^3$, Turan et al. [92] measured the zinc content of colostrum and milk of Turkish mothers by flame atomic absorption spectrophotometer to be $12.9 \text{ mg}/\text{dm}^3$.

Santos da Costa et al. [83] found the zinc content of the colostrum of Brazilian mothers on the average to be $6.97 \text{ mg}/\text{dm}^3$ between the first and fourth day of lactation. According to Domellöf et al. [26] zinc content of milk of Swedish mothers is $0.46 \text{ mg}/\text{dm}^3$, that of Honduran mothers is $0.70 \text{ mg}/\text{dm}^3$. A negative relationship was found between the energy-intake and the zinc content, and it was also established that the zinc concentration increased during the breast-feeding. It was concluded that the zinc content of the milk during nine months after the childbirth was not influenced by the mother's mineral status.

Leotsinidis et al. [62] determined the zinc content of the mother's milk using flame atomization atomic absorption spectrophotometer and obtained a value of $5010 \mu\text{g}/\text{dm}^3$. Its amount decreases in the course of the lactation which is in a close connection with the lower protein and fat content of the transitional and ripe milk since it is well-known that zinc is bonded to the protein fractions. Fruits and rice increased the zinc content, while the other foods of the mother did not affect the milk's zinc content. Coni et al. [20] measured the zinc content of the mother's milk to be $3080 \mu\text{g}/\text{kg}$. It was established that zinc is mainly linked to the low molecular weight protein fractions.

2.5 Manganese

According to Arnaud and Favier [4] manganese content of colostrum and transitional milk of French mothers increases from $120 \text{ nmol}/\text{dm}^3$ measured on the first day to $220 \text{ nmol}/\text{dm}^3$ on the second day, then continuously decreasing reaches a value of $70\text{--}80 \text{ nmol}/\text{dm}^3$ on the seventh day. It was established that

the nutrition of the mothers as well as the environment did not have an effect on the manganese content of the mother's milk. Rossipal and Krachler [80] measured the manganese content of the mother's colostrum, transitional milk and ripe milk between day 1–3 of the lactation to be $7.2 \mu\text{g}/\text{dm}^3$; between day 42–60 to be $3.9 \mu\text{g}/\text{dm}^3$ and between day 97–293 to be $4.0 \mu\text{g}/\text{dm}^3$. According to Picciano [77] the manganese content in the first month of the lactation in the ripe milk is on the average $6 \mu\text{g}/\text{dm}^3$ that decreases between month 3 and 6 of the lactation to $3 \mu\text{g}/\text{dm}^3$.

Yamawaki et al. [97] measured the average manganese content of milk of mothers from different areas of Japan to be $1.1 \mu\text{g}/100 \text{ cm}^3$. It was established that in the course of the lactation the manganese content decreased from 1.2 to $0.8 \mu\text{g}/100 \text{ cm}^3$ and was higher in the winter's months than in the summer (0.9 – $1.2 \mu\text{g}/100 \text{ cm}^3$).

According to Khatir Sam et al. [58] the manganese content of milk of Sudanese mothers is $14.2 \mu\text{g}/\text{dm}^3$ on the average. Krachler et al. [60] measured manganese content of transitional and ripe milk of 27 mothers to be $6.3 \mu\text{g}/\text{dm}^3$. Shores et al. [86] measured the concentration of the manganese in the milk of Fulani mothers to be $16 \mu\text{g}/\text{dm}^3$. Between the middle-chain fatty acids and the manganese content no relationship could be found.

Al-Awadi and Srikumar [1] examining manganese content of milk of 34 Kuwaiti and non-Kuwaiti breast-feeding mothers established that it decreased in both cases during the lactation. Manganese content of milk of the Kuwaiti mothers was measured to be 6.0, and that of the non-Kuwaiti mothers to be $5.7 \mu\text{g}/\text{dm}^3$. According to Turan et al. [92] manganese content of the colostrum of middle-class Turkish mothers is $43.2 \mu\text{g}/\text{dm}^3$. Coni et al. [20] measured manganese content of milk of 30 mothers living in Torino to be $16 \mu\text{g}/\text{kg}$. It was established that manganese occur in a considerable amount, around 70% in the middle molecular weight protein fraction.

Sharma and Pervez [84] determined manganese content of milk and blood of 120 mothers living in the neighbourhood of a steel factory in Middle India, and compared with milk of mothers who lived far away from this environment. In case of manganese a close relationship was obtained between the concentrations in the blood and the mother's milk. The manganese content was measured to be between 0.8 – $21.5 \mu\text{g}/\text{dm}^3$. Comparing the data of milk of mothers living at the polluted area and that of mothers living far away from that it was established that in case of the manganese accumulation in the blood is four times bigger than in the mother's milk. Manganese content of milk of mothers aged between 20–25 years was $4.6 \mu\text{g}/\text{dm}^3$, whereas that of mothers aged 40–45 years was $24.5 \mu\text{g}/\text{dm}^3$. In similar age groups in case of mothers

living far away from the industrial areas, in pollution-free environment, the manganese content was between $0.1 \mu\text{g}/\text{dm}^3$ and $1.5 \mu\text{g}/\text{dm}^3$. Leotsinidis et al. [62] determined manganese content of the mother's milk by electrothermal atomic absorption spectrophotometer to be $3.58 \mu\text{g}/\text{dm}^3$. It appears that by consumption of nuts the manganese content of the mother's milk can be influenced.

2.6 Other micro elements

Kumpulainen et al. [61] examined chromium burden of 50 breast-feeding Finnish mothers and chromium content of the mother's milk, respectively. Parallely with the milk analysis the chromium content of the consumed foodstuffs was measured, which was $31 \mu\text{g}/\text{day}$ on the average (the extreme values were $25\text{--}37 \mu\text{g}/\text{day}$). These values are much lower than that are considered as still tolerable. Chromium concentration of the mother's milk varied in case of higher chromium intake between $0.19\text{--}0.69 \mu\text{g}/\text{dm}^3$, whereas in case of lower chromium intake between $0.24\text{--}0.54 \mu\text{g}/\text{dm}^3$, thus it can be concluded that chromium consumption of the mothers has no effect on the chromium content of the mother's milk. Khatir Sam et al. [58] measured the chromium content in the milk of Sudanese mothers to be $1.11 \mu\text{g}/\text{dm}^3$.

Krachler et al. [60] determined chromium content of transitional and ripe milk of 27 mothers by a common ICP-MS (inductively coupled plasma emission-mass spectrometer) technique, and measured the average chromium concentration to be $24.3 \mu\text{g}/\text{dm}^3$. Wappelhorst et al. [94] examined the absorption of chromium from foodstuffs and its transfer into the mother's milk in case of German mothers. The composition of the foods consumed by the mothers was analyzed then milk samples were taken between week 2 and week 8 of the lactation. Destruction of the samples was carried out using a microwave pressure destructor, the listed elements were analyzed by inductively coupled plasma emission and linked mass spectrometer, and the chromium content was measured to be $0.100 \mu\text{g}/\text{kg}$. Based on the chromium content of the food and the milk was calculated in what portion the chromium are transferred into the milk. The calculated transfer factor was on the average 6.9, which in the case of the individuals significantly differed from each other. These differences were explained by the differences of the mother's milk and the milk production depending on the individuals, as well as by the individual differences relating to the absorption of chromium.

Turan et al. [92] measured the chromium content of the colostrum of 30 Turkish mothers to be $8.6 \mu\text{g}/\text{dm}^3$, nickel content to be $27.8 \mu\text{g}/\text{dm}^3$. Ya-

mawaki et al. [97] measured the average chromium content of milk of mothers from different areas of Japan to be $5.9 \mu\text{g}/100 \text{ cm}^3$, selenium content to be $1.7 \mu\text{g}/100 \text{ cm}^3$. It was established that in the course of the lactation the chromium content increased from 1.7 to $5.0 \mu\text{g}/100 \text{ cm}^3$, whereas the selenium content decreased from 2.5 to $1.8 \mu\text{g}/100 \text{ cm}^3$. Selenium content of the Japanese mothers was found relatively high and it was established that it was influenced mainly by selenium intake along with the food. The chromium concentration was found to be higher in the summer's months than in the winter (6.7 ; $5.1 \text{ mg}/100 \text{ cm}^3$), the selenium content (1.8 ; $1.7 \mu\text{g}/100 \text{ cm}^3$) hardly changed seasonally, however. Wappelhorst et al. [94] measured cobalt content of milk of German mothers to be $0.058 \mu\text{g}/\text{kg}$, molybdenum content to be $0.008 \mu\text{g}/\text{kg}$.

Krachler et al. [60] measured the average cobalt concentration of the mother's milk to be $0.19 \mu\text{g}/\text{dm}^3$, nickel content to be $0.79 \mu\text{g}/\text{dm}^3$, selenium content to be $17 \mu\text{g}/\text{dm}^3$ and vanadium content to be $0.18 \mu\text{g}/\text{dm}^3$. According Khatir Sam et al. [58] molybdenum content of the mother's milk was $3.84 \mu\text{g}/\text{dm}^3$, cobalt content was $1.23 \mu\text{g}/\text{dm}^3$, and nickel content was $7.8 \mu\text{g}/\text{dm}^3$. Rossipal and Krachler [80] examining cobalt and molybdenum content of 79 milk samples taken from 46 healthy mothers established that the cobalt increased almost to its double value during the lactation (colostrum day 1–3: $1.35 \mu\text{g}/\text{dm}^3$; transitional milk day 42–60: $1.64 \mu\text{g}/\text{dm}^3$; ripe milk day 97–293: $2.96 \mu\text{g}/\text{dm}^3$); and the concentration of the molybdenum decreased ($9.00 \mu\text{g}/\text{dm}^3$ in the colostrum, $1.02 \mu\text{g}/\text{dm}^3$ in the transitional milk and $1.56 \mu\text{g}/\text{dm}^3$ in the ripe milk). During the suckling concentration of the molybdenum increases even by 60%, therefore this has to be taken into consideration when collecting mother's milk samples.

According to Picciano [77] selenium concentration of the mother's milk in connection with some selenium-containing protein fractions, is high at the beginning of the lactation ($40 \mu\text{g}/\text{dm}^3$), while in the ripe milk it varies between 7 – $33 \mu\text{g}/\text{dm}^3$ on the average due to differences of the geographical circumstances. Selenium status of the mother influences extremely the selenium content of the milk, that decreases considerably with the advance of the lactation. Selenium content of the milk is in a positive relationship with the plasma selenium concentration of the newborn and with the activity of a selenium-containing enzyme, the glutathione peroxidase. Iodine content of the mother's milk considerably changes due to geographical environment and the mother's iodine intake. In iodine-deficient areas the iodine content of the mother's milk is $15 \mu\text{g}/\text{dm}^3$, but in case of consumption of appropriate iodine-containing foodstuffs can be by an order of magnitude higher ($150 \mu\text{g}/\text{dm}^3$). Fluorine

content of the ripe milk is between 4–15 $\mu\text{g}/\text{dm}^3$.

Bermejo-Barrera et al. [9] determined the silicon content in the milk of 13 mothers by electrothermal atomic absorption spectrophotometry. The milk samples were taken that they were not polluted by the environment. Average silicon content of the samples was 112 $\mu\text{g}/\text{dm}^3$, where the extreme values ranged between 50–440 $\mu\text{g}/\text{dm}^3$. With the exception of one sample (440 $\mu\text{g}/\text{dm}^3$), the samples showed values between 50 and 164 $\mu\text{g}/\text{dm}^3$. Theodorolea et al. [91] determined selenium content of milk of Greek mothers using electrothermal atomic absorption spectrophotometry and chemical modifying. 5–10 cm^3 milk was collected from the mothers by hand-pump in glass vessels, and stored at -18°C until the analysis. Using the elaborated new method as selenium content of the mother's milk 16.7–42.6 $\mu\text{g}/\text{dm}^3$ was obtained, on the average 27.4 ± 5.5 $\mu\text{g}/\text{dm}^3$.

Hunt et al. [53] examined boron concentration of milk of mothers with premature childbirth and mothers bearing at normal time and established that the boron concentration was practically unchanged between week 1 and week 12 of the lactation in case of mothers bearing at time (30 and 28 $\mu\text{g}/\text{dm}^3$), but considerably changed in case of mothers with premature childbirth (37 and 27 $\mu\text{g}/\text{dm}^3$). Selenium content decreased in the milk of mothers bearing at normal time from 26.9 $\mu\text{g}/\text{dm}^3$ to 18.6 $\mu\text{g}/\text{dm}^3$, in the milk of mothers with premature childbirth from 28.7 $\mu\text{g}/\text{dm}^3$ to 20.4 $\mu\text{g}/\text{dm}^3$. Hunt et al. [52] examining the boron concentration of the mother's milk established that in case of a healthy childbirth boron content of the mother's milk between month 1 and 4 decreased from 42 $\mu\text{g}/\text{dm}^3$ to 35 $\mu\text{g}/\text{dm}^3$.

3 Poisonous trace elements

3.1 Cadmium

Erković et al. [44] examined cadmium content of milk of mothers living at the North-Adriatic part of Croatia between September and January. Milk samples were collected from 29 mothers out of whom 14 gave birth to the first child, 12 to the second one, and 13 to the third one. The heavy metal content was determined by a graphite cuvette atomic absorption spectrophotometer, with atomizing temperature of 2060°C . Cadmium content of mother's milk in the neighbourhood of Rijeka varied between 0.45–9.10 $\mu\text{g}/\text{dm}^3$, with average value of 2.54 $\mu\text{g}/\text{dm}^3$. Comparing the cadmium content of milk of mothers of different ages, with one and more children, smoking and non-smoking, as well as living in town and in the countryside, no significant difference between the

different groups could be established [75].

According to Rossipal and Krachler [80] the concentration of cadmium in the colostrum is much higher ($1.1 \mu\text{g}/\text{dm}^3$) than in the transitional ($0.18 \mu\text{g}/\text{dm}^3$) or ripe milk ($0.24 \mu\text{g}/\text{dm}^3$). Coni et al. [20] measured cadmium content of the mother's milk to be $0.8 \mu\text{g}/\text{kg}$. It was established that cadmium occurred mainly in the low and the high molecular weight protein fraction. Turan et al. [92] measured cadmium content of the colostrum of Turkish middle-class mothers to be $2.8 \mu\text{g}/\text{dm}^3$.

Honda et al. [49] examined cadmium content of the mother's milk due to cadmium consumption of different amounts. The cadmium amount entered the organism was established based on a questionnaire and it was taken into consideration whether it was about smoking or non-smoking mothers. Cadmium content of examined mother's milk varied between 0.07 – $1.23 \mu\text{g}/\text{dm}^3$, and was not affected by the age of mother and the course of the childbirth. Between cadmium content of the mother's milk and the urine there was a significant relationship. Between cadmium and calcium content of the mother's milk a negative relationship was established.

Sharma and Pervez [84] found no close relationship between the cadmium concentration in the blood and the mother's milk. Cadmium content of the mother's milk varied between 0.1 – $3.8 \mu\text{g}/\text{dm}^3$. It was established that cadmium content of milk of older mothers was higher than that of the younger ones. Cadmium content of milk of mother aged between 20–25 years was measured to be $0.6 \mu\text{g}/\text{dm}^3$, while that of mothers aged between 40–45 year to be $0.3 \mu\text{g}/\text{dm}^3$. In similar age groups, in case of mothers living far away from the industrial areas, in pollution-free environment, the cadmium content varied between $0.1 \mu\text{g}/\text{dm}^3$ and $0.3 \mu\text{g}/\text{dm}^3$.

Ursinyova and Masanova [93] determined cadmium, lead and mercury content of milk of 158 healthy mothers who lived in eight differently polluted areas of the Slovak Republic. The effect of age of mother, family position, tooth fillings, sex and birth mass of the newborn as well as smoking habits in the family on the composition of the mother's milk. The examined mothers were 25.6 years old on the average, had 6.9 filled teeth and gave birth to their child in week 40 of the pregnancy. Average body mass of the newborns was 3.45 kg, 54.4% of them was a boy, 45.6% of them a girl. 22.8% of the mothers smoked before the pregnancy, 3.8% also during the pregnancy, and 42.7% of the fathers smoked. In the average of 158 analyses the cadmium content of the mother's milk was measured to be $0.36 \mu\text{g}/\text{kg}$. It was established that both the active and passive smoking significantly increased the cadmium content of the milk. Comparing the cadmium content of milk of mothers living in

different parts of the world, outstandingly high value was obtained in the milk of German urban mothers (countryside: $17.3 \mu\text{g}/\text{dm}^3$, urban: $24.6 \mu\text{g}/\text{dm}^3$).

Leotsinidis et al. [62] examining cadmium content of the mother's milk by electrothermal atomic absorption spectrophotometry established that it was for 11% of the colostrum samples below the detection limit. Similar ratios were obtained also in the case of the transitional milk. It was established that the decrease of the milk's cadmium content was in a close connection with the lower protein and fat content of the transitional and ripe milk, since it is well-known that major part of the cadmium can be found in the fat. 34% of the mothers taking part in the experiment smoked during the pregnancy, and almost each of them consumed some kind of food supplementation. By the examination of the cadmium content of the colostrum, the transitional milk and ripe milk it was established that this decreased in the course of the lactation. Average cadmium concentration of the mother's milk was $0.130 \mu\text{g}/\text{dm}^3$. It was established that milk of smoking mothers contained more cadmium and that consumption of meat of animals (lamb, calf) from clean pasture reduced the amount of the poisonous micro elements, consumption of fresh vegetables and the nuts increased the cadmium content, however.

3.2 Lead

Erković et al. [44] measured lead content of milk of Croatian mothers to be $7.3 \mu\text{g}/\text{dm}^3$, which was considerably lower than that of milk made from food preparations. Lead content of the mother's milk varies in the industrialized countries between $5\text{--}20 \mu\text{g}/\text{dm}^3$, in strongly polluted areas it can be 20times higher, however [88]. According to an investigation in Mexico the average lead content of the mother's milk is $62 \mu\text{g}/\text{dm}^3$ with extreme values of 9 and $350 \mu\text{g}/\text{dm}^3$ [73]. According to a Swedish analysis in a polluted environment the lead content of the mother's milk is $0.9 \mu\text{g}/\text{dm}^3$, while in a less polluted environment is around $0.5 \mu\text{g}/\text{dm}^3$. This very low lead content can be explained by the drastically reduced lead emission on the one hand, and the spreading of unleaded fuels. In a comparative investigation in 6 countries Palminger et al. [75] measured lead content of the mother's milk to be between $2.0\text{--}17.8 \mu\text{g}/\text{dm}^3$. Lead content of milk samples measured in the neighbourhood of Rijeka varied between $0.3\text{--}44.0 \mu\text{g}/\text{dm}^3$. Comparing lead content of milk of mothers aged above and below 25 years, having one and more children, living in Rijeka and in the neighbourhood of Rijeka, smoking and non-smoking, it was established that lead content of milk of mothers below 25 years was higher ($10.4 \mu\text{g}/\text{dm}^3$) compared to that of mothers older than

25 years ($5.7 \mu\text{g}/\text{dm}^3$), the difference was not significant, however [87]. Lead content of milk of mothers having one child was $5.8 \mu\text{g}/\text{dm}^3$, whereas that of mothers with more children was $8.7 \mu\text{g}/\text{dm}^3$, the difference is not significant. No significant difference was found in the lead content of milk of the smoking ($5.7 \mu\text{g}/\text{kg}$) and non-smoking mothers ($7.9 \mu\text{g}/\text{kg}$). The difference was significant only between mothers living in Rijeka ($10.6 \mu\text{g}/\text{kg}$) and in the region ($4.7 \mu\text{g}/\text{kg}$). Lead exposition of mothers living in town also appeared in the higher lead content of milk. Turan et al. [92] measured lead content of the colostrum of Turkish middle-class mothers to be $14.6 \mu\text{g}/\text{dm}^3$.

In their examinations Rossipal and Krachler [80] established that the decrease of lead from the colostrum to the ripe milk was substantially smaller compared to the other trace elements ($1.0\text{--}0.12 \mu\text{g}/\text{dm}^3$). Coni et al. [20] measured the lead content of the mother's milk to be $13 \mu\text{g}/\text{kg}$. It was established that lead was bonded in the same concentration both to high and low molecular weight protein fractions.

Gundacker et al. [47] collected $5\text{--}10 \text{ cm}^3$ milk samples from 59 mothers living in Vienna (urban), 47 mothers living in Linz (industrial) and 59 mothers living in Tulln (countryside), aged 29 ± 5 years, and determined the lead content. 60% of the mothers gave birth to her first child. Dwelling place, nutritional habits of the mothers were surveyed, data were collected on the smoking as well as regarding tooth filling and tooth extraction. The milks were lyophilized between -20°C and -48°C , then homogenized, and the samples were taken out of this homogenous "milk" then after appropriate preparation the analysis was done by atomic absorption spectrophotometry. Lead content of the mother's milk was measured to be $1.63 \pm 1.66 \mu\text{g}/\text{dm}^3$. It was established that in Austria the lead exposition considerably decreased during the last 20 years. In 1981 lead content of milk was measured to be $50 \mu\text{g}/\text{dm}^3$, which reduced to 1993 to $36 \mu\text{g}/\text{dm}^3$. According to their investigation lead content of the mother's milk was affected mainly by the dwelling place (Tulln: $1.22 \mu\text{g}/\text{dm}^3$, Linz: $2.48 \mu\text{g}/\text{dm}^3$, Vienna: $1.29 \mu\text{g}/\text{dm}^3$), consumption of fish ($0.80\text{--}1.82 \mu\text{g}/\text{dm}^3$) and corns ($1.46\text{--}1.71 \mu\text{g}/\text{dm}^3$), vitamin supplementation ($1.78 \mu\text{g}/\text{dm}^3$) and the smoking. Lead content of milk of smoking mothers was higher ($2.40 \mu\text{g}/\text{dm}^3$) than that of the non-smoking ones ($1.57 \mu\text{g}/\text{dm}^3$). Lead content of milk of mothers weighing less than 60 kg was measured to be $1.81 \mu\text{g}/\text{dm}^3$. These values for mothers weighing between 60–80 kg was $1.52 \mu\text{g}/\text{dm}^3$, and for mothers weighing more than 80 kg was $1.36 \mu\text{g}/\text{dm}^3$. In summary, it was established that the lead concentration was below the critical level in the examined milk samples. Based on the investigations in the year 2002 it is not to be expected that lead content of milk of healthy mothers

influence the health of the breast-fed baby.

Leotsinidis et al. [62] determined lead content of the mother's milk by electrothermal atomic absorption spectrophotometry. The average lead content was measured to be $0.44 \mu\text{g}/\text{dm}^3$, which decreased in the course of the lactation. Milk of mothers who lived in urban environment contained more lead. It was also established that its concentration was higher in the milk of mothers living in urban environment as well as in industrialized regions than in that of mothers living in the countryside. It seems that consumption of red meat decreases, while cheeses, especially the Greek feta cheese and the rice increase the mother's milk's lead content. Consumption of meat of animals (lamb, calf) from clean pasture reduced the amount of the poisonous micro elements. Comparing the values obtained for lead with data from the previous years, it was established that it decreased by almost two orders of magnitude in the last years which was due to the widespread unleaded fuels.

Sharma and Pervez [84] compared lead content of milk of mothers living in polluted environment in Middle India, and that of mothers living more distant from this environment. Toxic element content of the blood was found to be significantly higher than that of mother's milk, and in case of lead a close relationship was obtained between concentrations in the blood and the mother's milk. Lead content of milk of mothers aged between 20–25 years was $3.6 \mu\text{g}/\text{dm}^3$, whereas that of mothers aged between 40–45 years was $16.7 \mu\text{g}/\text{dm}^3$. Lead content of milk of 20–25 years old mothers living far away from the industrial areas in unpolluted environment was $0.1 \mu\text{g}/\text{dm}^3$, while that of mothers aged between 40–45 years was $0.7 \mu\text{g}/\text{dm}^3$.

Ursinyova and Masanova [93] measured average lead content of milk of 158 healthy Slovak mothers to be $3.4 \mu\text{g}/\text{kg}$. Comparing the values for the milk of mothers living in different parts of the world, it can be established that lead content is outstandingly high in the milk of Italian mothers living in town ($126.55 \mu\text{g}/\text{dm}^3$), followed by lead content of milk of mothers living countryside ($46.52 \mu\text{g}/\text{dm}^3$), Singaporean ($47.7 \mu\text{g}/\text{dm}^3$), Austrian (in 1993: $35.8 \mu\text{g}/\text{dm}^3$, in 2000: $1.5\text{--}1.8 \mu\text{g}/\text{dm}^3$), Malaysian, Canadian and mothers living in different parts of China.

3.3 Mercury

Drasch et al. [33] examined mercury content of 70 milk samples taken from 46 German mothers on the first seven days of the lactation in the function of amalgam filling and other factors. Mercury content of nine milk samples was measured on the average to be $0.37 \mu\text{g}/\text{dm}^3$, where the extreme values

varied between 0.20–6.86 $\mu\text{g}/\text{dm}^3$, in the case of most of the milk samples between 0.4 and 2.5 $\mu\text{g}/\text{dm}^3$. Mercury content of the mother's milk had a positive relationship with the number of teeth filled with amalgam, as in case of mothers whose teeth were filled not with amalgam, the mercury content was less than 0.2 $\mu\text{g}/\text{dm}^3$, in case of those having 1 to 7 teeth filled with amalgam the mercury content was up to 0.50–0.57 $\mu\text{g}/\text{dm}^3$, and for those with more than 7 teeth filled, the mercury content was 11 $\mu\text{g}/\text{dm}^3$. The frequency of fish consumption also increased the mercury concentration in the milk, whereas age of mothers was not in a significant relationship with it. Comparing the mercury content of the mother's milk it was established that mercury content of colostrum samples taken on the second and third day of the lactation was higher, afterwards the same and lower, respectively, than that of the baby food preparations.

Rossipal and Krachler [80] examining mercury content of colostrum, transitional and ripe milk of 46 healthy mothers on day 1–293 of the lactation, established that it decreased from 2.7 $\mu\text{g}/\text{dm}^3$ measured in the colostrum to 0.52 $\mu\text{g}/\text{dm}^3$ in the transitional milk, then stabilized at this value in the ripe milk.

Gundacker et al. [47] measured mercury content of milk of mothers living at different places of Austria to be $1.59 \pm 1.21 \mu\text{g}/\text{dm}^3$. Mercury content of 9% of the samples exceeded 3.5 $\mu\text{g}/\text{dm}^3$.

According to their investigation mercury content of the mother's milk was affected mainly by the dwelling place (Tulln: 1.07 $\mu\text{g}/\text{dm}^3$, Linz: 1.82 $\mu\text{g}/\text{dm}^3$, Vienna: 2.17 $\mu\text{g}/\text{dm}^3$), consumption of fish (1.54–1.92 $\mu\text{g}/\text{dm}^3$) and corns (0.87–1.85 $\mu\text{g}/\text{dm}^3$), vitamin supplementation (1.96 $\mu\text{g}/\text{dm}^3$) and the smoking. Mercury content of milk of smoking mothers was lower (1.42 $\mu\text{g}/\text{dm}^3$) than that of the non-smoking ones (1.60 $\mu\text{g}/\text{dm}^3$). Mercury content of milk of mothers weighing less than 60 kg was measured to be 2.09 $\mu\text{g}/\text{dm}^3$, that of mothers weighing between 60–80 kg to be 1.38 $\mu\text{g}/\text{dm}^3$, and that of mothers weighing more than 80 kg to be 1.24 $\mu\text{g}/\text{dm}^3$.

Sharma and Pervez [84] measured mercury content of milk of 20–25 years old mothers living far away from industrial areas, in unpolluted environment to be 0.1 $\mu\text{g}/\text{dm}^3$, and that of mothers aged between 40–45 years to be 0.9 $\mu\text{g}/\text{dm}^3$. A close relationship was obtained between concentrations in the blood and mother's milk.

Ursinyova and Masanova [93] measured mercury content of milk of Slovak mothers to be 0.72 $\mu\text{g}/\text{kg}$. It was established that only the amalgam tooth filling caused significantly higher mercury content in the milk, therefore with increasing number of teeth filled with amalgam significantly increased the

mercury content.

Da Costa et al. [23] examined mercury content of milk of 23 Brazilian mothers between day 7 and day 30 of the lactation in the function of whether the mothers had amalgam tooth filling and what surface of the filling had, because mercury used for filling teeth in dental treatments is the primary source of mercury for the humans. Number of teeth filled with amalgam in case of mothers drawn into the examination was 6.87. Average mercury content of the mother's milk varied between 0 and 23.07 $\mu\text{g}/\text{kg}$, with an average value of 5.73 $\mu\text{g}/\text{kg}$. Between number of teeth filled with amalgam and mercury concentration of the mother's milk a significant positive relationship was found.

4 Other poisonous trace elements

Rossipal and Krachler [80] examined content of 19 trace elements of 79 milk samples taken from 46 healthy mothers on days 1–293 of the lactation. Barium, beryllium, bismuth, cadmium, caesium, lanthanum, lithium, rubidium, antimony, tin, strontium, thallium content was determined not only in the course of lactation, but also during the nursing. It was established that concentration of such toxic elements like thallium (0.13 $\mu\text{g}/\text{dm}^3$, 0.08 $\mu\text{g}/\text{dm}^3$), barium, beryllium, lanthanum, lithium and antimony was considerably higher in the colostrum than in the ripe milk, and it appears that bismuth, caesium and strontium does not change during the lactation. Concentration of barium, caesium, rubidium, strontium decreases the suckling, which can mean even a difference of 60%, that must be taken into consideration when collecting the mother's milk samples.

Krachler et al. [60] determined toxic element of transitional and ripe milk of 27 mothers and of four baby food preparation (silver, aluminium, arsenic, gold, platinum, scandium, titanium) by traditional ICP-MS (inductively coupled plasma emission-mass spectrometer) technique. The average aluminium concentration was measured to be 67 $\mu\text{g}/\text{dm}^3$, arsenic concentration to be 6.7 $\mu\text{g}/\text{dm}^3$ and silver concentration to be 0.41 mg/dm^3 with extreme values between 0.13–42.0 $\mu\text{g}/\text{dm}^3$. Average concentration of gold was 0.29 $\mu\text{g}/\text{dm}^3$ with extreme values between 0.10–2.06 $\mu\text{g}/\text{dm}^3$. These extreme values were explained by the tooth fillings and use of jewelry. Platinum concentration was very low in each sample, remained below the detection limit of 0.01 $\mu\text{g}/\text{dm}^3$.

Coni et al. [20] analyzed some trace elements of healthy mothers in Torino and their absorption. For the mother's milk samples the following trace element concentrations were obtained: barium 17 $\mu\text{g}/\text{kg}$, bismuth 0.1 $\mu\text{g}/\text{kg}$,

lithium $1\text{ }\mu\text{g/kg}$, strontium $85\text{ }\mu\text{g/kg}$, thallium $0.09\text{ }\mu\text{g/kg}$. Beyond determination of the micro elements it was also examined to what protein fractions the materials of interest were linked in the milk. In order to determine this the milk protein fractions were divided into five parts by size-exclusion chromatography. It was established that bismuth and lithium occurred mainly in the low and high molecular weight protein fractions in nearly equal concentration. Barium, strontium and thallium belonging to the group two of the elements are bonded to the low molecular weight fractions.

Wappelhorst et al. [94] determined antimony, cerium, gallium, lanthanum, niobium, ruthenium, silver, thorium, titanium and uranium content of milk of 19 mothers living in Germany and examined the absorption of the foodstuff, the transfer into the mother's milk. Based on micro element content of the foodstuff and the milk it was calculated in what ratio the micro element present in the foodstuff transferred into the milk. The calculated transfer factor for silver was 5.1, for cerium 16.1, for gallium 19.1, for lanthanum 13.8, for niobium 20.7, ruthenium 4.1, for antimony 13.2, for thorium 20.2, for titanium 5.6, and for uranium 21.3. The transfer factors significantly differed from each other in case of the individuals. These differences were explained by the differences in the milk production and in the absorption of the elements both depending on the entities. Average silver content of the mother's milk was measured to be $0.334\text{ }\mu\text{g/kg}$, cerium content to be $0.030\text{ }\mu\text{g/kg}$, gallium content to be $0.027\text{ }\mu\text{g/kg}$, lanthanum content to be $0.043\text{ }\mu\text{g/kg}$, niobium content to be $0.023\text{ }\mu\text{g/kg}$, ruthenium content $0.180\text{ }\mu\text{g/kg}$, antimony content to be $0.041\text{ }\mu\text{g/kg}$, thorium content to be $0.028\text{ }\mu\text{g/kg}$, titanium content to be $0.080\text{ }\mu\text{g/kg}$ and uranium content to be $0.022\text{ }\mu\text{g/kg}$.

Sharma and Pervez [84] did not find a close relationship between the concentration of arsenic in the blood and mother's milk. Arsenic content of milk of mothers aged 20–25 years, living in polluted area was $0.9\text{ }\mu\text{g/dm}^3$, and that of mothers aged between 40–45 years was $5.2\text{ }\mu\text{g/dm}^3$. In similar age groups, in case of mothers living far away from industrial areas, in unpolluted environment the arsenic content ranged between $0.1\text{--}0.9\text{ }\mu\text{g/dm}^3$.

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