British Journal of Nutrition (2001), **85**, 517–547

DOI: 10.1079/BJN2000280

Review article

Selenium in global food systems

Gerald F. Combs Jr*

Division of Nutritional Sciences, Cornell University, Ithaca, NY 14853, USA

(Received 12 April 2000 – Revised 5 October 2000 – Accepted 20 October 2000)

Food systems need to produce enough of the essential trace element Se to provide regular adult intakes of at least 40 μg/d to support the maximal expression of the Se enzymes, and perhaps as much as 300 μg/d to reduce risks of cancer. Deprivation of Se is associated with impairments in antioxidant protection, redox regulation and energy production as consequences of suboptimal expression of one or more of the Se-containing enzymes. These impairments may not cause deficiency signs in the classical sense, but instead contribute to health problems caused by physiological and environmental oxidative stresses and infections. At the same time, supranutritional intakes of Se, i.e. intakes greater than those required for selenocysteine enzyme expression, appear to reduce cancer risk. The lower, nutritional, level is greater than the typical intakes of many people in several parts of the world, and few populations have intakes approaching the latter, supranutritional, level. Accordingly, low Se status is likely to contribute to morbidity and mortality due to infectious as well as chronic diseases, and increasing Se intakes in all parts of the world can be expected to reduce cancer rates.

Selenium: Cardiomyopathy: Cancer: Food systems: Chemoprevention

Introduction

Se was recognized as an essential nutrient in the late 1950s when it was found to be the active principle in liver that could replace vitamin E in the diets of rats and chicks for the prevention of vascular, muscular and/or hepatic lesions (Schwarz & Foltz, 1957; Schwarz *et al.* 1957). Since that time, Se has emerged as an essential trace element important in human health, both for averting morbidity associated with deficiency as well as for reducing cancer risks at supranutritional intakes. The immediate health significance of Se may vary among countries, as the regular intakes of the element appear to vary considerably between various populations. With that in mind, this present review undertakes to summarize present knowledge of human Se status in the context of that global variation.

Metabolic roles of selenium

In the early 1970s, Se was found to be an essential component of the enzyme glutathione peroxidase (GPX) (Rotruck *et al.* 1972). Since that enzyme was known to participate in the antioxidant protection of cells by reducing hydroperoxides, this finding was taken to explain the nutritional ‘sparing’ by Se of vitamin E, a known lipid-soluble antioxidant. At present, several Se-containing enzymes are recognized: at least five GPX isoforms, three iodothyronine 5′-deiodinases, three thioredoxin reductases, selenophosphate synthetase (Allan *et al.* 1999). In addition, at least four other proteins are recognized as specifically incorporating Se, although their metabolic functions remain unclear: plasma selenoprotein P (Hill *et al.* 1991), muscle selenoprotein W (Vendeland *et al.* 1995) and selenoproteins in prostate and placenta (Behne *et al.* 1996; Gladyshev *et al.* 1998; Allan *et al.* 1999). In each of these proteins, Se is incorporated into the amino acid selenocysteine (SeCys) by the co-translational modification of tRNA-bound serinyl residues (Fig. 1) at certain loci encoded by UGA codons containing SeCys-insertion sequences in their 3′-untranslated regions (Berry *et al.*

Abbreviations: GPX, glutathione peroxidase; SeCys, selenocysteine; SeMet, selenomethionine.

* **Corresponding author:** Dr Gerald F. Combs Jr, fax +1 607 255 1033, email gfc2@cornell.edu

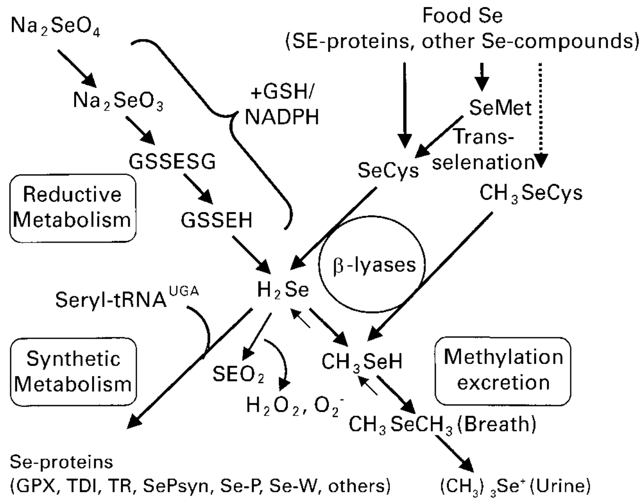

Fig. 1. Pathways of Se metabolism. Oxidized inorganic Se forms (selenate, selenite) undergo reductive metabolism yielding hydrogen selenide (H_2Se), which is incorporated into selenoproteins (the glutathione peroxidases (GPX), iodothyronine 5′-deiodinases (TDI), thioredoxin reductases (TR), selenophosphate synthetase (SePsyn), selenoprotein P (Se-P) and W (Se-W) and others) co-translationally through modification of tRNA-bound serinyl residues at certain loci encoded by specific UGA codons. Successive methylation of H_2Se detoxifies excess Se, yielding methylselenol (CH_3SeH), dimethylselenide ($[CH_3]_2Se$) and trimethylselenonium $(CH_3)_3Se^+$; the latter two metabolites are excreted in breath and urine respectively. Food proteins can contain selenomethionine (SeMet) which can be incorporated non-specifically into proteins in place of methionine, and selenocysteine (SeCys) which is a product of SeMet catabolism and is itself catabolized to H_2Se pool by a β-lyase. Another lyase releases CH_3SeH from Se-methylselenocysteine (CH_3SeCys) present in some foods (e.g. *Allium* vegetables). Oxidation of excess H_2Se leads to production of superoxide and other reactive oxygen species. SeCys, selenocysteine; SeMet, Selenomethionine.

1993; Stadtman, 1996). This enables the decoding of UGA as SeCys rather than as a stop signal, which is its usual function. The nutritional essentiality of Se, therefore, appears to be due to the functions of SeCys proteins: antioxidant protection by the GPX, energy metabolism affected by the iodothyronine 5′-deiodinases, and redox regulation of transcriptional factors and gene expression by the thioredoxin reductases.

Nève (1995) reviewed several studies of human subjects and concluded that the minimum concentration of Se that might be expected in plasma under conditions of maximal expression of plasma GPX is at least 70 ng Se/ml. This level may be taken as a criterion of nutritional adequacy as it corresponds to the amount of Se contained in maximally expressed plasma selenoproteins (Hill *et al.* 1996). Plasma Se concentrations at this level appear to be supported by dietary Se intakes as little as 40 μg/d (Yang *et al.* 1989*b*). Current dietary recommendations meet or exceed this level. For example, the recently revised US Recommended Dietary Allowance for Se is 55 μg for both women and men (Panel on Dietary Antioxidants and Related Compounds, 2000), and the World Health Organization (1996) identified 40 μg Se/d as the average intake level indicated as needed to ensure meeting that normative requirements of most healthy adults.

Selenium in food systems

Fundamental importance of soil selenium

Most of the Se in any food system resides in the soil at any particular time, primarily as a result of the weathering of Se-containing rocks, although volcanic activity, dusts (e.g. in the vicinity of coal burning), Se-containing fertilizers, and some waters can also be sources of Se for soils. Most soils contain 0·1–2 μg Se/kg (Swaine, 1955; Rosenfeld & Beath, 1964). Some parts of the world (e.g. Denmark, Finland, New Zealand, eastern and central Siberia (Russia) and a long belt extending from northeast to south-central China including parts of Heilongjiang, Jilin, Liaoning, Hebei, Shanxi, Shaanxi, Sichuan and Zhejiang Provinces and Inner Mongolia) are notable for having very low amounts of Se in their soils and, therefore, their food systems. In contrast, other areas (e.g. the Great Plains of the USA and Canada; Enshi County, Hubei Province, China; and parts of Ireland, Colombia and Venezuela) are seleniferous. For example, soils derived from the Se-rich Niobara and Pierre shales of ND, USA, contain as much as 90 mg Se/kg, while most non-seleniferous soils based on low-Se granites and metamorphic sandstone contain appreciably less than 2 mg Se/kg (Trelease, 1945; Ermakov, 1992). The biogeochemical mapping of Se has been accomplished for the USA and parts of Canada (National Research Council, 1983), China (Liu *et al.* 1987), Europe (Gissel-Nielsen, 1998), Denmark (Gissel-Nielsen, 1975), Norway (Lag, 1998), Finland (Sippola, 1979; Lahermo *et al.* 1998), New Zealand (Wells, 1967), parts of Australia (McCray & Hurwood, 1963; Noble & Berry, 1982; Judson & Reuter, 1998), the countries of the former Soviet Union (Ermakov, 1992; Golubkina & Alfthan, 1999), Greece (Bratakos & Ioannou, 1989), the former Yugoslavia (Maksimovic *et al.* 1992), and a few countries in Africa (Waiyaki, 2000). Soil Se has also been studied in the UK (Fleming & Walsh, 1957; Fleming, 1962), Spain (Torra *et al.* 1996) and Turkey (Orack & Yanardag, 1996); but very little is known about the Se status of soils in most of the rest of the world. A brief compilation of this work has been presented recently by Oldfield (1999).

Se cycles through food systems, being removed from soils by plants and micro-organisms which can take up the element into their tissue proteins and convert some of it to volatile metabolites (e.g. dimethylselenide) that enter the atmosphere ultimately to be brought down with precipitation and airborne particulates (Shrift, 1964; Allaway *et al.* 1967; Stork *et al.* 1999). Mobilization of Se from soils is influenced by soil pH: alkaline conditions favour the conversion of inorganic Se to selenate (Se^{+6}) which is not fixed in the soils, whereas acidic conditions favour selenite (Se^{+4}) which adsorbs to clays and is strongly fixed by iron hydroxides. The availability of Se to plants is also affected by soil moisture: the element is most available to plants under conditions of low precipitation and low soil leaching. This means that the availability of soil Se to crops can be affected by such soil management procedures as irrigation, aeration, liming and Se fertilization (Gissel-Nielsen, 1998).

Selenium in plant materials

The Se contents of plants vary according to the amounts of the element available in soils. For example, wholewheat grain may contain more than 2 mg Se/kg (air-dry basis) if produced in the ND and SD, USA, but as little as 0·11 mg Se/kg if produced in New Zealand, and only 0·005 mg Se/kg if produced in Shaanxi Province, China (Combs & Combs, 1986*a*). On a global basis, foods with the lowest Se contents are found in the low-Se regions of China: Heilongjiang, northern Shaanxi and Sichuan Provinces. Ironically, foods containing the greatest concentrations of Se have also been found in the same country, although only in a few discrete locales (e.g. Enshi County, Hubei Province) with extraordinarily high soil Se levels. Se is not considered an essential nutrient for higher plants (Terry *et al.* 2000), although Se deprivation has been reported to reduce the growth of rice (Zhou, 1990) and wheat (Peng *et al.* 2000), and increase sensitivities of ryegrass and lettuce to u.v. light (Xue & Hartikainen, 2000).

Selenium in animal products

Food animals raised using low-Se feedstuffs deposit relatively low concentrations of the mineral in their tissues and edible products (e.g. milk, eggs), while animals raised with relatively high Se nutriture yield food products with much greater Se concentrations. Due to the needs of livestock for Se to prevent debilitating deficiency syndromes, Se (usually in the form of Na_2SeO_3) is commonly used as a feed supplement in commercial animal agriculture in many parts of the world. This practice became widespread in North America and Europe within the last 25 years and has reduced what would otherwise be a stronger geographic variation in the Se contents of animal food products. Within the normal ranges of Se-supplementation of livestock diets (0·1–0·3 mg/kg, air-dry basis), muscle meats from most species tend to contain 0·3–0·4 mg Se/kg (fresh weight basis) (Combs & Combs, 1986*b*). Organ meats usually accumulate greater concentrations of Se; the livers of most species generally contain about four times as much Se as skeletal muscle, and the kidneys of steers, lambs and swine have been found to accumulate 10–16-fold the amounts in muscle (Combs & Combs, 1986*b*).

Selenium in human diets

In most diets, the dominant food sources of Se are cereals, meats and fish. Dairy products and eggs contribute small amounts of Se to the total intakes in most countries, although these can represent large percentages of the total Se intakes in countries where their consumption is relatively great and/or where the rest of the diet provides little Se (e.g. New Zealand). Vegetables and fruits are uniformly low in Se (when expressed on a fresh weight basis), and provide only small amounts (<8 % total intake) of the mineral in most human diets. An analysis of US diets (Schubert *et al.* 1987) revealed that five foods (beef, white bread, pork, chicken and eggs) contributed about 50 % total Se in the 'typical' diet, and that 80 % total dietary Se was provided by only twenty-two core foods.

The dominance of cereal-based foods as core sources of Se means that, in many countries, Se intakes can be affected by factors (e.g. domestic harvests, international grain prices, national agricultural and trade policies) that affect the importation of grain from the world market, most of which comes from the relatively Se-rich areas of the USA, Canada and Australia. Indeed, changes in wheat importation have been linked to corresponding changes in Se intakes in Finland (Mutanen, 1984; Mäkelä *et al.* 1993), New Zealand (Thomson & Robinson, 1996) Scotland, UK (MacPherson *et al.* 1997) and Russia (Golubkina, 1997), and several investigators (MacPherson *et al.* 1997; Rayman, 1997; Zimmleri *et al.* 1998; Golubkina & Alfthan, 1999) have cited reductions of North American wheat imports as having caused general reductions in Se intakes in Europe in recent years.

Inter-individual differences in patterns of food consumption can significantly affect both the amount and quality of Se intake. In a study of free-living adults in MD, USA, the mean daily Se intake was 81 μg/person; however, 17 % of diets provided <50 μg Se/person per d, while 5 % of diets provided >150 μg Se/person per d (Levander & Morris, 1984). Marine coastal populations (e.g. Japan, Norway) tend to have greater Se intakes than inland ones due to their higher intakes of fish, which tend to be good sources of the element (Table 1). Individuals with the low intakes of animal products can be expected, in general, to consume relatively low amounts of Se. However, as Burk (1986) pointed out, because plant-based diets tend to provide mostly selenomethionine (SeMet) (which is incorporated non-specifically into plasma and erythrocyte proteins), the blood Se levels of such individuals can still be relatively high. Accordingly, several studies (Srikumar *et al.* 1992; Krajčovičová-Kudláčková *et al.* 1995; Drobner *et al.* 1997) have shown that vegetarians can have greater blood Se levels than non-vegetarians within the same food system.

Selenium bioavailability

In general, the apparent absorption of the organic Se compounds in foods appears to be good (about 70–95 %) (Combs & Combs, 1986*b*). However, it can vary according to the digestibilities of the various Se-containing food proteins and to the pattern of Se compounds present in a particular food. For example, SeMet enters the general protein metabolic pool as a mimic for methionine and is, thus, well retained; however, it cannot support SeCys-enzyme expression without first being released from the protein pool and then being catabolysed through SeCys, ultimately to hydrogen selenide (H_2Se) (Fig. 1). In contrast, SeCys cannot be incorporated directly into proteins. Instead, it is catabolized to H_2Se and is, therefore, better utilized for the SeCys-enzymes but less well retained in tissues. The intermediate, H_2Se, necessary for SeCys-enzyme expression and, therefore, nutritional action, can also be methylated to forms that are readily excreted across the lung (dimethyl selenide, $(CH_3)_2Se$) or kidney (trimethyl selenonium ion, $(CH_3)_3Se^+$). This pattern of metabolism produces differences in the bioavailabilities of Se in foods. In general, the bioavailability of the Se in SeMet, SeCys and most plant materials appears to be reasonably good,

Table 1. Estimated selenium intakes of adults in several countries

Country	Se intake (μg/person per d)	Reference
Austria	48†	Sima & Pfannhauser, 1998
Belgium	45†	Robberecht *et al.* 1994
Canada	98–224	Gissel-Nielsen, 1998
China		
Keshan disease area	7–11*†	Combs & Combs, 1986*c*
Moderate Se area	40*†–120	Combs & Combs, 1986*c*; Xian *et al.* 1997
Selenosis area	750–4990	Yang *et al.* 1989*b*
Croatia	27*†	Klapec *et al.* 1998
Denmark	40†	Gissel-Nielsen, 1998
Egypt	49†	Hussein & Bruggeman, 1999
England	12*†–43†	Barclay *et al.* 1995; Drobner *et al.* 1997 Joint Food Safety and Standards Group (1997)
Finland		
Before 1984	25*†	Aro *et al.* 1995
After 1984	67–110	Aro *et al.* 1995; Anttolainen *et al.* 1996
France	29–43*†	Lamand *et al.* 1994; Ducros *et al.* 1997
Germany	35*†	Kumpulainen & Salonen (cited by Rayman, 2000)
Greece	110	Bratakos *et al.* 1990*a*
Hungary	41†–92	Alfthan *et al.* 1992
Japan	104–127	Suzuki *et al.* 1988; Yoshita *et al.* 1998
Netherlands	67	Kumpulainen (cited by Rayman, 2000)
New Zealand	19*†–80	Robinson & Thomson, 1987; Duffield & Thomson, 1999
Poland	11*†–94	Kvíčala *et al.* 1995; Marzec, 1999
Russia	54†–80	Golubkina, 1994; Aro & Alfthan, 1998
Scotland	30*†–60	MacPherson *et al.* 1997; Shortt *et al.* 1997
Serbia	30*†	Djujic *et al.* 1995
Slovakia	27*†–43†	Kadrabová *et al.* 1998
Sweden	38*†	Kumpulainen (cited by Rayman, 2000)
Switzerland	70	Kumpulainen (cited by Rayman, 2000)
USA	60–220	Combs & Combs, 1986*c*
Uzbekistan	60–93	Kavas-Ogly *et al.* 1995
Venezuela	200–350	Combs & Combs, 1986*c*

* This level does not meet the WHO normative requirement (World Health Organization, 1996).
† This level does not meet the recommended dietary allowance (Panel on Dietary Antioxidants and Related Compounds, 2000).

while that of the Se in many animal products appears to be moderate and, in some cases (e.g. some fish) low.

Global variation in selenium status

Due to differences in geography, agronomic practices, food availability and preferences, most of which are difficult to quantify, evaluations of Se intakes of specific human population groups are seldom precise. General comparisons can be made, however, of the Se contents of different food supplies by using the average Se concentrations determined within specific major classes of foods in different locales. Table 2 presents the typical Se contents of the major classes of foods from several countries. Estimates of per capita dietary Se intakes vary widely among different countries (Table 1), the lowest being only 7–11 μg Se/person per d in parts of China where human diseases have been associated with severe endemic Se deficiency. In other countries with histories of Se-deficiency disorders in livestock (i.e. Finland and New Zealand) the Se intakes of people are estimated to be at least 3-fold those of the Se-deficient regions of China. Residents of the USA (e.g. OH, Pacific north-west, south-eastern seaboard) have estimated Se intakes two to five-fold those of Finns or New Zealanders.

These estimates suggest that millions of people may be unable to consume enough of the element to support their maximal expressions of the SeCys-enzymes, i.e. at least 40 μg Se/d (Yang *et al.* 1987). The best described Se-deficient areas are New Zealand, Finland (prior to 1984), and a long belt of mountainous terrain extending from the north-east to south-central portions of mainland China (Combs & Combs, 1986*c*). In each case, low amounts of Se in soils results in a generalized deficiency of the element throughout the food system, being low in the plants grown on those soils as well as the livestock and people fed those plant foods. Low Se intakes have also been reported in parts of eastern Europe (Kasperak *et al.* 1982; Gondi *et al.* 1992; Djujic *et al.* 1995; Dastych *et al.* 1997; Drobner *et al.* 1997; Bergmann *et al.* 1998; Klapec *et al.* 1998), Russia (Aro *et al.* 1994; Golubkina, 1994; Golubkina & Sokolov, 1997), and Africa (Benemariya *et al.* 1993).

The inter-regional differences in food system Se contents suggested above appear to be manifest as differences in nutritional Se status. Table 3 is a compilation of reported concentrations of Se in whole blood, or serum or plasma, from some sixty-nine countries. While this table is a more comprehensive collation of such data than has heretofore been presented, it is by no means an exhaustive summary of reported variables of Se status. For the most part, it cites studies that have reported plasma or serum Se levels for healthy adults, giving means and estimates of variance or sufficient data to allow the calculation of those statistics. Some exceptions were made for countries for which few

Table 2. Typical selenium contents (μg/g as consumed) reported for major classes of foods from several countries

Food Class	USA*†	England*‡	Germany*	Finland		New Zealand*	China, by Se-area			Venezuela*
				Pre-1984*§	Post-1984§		Low*‖	Moderate*	High*¶	
Cereal products	0·06–0·66	0·02–0·53	0·03–0·88	0·005–0·12	0·01–0·27	0·004–0·09	0·005–0·02	0·017–0·11	1·06–6·9	0·123–0·51
Vegetables	0·001–0·14	0·01–0·09	0·04–0·10	0·001–0·02	0·01–0·02	0·001–0·02	0·002–0·02	0·002–0·09	0·34–45·7	0·002–2·98
Fruits	0·005–0·06	0·005–0·01	0·002–0·04	0·002–0·03	–	0·001–0·004	0·001–0·003	0·005–0·04	–	0·005–0·06
Red meats	0·08–0·50	0·05–0·14	0·13–0·28	0·05–0·10	0·27–0·91	0·01–0·04	0·01–0·03	0·05–0·25	–	0·17–0·83
Poultry	0·01–0·26	0·05–0·15	0·05–0·15	0·05–0·10	–	0·05–0·10	0·02–0·06	0·05–0·10	–	0·10–0·70
Fish	0·13–1·48	0·10–0·61	0·24–0·53	0·18–0·98	–	0·03–0·31	0·03–0·20	0·10–0·60	–	0·32–0·93
Milk products	0·01–0·26	0·01–0·08	0·01–0·10	0·01–0·09	0·01–0·25	0·003–0·025	0·002–0·01	0·01–0·03	–	0·11–0·43
Eggs	0·06–0·20	0·05–0·2	0·05–0·20	0·05–0·20	0·02–0·15	0·24–0·98	0·02–0·06	0·05–0·15	–	0·50–1·5

* Combs & Combs, 1986c.
† United States Department of Agriculture, 1999.
‡ Barclay *et al.* (1995).
§ Aro & Alfthan, 1998.
‖ Keshan disease-endemic areas.
¶ Endemic selenosis areas.

data were available, and some reports of whole blood Se concentrations were included to facilitate the interpretation of cases (e.g. Georgia, Greenland, Guatemala, Libya, Vietnam) for which only that variable is available. (Direct comparisons of the Se contents of plasma and whole blood drawn from the same subjects has revealed that the Se concentrations (ng/ml) of plasma are about 81 % those of whole blood (Burk *et al.* 1967; Robinson *et al.* 1979, 1983*b*; Thomson *et al.* 1982; Verlinden *et al.* 1983; Vernie *et al.* 1983; Zachara *et al.* 1988) and about 94 % those of serum (Harrison *et al.* 1996).) While blood Se levels can be affected by such factors as sex, age, smoking status and environmental exposures, these effects tend to be small and the effect of dietary Se intake being the major determinant of the level plasma or serum level of the element (Robberecht & Deelstra, 1994).

These country-level data can be evaluated using as a criterion of nutritional Se adequacy the serum or plasma Se concentration of 70 ng/ml, which is the minimum reported level for which further Se supplementation has been found to produce no detectable increases in plasma or serum GPX activities (Nève, 1995). (This criterion may be a bit conservative; Rayman (1997) has suggested using the value of 100 ng Se/ml serum as a criterion of nutritional adequacy, based on the studies of Thomson *et al.* (1993).) Using that criterion and assuming normal distributions of plasma or serum Se values (In Americans, whose Se intakes are typically above recommended dietary allowance levels including some degree of Se supplement use (Clark *et al.* 1996; A Nafsiger and GF Combs Jr, unpublished results; Nomura *et al.* 2000), the distribution of plasma or serum Se values tends to be slightly skewed; one might expect more normal distributions for populations with lower intakes of the element.), such an analysis indicates that nutritional Se deficiency would appear to affect substantial numbers of people (>10 %) in most countries for which data are available, and to be highly prevalent (affecting >50 % of the population) in almost half of those countries (Table 4). This does not imply that any disease in those populations may necessarily be related to such low plasma or serum Se concentrations; indeed, the only direct evidence of such causal relationships to date are those involving Keshan Disease in China (Keshan Disease Research Group, 1979; Xu *et al.* 1997*a*,*b*) and I-deficiency disorders in Zaire (Vanderpas *et al.* 1990, 1993; Thilly *et al.* 1992, 1993). Instead, this implies the limited expression of one or more selenoenzymes, which would constitute at least a subclinical deficiency of the element. Only in Canada, Japan, Norway and the USA does low Se status not appear to affect many people. This classification must be considered provisional, as the database is of varying quality, is sparse for most of the countries listed, and includes little or no information for several large and populous areas of the world (e.g. most of Africa, South America, central and south Asia). Even with those caveats, available data suggest that hundreds of millions of people may be Se deficient.

Selenium and human disease

The wide apparent variation in global Se status raises

Table 3. Selected reports of blood selenium concentrations (μg/l) of healthy adults worldwide*

Country	Whole blood		Serum or plasma		Reference
	Mean	SD	Mean	SD	
Austria			67	24	Tiran *et al.* 1992
Australia	110				Pearn & McCay, 1979
	101	19			Cumming *et al.* 1992
			91	12	McOrist & Fardy, 1989
			101	10	Lux & Naidoo, 1995
			92	15	Dhindsa *et al.* 1998
Azerbaijan	110				Abdullev, 1976
Belgium			97	12	Verlinden *et al.* 1983
			96	21	Nève *et al.* 1983*a*
			99	18	Vertongen *et al.* 1984
			79	44	Nève *et al.* 1984
			130	21	Wallaeys *et al.* 1986
			100	9	Thorling *et al.* 1986
			84	15	Peretz *et al.* 1988
			100	20	Nève *et al.* 1988*b*
			97	35	Beguin *et al.* 1989
			88	25	Peretz *et al.* 1991
			83	11	Van Gossum & Nève, 1995
			87	11	Van Gossum *et al.* 1996
Bolivia	132	20	87	13	Imai *et al.* 1995
Bulgaria			45	6	Marinov *et al.* 1998
Burundi			15	2	Benemariya *et al.* 1993
Canada	180				Iyengar, 1984
			144	29	Dickson & Tomlinson, 1967
			115	3	Gibson *et al.* 1985
			132	8	Lemoyne *et al.* 1988
			135	13	Burk *et al.* 1992
			146	27	Vézina *et al.* 1996
			67	7	Allard *et al.* 1998
Chile			66	2	Ribalta *et al.* 1995
China					
Eastern urban areas	136	48			Wang *et al.* 1979
	93	8			Yang *et al.* 1982
	123	20	88	10	Chu *et al.* 1984
			94	6	Luo *et al.* 1985
			102	25	Yang *et al.* 1989*a*
			111	11	Xia *et al.* 1989
			96	11	Xia *et al.* 1992
			80	10	Whanger *et al.* 1994
Rural non-Keshan disease areas					
	76	24			Yu *et al.* 1999
	110	14	98	30	Chu *et al.* 1984
			39	7	Yang *et al.* 1987
			96	29	Huang *et al.* 1997
			52	9	Xia *et al.* 1992
			42	11	Xia *et al.* 1992
Keshan disease areas	17	2			Wang *et al.* 1979
	18	1			Yang *et al.* 1982
	9	23			Yang *et al.* 1983
	29	1			Yang *et al.* 1987
	19	1			Yang *et al.* 1987
	22	7			Xia *et al.* 1992*a*
			24	1	Luo *et al.* 1985
			16	4	Xia *et al.* 1989
			17	6	Xia *et al.* 1992*b*
			21	6	Whanger *et al.* 1994
Kaschin-Beck disease area	23	2			Jiang & Xu, 1989
Selenosis area	3480	1320			Liu & Li, 1987
	1510	50			Yang *et al.* 1989*a,b*
	896	86			Yang & Zhou, 1994
			494	140	Whanger *et al.* 1994
			357	36	Janghorbani *et al.* 1999
Other areas			94	30	Chu *et al.* 1984
			39	7	Yang *et al.* 1987
			51	8	Yu *et al.* 1990
Colombia			112	29	P Correa and GF Combs Jr, unpublished results
Cuba	90		69		Prieto *et al.* 1994
Czech Republic			72		Koranová *et al.* 1993

Table 3. *continued*

Country	Whole blood		Serum or plasma		Reference
	Mean	SD	Mean	SD	
			76		Koranová *et al.* 1993
			56	9	Madaric *et al.* 1994
			65	17	Kvíčala *et al.* 1994
			61	12	Kvíčala *et al.* 1994
			63	16	Kvíčala *et al.* 1995
			51	16	Kvíčala *et al.* 1995
			46	14	Kvíčala *et al.* 1995
			64	19	Dastych *et al.* 1997
			78	3	Zima *et al.* 1998
Denmark	111	24			Tarp *et al.* 1990
			79	10	Thorling *et al.* 1985
			78	15	Thorling *et al.* 1986
			88	11	Tarp *et al.* 1986
			81	12	Bro *et al.* 1988
			108	31	Clausen *et al.* 1989
			88	13	Clausen *et al.* 1989
			97	28	Clausen *et al.* 1989
			94	19	Suadicani *et al.* 1992
			84	20	Grandjean *et al.* 1992
Egypt	68		52		Maxia *et al.* 1972
			117	16	Samir & el-Awady, 1998
England	134	20			Ellis *et al.* 1984
	138	23			Ellis *et al.* 1984
			120	5	Lloyd *et al.* 1983*a*
			115	15	Lloyd *et al.* 1983*b*
			107	13	Thorling *et al.* 1986
			108	13	Tanner *et al.* 1986
			99	23	Damyanova *et al.* 1987
			116	17	Foote *et al.* 1987
			132	15	Hinks *et al.* 1988
			117	17	Yadav *et al.* 1991
			102	21	Overvad *et al.* 1991
			88	21	Thuluvath & Triger, 1992
Estonia			63		Kantola *et al.* 1997
			48		Kantola *et al.* 1997
Finland					
Before 1984†	62	14			Wikström *et al.* 1976
	67	16			Westermarck, 1977
	73	13			Korpela *et al.* 1984
	85	17			Tolonen *et al.* 1988
			66	11	Westermarck, 1977
			60	15	T Westermarck, T Rahola, M Suomela and A Salmi, unpublished results
			55	15	Salonen *et al.* 1982
			83	16	Välimäki *et al.* 1983
			70	10	Levander *et al.* 1983
			74	9	Arvilommi *et al.* 1983
			100	6	Kauppila *et al.* 1984
			74	14	Luoma *et al.* 1985
			71	10	Kaupplia *et al.* 1987
			55	18	Virtamo *et al.* 1987
			68	6	Marklund *et al.* 1987
			70	12	Alfthan, 1988
			70	3	Aro *et al.* 1989
			63	15	Knekt *et al.* 1990
After 1984†	162	20			Tolonen *et al.* 1988
			126	3	Sundström *et al.* 1986
			98	12	Välimäki *et al.* 1987
			108	17	Korpela *et al.* 1989
			73	18	Kivelä *et al.* 1989
			86	20	Salonen *et al.* 1988
			92	5	Mutanen *et al.* 1989
			110	8	Alfthan *et al.* 1991
France			96	21	Nève *et al.* 1983*a*
			122	27	Nève *et al.* 1983*b*
			92	21	Sinet *et al.* 1984
			82	11	Thuong *et al.* 1986
			80	14	Thorling *et al.* 1986

Table 3. *continued*

Country	Whole blood Mean	Whole blood SD	Serum or plasma Mean	Serum or plasma SD	Reference
			85	13	Wilke *et al.* 1988
			123	4	Thérond *et al.* 1988*a*
			136	40	Thérond *et al.* 1988*b*
			77	9	Nève *et al.* 1988*a*
			88	17	Saint-Georges *et al.* 1988
			76	13	Arnaud *et al.* 1988
			69	12	Dubois *et al.* 1988
			105	13	Richard *et al.* 1988
			88	21	Gerber *et al.* 1998
			81	9	Pucheu *et al.* 1995
			76	8	Terrier *et al.* 1995
			69	11	Lee *et al.* 1995
			87	16	Coudry *et al.* 1997
			57	16	Monget *et al.* 1996
			50	10	Ceballos-Picot *et al.* 1996
			83	4	Ducros *et al.* 1997
Georgia	123	45			Mosulishvili *et al.* 1985
Germany	87	25			Lombeck *et al.* 1987*a*
	92	18			Oster *et al.* 1988*b*
	80	24			Schramel *et al.* 1988
	93	18			Oster & Prellwitz, 1990*a*
	107	20	63	28	Rukgauer *et al.* 1997
			88	11	Behne & Wolters, 1979
			81	14	Oster & Prellwitz, 1982
			48	30	Kasperek *et al.* 1982
			80	11	Oster *et al.* 1983
			71	10	Thorling *et al.* 1986
			78	11	Oster *et al.* 1986
			72	13	Oster *et al.* 1988a
			77	16	Koehler *et al.* 1988
			81	2	Reinhold *et al.* 1989
			66	11	Oster & Prellwitz, 1990*b*
			79	13	Theile *et al.* 1995
			65	13	Bononmini *et al.* 1995
			86	13	Meissner, 1997
			94	27	Bergmann *et al.* 1998
Greece	151	33			Bratakos *et al.* 1990*a*
	174	26			Bratakos *et al.* 1990*b*
			63	14	Thorling *et al.* 1986
			68	16	Van Cauwenbergh *et al.* 1994
Greenland	151				Hansen *et al.* 1984
Guatemala	240				Burk *et al.* 1967
Hungary	64	11	50	11	Cser *et al.* 1996
			69	10	Gondi *et al.* 1992
			54	7	Cser *et al.* 1992
India	150	10			Lal *et al.* 1991
	165	43	133	39	Gambhir & Lali, 1996
			117	16	Yadav *et al.* 1991
			125	19	Srikumar *et al.* 1992
			74	12	Srikumar *et al.* 1992
			72	4	Mahalingam *et al.* 1997
Republic of Ireland			94		Darling *et al.* 1992
			112		Darling *et al.* 1992
Israel			119	23	Chaitchik *et al.* 1988
Italy			75	20	Perona *et al.* 1979
			79	10	Calautti *et al.* 1980
			61	18	Mazzella *et al.* 1983
			90	15	Morisi *et al.* 1988
			86	19	Bortoli *et al.* 1990
			119	2	Sesama *et al.* 1992
			65	13	Bellisola *et al.* 1993
			79	17	Burrini *et al.* 1993
			93	15	Olivieri *et al.* 1994
			88	15	Olivieri *et al.* 1995
			92	13	Menditto *et al.* 1995
			94	19	Azzini *et al.* 1995
			78	10	Bonomini *et al.* 1995
			87	17	Casaril *et al.* 1995

https://doi.org/10.1079/BJN2000280 Published online by Cambridge University Press

Table 3. *continued*

Country	Whole blood		Serum or plasma		Reference
	Mean	SD	Mean	SD	
			82	23	Piccinni *et al.* 1996
			58		Ravaglia *et al.* 2000
			64		Ravaglia *et al.* 2000
Jamaica			86		Murphy *et al.* 1988
Japan	206	21			Kurashi *et al.* 1980
	286	21			Schrauzer *et al.* 1985
			196	71	Nakamura *et al.* 1980
			87	7	Aihara *et al.* 1984
			142	16	Koyama *et al.* 1995
			99	13	Hatano *et al.* 1985
			132	14	Uehara *et al.* 1988
			130	10	Suzuki *et al.* 1989
			111	19	Imai *et al.* 1990
			84	10	Yamaguchi *et al.* 1992
			117	16	Matsuda *et al.* 1997
Korea			197	9	Shin *et al.* 1991
Libya	235	16			El-Amri *et al.* 1994
Mexico			100	18	Sanchez-Ocampo *et al.* 1996
The Netherlands			110	10	Vernie *et al.* 1983
			93	12	Thorling *et al.* 1986
			93	15	van ‘t Veer *et al.* 1990
			108	3	Kok & Hofman, 1989
			106	24	Bukkens *et al.* 1990
			69	6	Van der Torre *et al.* 1991
New Zealand					
North Island	69				Watkinson, 1974
	83	12			McKenzie *et al.* 1978
South Island	68	12			Griffiths & Thomson, 1974
	63	10			McKenzie *et al.* 1978
	64	13			Robinson *et al.* 1981
			58	9	Stewart *et al.* 1978
			43	12	Robinson *et al.* 1979
			48	10	Rea *et al.* 1979
			43	1	van Rij *et al.* 1981
			54	11	Thomson *et al.* 1982
			49	12	Robinson *et al.* 1983*a*
			60	12	Robinson *et al.* 1983*b*
			69	15	Robinson *et al.* 1985
			59	11	Thomson *et al.* 1985
			64	13	Thomson & Robinson, 1986
			48	19	Robinson & Thomson, 1987
			47	12	Thomson *et al.* 1988
			59	11	Whanger *et al.* 1988
			63	17	Thomson & Stevens, 1988
			56	9	Thomson *et al.* 1989
			69	8	Butler *et al.* 1991
			94	24	Sluis *et al.* 1992
			53	6	Thomson & Robinson, 1993
			55	6	Thomson *et al.* 1993
			56	6	Robinson *et al.* 1997
			65	12	Duffield & Thomson, 1999
Niger			79	15	Arnaud *et al.* 1993
			77	16	Cenac *et al.* 1992
Nigeria	80	40	50	31	Ojo *et al.* 1994
Northern Ireland			60	13	Strain *et al.* 1997
Norway	151	14			Bibow *et al.* 1989
			114	15	Saeed *et al.* 1979
			119	20	Aaseth *et al.* 1987
			126	16	Bjørneboe *et al.* 1988
			116	15	Glattre *et al.* 1989
			122	13	Meltzer *et al.* 1992
			167	22	Ringstad *et al.* 1993*a*
			117	16	Meltzer *et al.* 1993
			110	13	Bibow *et al.* 1993
			114	12	Ringstad *et al.* 1993b
			119	16	Meltzer & Huang, 1995
			78	6	Karlsson *et al.* 1996
Poland	125	15			Zachara *et al.* 1986
	92	10	71	12	Iwanier & Zachara, 1995

Table 3. *continued*

Country	Whole blood Mean	Whole blood SD	Serum or plasma Mean	Serum or plasma SD	Reference
			78	18	Wasowicz & Zachara, 1987
			63	12	Zachara *et al.* 1987
			89	47	Masiak & Herzyk, 1984
			57	8	Zachara *et al.* 1988
			78	16	Pawlowicz *et al.* 1991
			59	5	Wasowicz *et al.* 1993
			51	14	Scieszka *et al.* 1997
Portugal			102	10	Thorling *et al.* 1986
			93	18	Viegas-Crespo *et al.* 1994
Russia					
Eastern			73		VN Ivanov and AV Voschenko, unpublished results
			65		Golubkina *et al.* 1995
			94		Golubkina *et al.* 1995
			126		Golubkina *et al.* 1995
			78		Golubkina *et al.* 1995
			89		Golubkina *et al.* 1995
			88		Kantola *et al.* 1997
			90		Golubkina & Sokolov, 1997
			102		Golubkina & Sokolov, 1997
			145		Golubkina & Alfthan, 1999
Ural area			98	11	Golubkina *et al.* 1996
			96	10	Golubkina *et al.* 1996
			84	13	Golubkina *et al.* 1996
			87	11	Golubkina *et al.* 1996
			103	11	Golubkina *et al.* 1996
			86	9	Golubkina *et al.* 1996
Eastern Siberia			102		Golubkina *et al.* 1992
			96	4	Golubkina *et al.* 1998*a*
			84	4	Golubkina *et al.* 1998*a*
			86	4	Golubkina *et al.* 1998*a*
			86	3	Golubkina *et al.* 1998*a*
			74		Golubkina *et al.* 1998*b*
Trans-Baikal			80	30	Aro *et al.* 1994
			63		Golubkina & Alfthan, 1999
Saudi Arabia			103		Raines *et al.* 1999
Scotland, UK	117				Ward *et al.* 1984
			91	4	Harrison *et al.* 1996
Singapore	164	28			Xu *et al.* 1994
			116		Hughes & Ong, 1998
			122		Hughes & Ong, 1998
Slovak Republic			67	26	Brtková *et al.* 1994
			48	3	Kadrobová *et al.* 1995
			57	8	Kadrobová *et al.* 1996*a*
			50	2	Kadrobová *et al.* 1996*b*
			58	4	Krajčovičová-Kudláčková *et al.* 1995
			79	19	Magalova *et al.* 1997
South Africa			117	11	Segal *et al.* 1995
Spain			87	14	Thorling *et al.* 1986
			52	14	JM Fraga, JA Cocho de Juan, ML Couce Pico and JR Cervilla, unpublished results
			60	4	Fernandez-Banares *et al.* 1990
			81	10	Torra *et al.* 1997
			64	9	Marchante-Gayon *et al.* 1996
			81	7	Alegria *et al.* 1998
			54	25	Navarro-Alarcaon *et al.* 1998
			75	27	Navarro-Alarcaon *et al.* 1999
			116	25	Moreno *et al.* 1999
			94	3	Ferrer *et al.* 1999
Sweden	120	20			Brune *et al.* 1966
			68	13	Gebre-Medhin *et al.* 1985
			45	15	Jacobson & Plantin, 1985
			82	10	Thorling *et al.* 1986
			108	3	Thorngren & Åkesson, 1987
			95	6	Borglund & Åkesson, 1987
			83	3	Åkesson & Johansson, 1987
			81	14	Ahlrot-Westerland *et al.* 1987
			102	15	Aursnes *et al.* 1988
			107	2	Michaelsson *et al.* 1989

Table 3. *continued*

Country	Whole blood		Serum or plasma		Reference
	Mean	SD	Mean	SD	
			95	20	Lundberg *et al.* 1992
			75	9	Srikumar *et al.* 1992
			110	20	Hardell *et al.* 1993
			88	19	Hardell *et al.* 1995
Switzerland			90	18	Forrer *et al.* 1991
			78	2	Karlsson *et al.* 1996
Taiwan			88	17	Chen *et al.* 1997
			126	10	Lin *et al.* 1998
			47	15	Chou *et al.* 1998
Turkey	94	7	75	12	F Hincal and N Basaran, unpublished results
	65	17	58	14	F Hincal and N Basaran, unpublished results
	100	10	79	21	F Hincal and N Basaran, unpublished results
			90	10	Turan *et al.* 1992
			94	7	F Hincal and N Basaran, unpublished results
			50	2	Guvenoc *et al.* 1995
			98	12	Güneral & Sunguroğlu, 1995
			168	46	Köse *et al.* 1996
			129		Saraymen *et al.* 1997
			106	26	Kocyigit *et al.* 1998
			71	2	Ozata *et al.* 1999
USA					
Eastern States	179	19			Allaway *et al.* 1968
	210	30			Rudolph & Wong, 1978
	166	29			Morris *et al.* 1983
			94	14	Pleban *et al.* 1982
			136	6	Willett *et al.* 1983
			131	3	Dutta *et al.* 1983
			100	20	Stead *et al.* 1984
			88	8	Stead *et al.* 1984
			134	12	Levander & Morris, 1984
			104	21	McAdam *et al.* 1984
			95	16	Dworkin & Rosenthal, 1984
			115	21	Pelag *et al.* 1985
			110	16	Menkes *et al.* 1986
			149	6	Levander *et al.* 1987
			122	16	Smith *et al.* 1987
			104	2	Feldman & Smith, 1987
			93	20	Dworkin *et al.* 1987
			129	8	Kant *et al.* 1989
			138	16	Swanson *et al.* 1990
			135	28	Clark *et al.* 1993
			124	21	GF Combs Jr and LC Clark, unpublished results
			140	41	GF Combs Jr and AM Nafziger, unpublished results
			113	15	Salvini *et al.* 1995
Southern States	188	32			Allaway *et al.* 1968
			148	7	McConnell *et al.* 1975
			157	25	McConnell *et al.* 1980
			95	27	Lane *et al.* 1982
			94	7	Miller *et al.* 1983
			91	17	Lane *et al.* 1983*a*
			100	30	Lane *et al.* 1983*b*
			80	10	Goodwin *et al.* 1983
			167	39	Milly *et al.* 1992
			130	30	Mask & Lane, 1993
			114	20	GF Combs Jr and LC Clark, unpublished results
			120	3	Lane *et al.* 1987
Central States	158	28			Allaway *et al.* 1968
	229	35			Shamberger *et al.* 1973
			122	10	Primm *et al.* 1979
			120	10	Sullivan *et al.* 1979
			108	19	Fleming *et al.* 1982
			119	3	Snook *et al.* 1983
			136	22	Moore *et al.* 1984
			133	15	Smith *et al.* 2000
Western States	208	34			Allaway *et al.* 1968
	176	24			Schrauzer & White, 1978
	171	24			Valentine *et al.* 1978
	191	23			Schrauzer *et al.* 1985

Table 3. *continued*

Country	Whole blood Mean	Whole blood SD	Serum or plasma Mean	Serum or plasma SD	Reference
	195	20			Olmsted *et al.* 1989
	202	25			Whanger *et al.* 1988
	397	128			Whanger *et al.* 1988
	404	139			Longnecker *et al.* 1991
	379	47			Salbe *et al.* 1993
			102	18	Schrauzer *et al.* 1973
			135	15	Levander *et al.* 1981
			72	27	Valentine *et al.* 1988
			166	29	Swanson *et al.* 1990
			198	55	Longnecker *et al.* 1991
			135	28	Clark *et al.* 1993
Hawaii			125	19	Nomura *et al.* 2000
Uzbekistan	108	1			Zhuk *et al.* 1988
	109	1			Zhuk *et al.* 1994
Venezuela			216	60	Brätter *et al.* 1984
			315	135	Brätter *et al.* 1984
			80	13	Burguera *et al.* 1990
Vietnam	400				Hai *et al.* 1984
Former Yugoslavia					
Bosnia-Herzegovina			64	19	Maksimovíc *et al.* 1992
Croatia			69	17	Beker *et al.* 1992
			64	12	Mikac-Dević *et al.* 1992
			71	18	Krsnjavi *et al.* 1992
Macedonia			35	7	Maksimović *et al.* 1992
Montenegro			51	26	Maksimović *et al.* 1992
Serbia			41	20	Maksimovic *et al.* 1992
			63	12	Mihailovic *et al.* 1992
			56	14	Maksimovic *et al.* 1995
			62	15	Maksimovic *et al.* 1998
			38	13	Backovic *et al.* 1999
Zaire			202	27	Vanderpas *et al.* 1990
			27	15	Thilly *et al.* 1992, 1993
			82	3	Vanderpas *et al.* 1993
Zambia			40	10	Z Cordera-McIntyre and GF Combs Jr, unpublished results

* These reports were selected for having included estimates of variance (SD) for these measures of Se status in healthy adults. Point estimates are cited in cases where SD values were not reported, particularly for infrequently studied countries.

† In 1984, Finland commenced a national programme adding Na_2SeO_4 to its chemical fertilizers (6 mg Se/kg for grain production, 16 mg Se/kg for hay/fodder production; the programme was modified in 1990, with 6 mg Se/kg being added to all fertilizers thereafter.

questions as to the health impact(s) of low as well as high Se intakes.

Health impacts of selenium deficiency

Two diseases have been associated with severe endemic Se deficiency in humans: a juvenile cardiomyopathy (Keshan disease), and a chondrodystrophy (Kaschin-Beck disease). Each occurs in rural areas of China and Russia (eastern Siberia) in food systems with exceedingly low Se supplies. For example, Keshan disease has been diagnosed in more than a dozen Chinese provinces in mountainous areas where the soil Se levels are very low (<0·125 mg Se/kg, of which <2·5 % is soluble) (Tan *et al.* 1987). In these areas, grains generally contain <0·040 mg Se/kg, Se and/or vitamin E-deficiency diseases of livestock (e.g. 'white muscle disease' in lambs, 'mulberry heart disease' in pigs) are endemic, and humans typically show the lowest tissue Se levels reported to date (e.g. blood Se <0·025 mg/l; hair Se <0·100 mg/kg).

Keshan disease is a multifocal myocarditis occurring primarily in children and, to a lesser extent, in women of child-bearing age (Keshan Disease Research Group, 1979; Xu *et al.* 1997*b*). It is manifested as acute or chronic insufficiency of cardiac function, cardiac enlargement, arrhythmias, and electrocardiographic and radiographic abnormalities. The case-fatality in China was greater than 80 % in the 1940s, but has declined in recent years to <30 % apparently as the result of better medical care. Dramatic reductions in the incidence of the disease have been achieved by the prophylactic administration of oral tablets containing Na_2SeO_3 (0·5–1 mg Se/child per week) or selenite-fortified table salt (10–15 mg Se/kg). A few cases of cardiomyopathy associated with low Se status have been reported outside of China; however, low Se status is not a general feature of cardiomyopathy patients in most countries. Improvements in Se intake have been insufficient to explain the decline in Keshan disease prevalence observed in China in recent years (Xu *et al.* 1997*b*), suggesting that other factors are also involved in its aetiology. Recent findings suggest that the disease may be caused by RNA-viruses, the pathogenicities of which are potentiated by severe deficiencies of Se and other antioxidants (Beck *et al.* 1994*a*,*b*, 1995; Beck, 1997).

Table 4. Estimated distribution of prevalence of low selenium status based on reported blood selenium levels*

Prevalence category*	Country	
High (>50 %)	Austria	New Zealand
	Bulgaria	Niger
	Chile	Nigeria
	China	Northern Ireland
	Cuba	Poland
	Czech Republic	Slovak Republic
	Estonia	Spain
	Germany	Uzbekistan
	Greece	Former Yugoslavia Republics
	Hungary	Zambia
	Jamaica	
Moderate (10–50 %)	Australia	Mexico
	Belgium	Portugal
	Bolivia	Russia
	Denmark	Sweden
	England	Switzerland
	France	Taiwan
	India	Turkey
	Italy	Venezuela
Low (<10 %)	Burundi	Korea
	Canada	Norway
	Egypt	Scotland
	Finland	USA
	Republic of Ireland	Parts of Zaire
	Japan	

* Based on estimated frequencies of plasma or serum Se concentrations <70 μg/l.

Kaschin-Beck disease is an osteoarthropathy affecting the epiphyseal and articular cartilage and the epiphyseal growth plates of growing bones. It is manifested as enlarged joints (especially of the fingers, toes and knees), shortened fingers, toes and extremities, and, in severe cases, dwarfism. The few studies of the effects of Se supplementation in the prevention and therapy of Kaschin-Beck disease have yielded encouraging results. Nevertheless, it is not clear that Se deficiency is a primary cause of Kaschin-Beck disease; it is more likely that severe endemic Se deficiency is a pre-disposing factor to the pathogenic effects of some other agent(s). Such roles have been proposed for fulvic acids in drinking water (Guo *et al.* 1997; Peng *et al.* 1999) and tricothecene mycotoxins in foods (Xiong *et al.* 1998).

Individuals with low intakes of protein will also have low intakes of Se because virtually all of the Se in foods occurs as the Se-amino acids in proteins. Therefore, children with kwashiorkor or marasmus, in which inadequate intake of protein results in the disease, will also tend to be low in Se. This has been documented in Guatemala (Burk *et al.* 1967) Morocco (Squali *et al.* 1997) and Egypt (Ashour *et al.* 1999); it is likely to be a factor in in South Asia and Sub-Saharan Africa where protein-malnutrition is widespread. In fact, malnourished children appear to have increased needs for Se and other antioxidant nutrients, due to the pro-oxidative effects of malnutrition and inflammation (Squali *et al.* 1997; Ashour *et al.* 1999). Neonates typically have lower blood Se levels than their mothers (Lee *et al.* 1995), and low plasma Se levels have been found to be associated with increased risk to respiratory morbidity among low-birth-weight newborns (Darlow *et al.* 1995). That Se-dependent GPX is important in protecting proliferating keratinocytes in wounded tissues (Munz *et al.* 1997) also suggests that Se-deficient individuals may also have compromised wound healing, although there have been no clinical reports of such effects.

It is likely that Se deficiency may also be a factor in some other diseases. Studies in central Africa found that the prevalences of the I-deficiency diseases, goitre and myxedematous cretinism, were greater among populations of relatively low Se status than among those of greater Se status (Vanderpas *et al.* 1990, 1993; Thilly *et al.* 1993). Because Se is known to be essential for the metabolic production of thyroid hormone (which requires the SeCys-containing iodothyronine 5-deiodinase to convert thyroxine to the active thyoid hormone) (Arthur *et al.* 1993), such a relationship suggests that the efficacy of I-supplementation programmes may be limited in Se-deficient populations, in which cases treatment with both Se and I would be indicated. Low Se status has been linked to increased risk of pre-eclampsia (Rayman *et al.* 1996), spontaneous abortions (Barrington *et al.* 1996), male infertility (Vézina *et al.* 1996; Scott *et al.* 1997). Recent findings have demonstrated that severe Se-deficiency in vitamin E-deficient hosts can increase the mutation rates of RNA-viruses (Beck *et al.* 1994*a*,*b*, 1995; Beck, 1997), making it plausible to suggest that Se deficiency may increase risks not only of Keshan-type cardiomyopathy but also of other diseases caused by RNA viruses (e.g. measles, influenza, hepatitis and AIDS) all of which are global problems.

Low blood Se levels have been measured in patients with several other diseases, particularly those affecting hepatic function. Such effects may be without significant biological consequence unless they are associated with reductions in blood GPX activities; otherwise, they may relate mostly to changes in protein metabolism and/or to differences in dietary management. For example, very low blood Se levels have been identified in infants with the inborn errors of amino acid metabolism, maple syrup urine disease, or phenylketonuria (Lombeck *et al.* 1987*a*; Jochum *et al.* 1999). Such patients show serum Se levels (e.g. as low as 0·005 mg/l) with erythrocyte GPX activities of only 10–20 % those of healthy children. This effect has been shown to be due to the use of parenteral nutrition fluids that contain negligible amounts of Se (van Rij, 1981; Lombeck *et al.* 1987*a*).

Health impacts of supranutritional selenium intakes

Emerging evidence indicates that Se has anti-carcinogenic potential. Most, but not all, epidemiological studies have shown inverse associations of nutritional Se status and cancer risk (Combs & Gray, 1998; Combs & Clark, 1999), and numerous studies with experimental animal tumour models have demonstrated that intakes of Se in excess of nutritional requirements can inhibit tumourigenesis (Combs, 1989; El-Bayoumy, 1991; Krämer *et al.* 1996; Ip, 1998; Combs & Gray, 1998). The results of the Nutritional Prevention of Cancer (NPC) trial (Clark *et al.* 1996, 1998) showed that Se supplementation of non-deficient subjects could be effective in reducing cancer risk in a randomized, double-blind, placebo-controlled trial. Those results showed that the use of a daily oral supplement of Se (200 μg Se/d in the form of Se-enriched yeast) was associated with significantly lower incidences of total non-skin cancers (37 % less), total carcinomas (45 % less) and cancers of the prostate (63 % less), colon-rectum (58 % less) and lung (46 % less), as well as mortality due to lung (53 % less) and total cancers (50 % less). Nevertheless, the supplement did not affect risks of recurrent basal or squamous cell carcinomas in that high-risk population. Other clinical intervention trials conducted in China have also showed reductions in risks of cancers of the liver (Yu *et al.* 1997) and oesophagus (Blot *et al.* 1993; Li *et al.* 1993) associated with Se supplementation. Thus, it is now widely accepted that high-level exposure to at least some Se compounds can be anti-tumourigenic.

The anti-tumourigenic effects in experimental carcinogenesis models have been consistently associated with supranutritional intakes of Se, that is, levels at least 10-fold those required to prevent clinical signs of Se deficiency. On a unit body weight basis (about 100 μg/kg body weight for rodents), they are also much greater than those experienced by most people worldwide, which tend to be much less than 100 μg/d (or 1–4 μg/kg body weight for adult humans). That the known SeCys-proteins appear to be expressed maximally in animal tissues at dietary levels no greater than 0·5 μg Se/kg has led to the current belief that the anti-carcinogenic effects of such higher levels of Se are not likely to be related to these proteins (Combs & Gray, 1998; Combs & Clark, 1999). Instead, Se-anticarcinogenesis is thought to be due to the production of Se metabolites, probably methylselenol (CH_3SeH; Fig. 1) (Ip, 1998; Ganther, 1999; Ip *et al.* 2000*b*,*c*), functioning to enhance carcinogen metabolism, affect gene expression, enhance immune surveillance, alter cell cycling, promote apoptosis and inhibit neo-angiogenesis (Combs & Lü, 2001). The results of the Nutritional Prevention of Cancer trial (Clark *et al.* 1996, 1998) offer some insight into the Se intakes necessary to support the production of effective levels of such anticarcinogenic metabolites. Subjects entering that trial with plasma Se levels in the cohort's lower tertiles (<106 μg/l and 106–121 μg/l respectively) had higher rates of subsequent cancer and also showed the strongest protective effects of Se supplementation (Clark *et al.* 1998). This might suggest that plasma Se levels about 120 μg/l may be a useful target value for minimizing cancer risk, or at least a useful upper level criterion for eligibility for future cancer prevention trials. Using the relationship of blood Se and Se intake established by Yang *et al.* (1989*b*), correcting for differences in the average body weights of their subjects (estimated to be 60 kg) and those in the Nutritional Prevention of Cancer trial (77 kg), and assuming similar fractional intakes of selenomethionine (SeMet) and related compounds in the foods consumed in the two studies, it would appear that dietary Se intakes of at least 1·5 μg/kg body weight per d are required to support the plasma Se concentrations at the 120 μg/l level.

Selenosis

Only a few cases of human exposure to hazardous levels of Se have been reported. Most of these have involved occupational exposures (e.g. workers in Cu smelters or Se-rectifier plants) due to the inhalation of Se-containing aerosols; some have involved the accidental oral consumption of various inorganic Se compounds (Combs & Combs, 1986*d*; Lombeck *et al.* 1987*b*; Gasmi *et al.* 1997). There has been one instance in which an over-the-counter supplement was erroneously formulated with excessive Se. These cases have demonstrated that acute exposure to high levels of Se can produce hypotension (resulting from vasodilation), respiratory distress and a garlic-like odour of the breath (due to the exhalation of $(CH_3)_2Se$ (Fig. 1), signs that reversed upon return to nutritional intakes of the element.

Chronic selenosis was identified in the 1960s among residents of Enshi County, Hubei Province, China, apparently resulting from exceedingly high concentrations of Se in the local food supplies and, in fact, throughout that local environment (Yang *et al.* 1983, 1989*a*,*b*; Liu & Li, 1987; Yang & Zhou, 1994). Local soils were found to contain nearly 8 mg Se/kg, and coal (the ash of which was used to amend the soil) contained as much as 84 g Se/kg. Consequently, locally produced foods contained the highest concentrations of Se ever reported: corn 6·33 mg Se/kg; rice 1·48 mg Se/kg. Even the water, which leached through seleniferous coal seams, contained unusually high concentrations of Se (e.g. 0·054 mg Se/l). In the five most heavily affected villages, morbidity was about 50 %. Almost all residents showed signs the most common of which were losses of hair and nails. Some also showed skin lesions (e.g. erythema, oedema, eruptions, intense itching), hepatomegaly, polyneuritis (e.g. peripheral anaesthesia, acroparesthesia, pain in the extremities, convulsions, partial paralysis, motor impairment, hemiplegia) and gastrointestinal disturbances. One death was attributed to selenosis, although a post-mortem examination was not made. In a village with a history of these signs and symptoms, it was estimated that local residents consumed 3200–6690 μg Se/person per day, i.e. 100 times the nutritionally significant level. The World Health Organization (1996) estimate of the upper safe limit of Se intake, 400 μg/d for an adult, is very likely to be too conservative, as it was derived arbitrarily by using one-half the estimate made by Yang *et al.* (1989*b*) for the same purpose. A review by the United States Environmental Protection Agency (Poirier, 1994), using the Enshi County study of Yang *et al.* (1989*a*,*b*) as the reference case, concluded that no adverse effects were observed among individuals with blood Se concentrations as great as 1000 μg/l, with a no adverse effect intake level for an adult of 853 μg Se/d.

Enhancing selenium in food systems

It is clear that the food systems of most populations do not currently provide enough Se to support the maximal expression of the SeCys-enzymes. It can, thus, be assumed that many individuals have compromised protection from oxidative stress, which increases their risks to various chronic diseases, including those of the heart and lungs, as well as cancer. Su and Lu (Q Su and ZH Lu, personal communication) have estimated that in China alone some 400 million people fall into this low-Se category. To minimize such risks, food systems need to provide at least 40 μg Se/d (per adult), and recent data on cancer prevention would suggest a goal of 200–300 μg Se/d. (This range is derived from the results of the Nutritional Prevention of Cancer (NPC) trial (Clark *et al.* 1996, 1998). It is important to note that such intakes are comfortably within the estimated range of safe Se exposure (Combs, 1994). LC Clark, GF Combs and BW Turnbull (unpublished results) studied 424 healthy, older Americans given either a placebo or 400 μg Se/d for several years. Plasma Se levels of the Se-supplemented group increased from the baseline level (120 μg/l) to >250 μg/l within 9–12 months; however, no abnormalities were observed in either clinical chemical variables, dermatological evaluations or patient-reported signs. These results indicate that this level of supplementation was safe for individuals consuming an additional 80–100 μg Se/d from dietary sources.) In order to support Se intakes at the lower, nutritional, level, changes will be needed in many food systems; in order to support higher, supra-nutritional, intakes of Se changes will be needed in almost all food systems.

Se is appropriately considered among the resource inputs to food systems. In this view, seleniferous areas become resources to the extent that they can be exploited for the production of Se-enriched plants. This approach is being used in China to produce a Se elixir from high-Se tea grown in Enshi County, Hubei Province. In non-seleniferous areas, Se fertilization has been an effective means of increasing the Se contents of crops (Mäkelä *et al.* 1993; Gissel-Nielsen, 1998; Chen, 1999). In 1984, the use of Se fertilizers was initiated on a national scale in Finland, dramatically increasing the Se contents of most foods, to increase dietary Se intakes four-fold and nearly double plasma or serum Se concentrations of the study population (Mäkelä *et al.* 1993; Aro & Alfthan, 1998). In the Se-reducing soils of Finland, this was accomplished without substantial apparent run-off of oxidized species of Se into lakes and streams (Lahermo *et al.* 1998); however, in TN, USA, the use of Se fertilizers caused run-off of the element, resulting in its accumulation in the aquatic biota (Maier *et al.* 1998). Se fertilization has also been used in low-Se areas to prevent Se deficiency in grazing livestock (Allaway *et al.* 1966; Watkinson, 1987); but the approach can also lend itself to the production of meat and milk with enhanced Se contents. Otherwise, these ends can be achieved through the use of Se supplements to livestock feeds; in many countries, this practice has become common in commercial livestock production in order to prevent Se-deficiency disorders.

In response to the need for Se to support human health, the element has become a focus of 'functional food' development (Reilly, 1998) using many of these approaches. Se-enriched foods of several types have been developed in recent years. This included several produced using Se compounds as direct fortificants: Se-fortified table salt (Wen *et al.* 1987; Xu *et al.* 1996; Yu *et al.* 1997), Se-fortified margarine (He, 1996), Se-fortified cereal gruel (Cao *et al.* 1997) and several se-fortified beverages. It has also included foods enriched in Se by various Se-fertilization and/or feeding techniques: high-Se Brussels sprouts (Stoewsand *et al.* 1989), high-Se broccoli (Finley, 1999), other high-Se Brassica vegetables (Kopsell & Randall, 1999), high-Se garlic (Ip *et al.* 1992; Ip & Lisk, 1994; Duan & Fu, 1997), high-Se onions (Ip *et al.* 1992), high-Se celery (Lee & Park, 1999), high-Se mint (Sekulovic *et al.* 1996), high-Se chamomille (Sekolovic *et al.* 1996), Se-containing tea (Hu & Ding, 1998), high-Se vinegar (Sune & Zhou, 1997), high-Se beer (Liu, 1997), high-Se yeasts (Golubkina *et al.* 1996; Hegoczki *et al.* 1997; Liou *et al.* 1998; Kyriakopoulos *et al.* 1998; Demirci & Pometto, 1999; Yoshida *et al.* 1999), high-Se mushrooms (Huang *et al.* 1997; Q Su and ZH Lu, personal communication), and high-Se mussels (Mao *et al.* 1997). To date there would appear to have been little attention given to possibilities of breeding for enhanced Se-uptake and/or retention by plants, although Wei (1996) was able to select a Se-accumulating cultivar of soyabean, and preliminary studies of RM Welch and GF Combs Jr (unpublished results) point to that possibility within the family of Brassica vegetables, which they found to vary in Se contents by at least 15-fold. Such findings would suggest that it should be possible to breed Se-efficient cultivars or to use genetic engineering to enhance specific Se metabolites in these or other common foods.

Efforts to optimize Se in foods should consider both the amounts as well as chemical form(s) of the element to be provided. While selenite or selenate can be effective as feed supplements to prevent Se deficiency in livestock, those forms have quite limited impacts on the Se contents of meats, milk and eggs because each can be retained only by being incorporated into the SeCys-containing proteins. Much greater tissue Se levels can be achieved using a source of SeMet as a feed supplement, as that selenoamino acid is readily incorporated into the general synthesis of tissue proteins. Plants can use either selenite or selenate to synthesize both SeMet and SeCys each of which they can incorporate non-specifically into proteins in their edible tissues (Stadtman, 1996). Those food-plant species with the greatest potential for accumulating Se would be those that naturally contain large amounts of S-amino acids, e.g. the Allium and Brassica vegetables. In contrast, lactic acid bacteria can take up inorganic selenium oxides transforming that Se only to SeCys, which is incorporated into proteins (Calomme *et al.* 1995*a*,*b*).

In order to enhance the contents in foods of proximal precursors of the putative anti-tumourigenic methylated Se-metabolites, it will be necessary to understand the speciation of Se in plant and animal tissues. To date, there has been very little work in this area. Only a few analytical groups have approached the speciation of Se in foods; these have worked with such high-Se foods as a commercial Se-enriched bakers' yeast (Saccharomyces cervisiae) product (Bird *et al.* 1997; Casiot *et al.* 1999; Ip *et al.* 2000*a*; Kotrebai *et al.* 2000*a*,*b*), Se-enriched garlic (Cai *et al.* 1994; Ip *et al.* 2000*a*), other high-Se Allium vegetables (Cai *et al.* 1995), and mushrooms (Slejkovec *et al.* 2000). These studies indicate these foods can differ with respect to their predominant Se constituents; for example SeMet appears to be the dominant form of Se in Se-enriched yeast, while γ-glutamyl-Se-methylselenocysteine is the dominant one in Se-enriched garlic (Ip *et al.* 2000*a*).

Studies of Se-enriched yeast products are of special relevance in as much as such a form of Se was found effective in reducing cancer risk in the Nutritional Prevention of Cancer trial (Clark *et al.* 1996). To date, results have been reported for only one product (Bird *et al.* 1997; Ip *et al.* 2000*a*; Kotrebai *et al.* 2000*a*,*b*), indicating that virtually all of its Se is protein-bound in several forms that are relevant to cancer prevention in different ways. Selenomethionine appears to comprise at least 65 % of total Se. The remainder includes SeCys, which like SeMet is metabolized to potentially anti-carcinogenic H2Se pool (Lü *et al.* 1994), as well as a smaller amount of Se-methylselenocysteine, which is a proximal metabolic precusor of the putative anti-carcinogenic metabolite methylselenol (Ip & Ganther, 1990, 1993; Ip *et al.* 2000*b*). Without similar compositional information for similar products, and with no standards of product identity for Se-enriched yeast, it is not clear whether these findings describe general characteristics of Se-enriched yeasts or specific traits of the particular product studied. This sort of speciation information will be needed for other foods, as optimization of Se should undertake not merely to increase total Se contents, but to achieve the specific enrichment of Se-compounds most directly associated with health benefits.

Consumer acceptance of enhanced-Se foods will also call for efforts to increase the salience of Se–health relationships. This will involve the delivery of scientifically sound information as part of food marketing, the inclusion of Se content information on food labels, and the establishment of quality control procedures to minimize risks of Se overexposure and to ensure delivery of known forms of the element.

Conclusion

Se is essential for a number of enzymes that perform important metabolic functions necessary for good health. A mineral element, Se enters food systems from soils, and there is ample evidence to indicate that the world's soils vary considerably with respect to their contents of biologically available Se. As a consequence, people in many countries do not appear to consume adequate amounts of Se to support the maximal expression of the Se enzymes. It would be difficult to quantify the total number of Se-deficient people in the world; but that number would very likely be in the range of 500–1000 million. In the most extreme cases, severe Se deficiency is now recognized to be a predisposing factor to certain kinds of heart disease, chondrodystrophies and I-deficiency disorders. The vast majority of people appear to be Se undernourished to lesser, i.e. subclinical, degrees. In consequence, they may experience the potentiation of viral diseases (e.g. measles, hepatitis, influenza and HIV–AIDS); and enhanced susceptibility to oxidative stresses associated with infection, inflammation and exposure to environmental pollutants. At the same time, supranutritional intakes of Se have emerged as a prospective means of reducing cancer risk. For several reasons, therefore, it is in the public health interest of many countries to develop effective and sustainable ways of increasing Se intakes.

References

Aaseth J, Aadland E & Thomassen Y (1987) Serum selenium in patients with short bowel syndrome. In *Selenium in Biology and Medicine*, vol. B, pp. 976–980 [GF Combs Jr, JE Spallholz, OA Levander and JE Oldfield, editors]. Westport, CN: AVI Publishing Co.

Abdullev GM (1976) Selenium levels in healthy subjects and those with certain haematological diseases. *Selen v Biologii* **1**, 136–139.

Ahlrot-Westerlund B, Plantin LO, Savic I, Siden A & Svensson J (1987) Selenium in plasma, erythrocytes, and platelets from patients with multiple sclerosis. In *Selenium in Biology and Medicine*, vol. B, pp. 981–984 [GF Combs Jr, JE Spallholz, OA Levander and JE Oldfield, editors]. Westport, CN: AVI Publishing Co.

Aihara K, Nishi Y, Hatano S, Kihura M, Yoshimitsu K, Takeichi N, Ito T, Ezaki H & Usui T (1984) Zinc, copper, manganese and selenium metabolism in thyroid disease. *American Journal of Clinical Nutrition* **40**, 26–35.

Åkesson B & Johansson U (1987) Selenium status in patients with liver cirrhosis. In *Selenium in Biology and Medicine*, vol. B, pp. 968–975 [GF Combs Jr, JE Spallholz, OA Levander and JE Oldfield, editors]. Westport, CN: AVI Publishing Co.

Alegria A, Barbera R, Farre R, Ferrer E, Legarda MJ & Torres MA (1998) Optimization of selenium determination in human milk and whole blood by flow injection hydride atomic absorption spectrometry. *Journal of the Association of Analytical Chemists International* **81**, 457–461.

Alfthan G (1988) Longitudinal study on the selenium status of healthy adults in Finland during 1975–1984. *Nutrition Research* **8**, 467–476.

Alfthan G, Aro A, Arvilommi H & Huttunen JK (1991) Selenium metabolism and platelet glutathione peroxidase activity in health Finnish men: effects of selenium yeast, selenite, and selenate. *American Journal of Clinical Nutrition* **53**, 120–125.

Alfthan G, Bogye G, Aro A & Feher J (1992) The human selenium status in Hungary. *Journal of Trace Elements and Electrolytes in Health and Disease* **6**, 233–238.

Allan CB, Lacourciere GM & Stadtman TC (1999) Responsiveness of selenoproteins to dietary selenium. *Annual Reviews of Nutrition* **19**, 1–16.

Allard JP, Aghdassi E, Chau J, Salit I & Walmsley S (1998) Oxidative stress and plasma antioxidant nutrients in humans with HIV infection. *American Journal of Clinical Nutrition* **57**, 143–147.

Allaway WH, Cary EE & Ehlig CF (1967) The cycling of low levels of selenium in soils, plants and animals. In *Selenium in Biomedicine*, pp. 273–296 [OH Muth, JE Oldfield and PH Weswig, editors]. Westport, CN: AVI Publishing Co.

Allaway WH, Kubota J, Losee F & Roth M (1968) Selenium, molybdenum and vanadium in human blood. *Archives in Environmental Health* **16**, 342–348.

Allaway WH, Moore DP, Oldfield JE & Muth OH (1966) Movement of physiological levels of selenium from soils to plants to animals. *Journal of Nutrition* **88**, 411–418.

Anttolainen M, Valsta LM, Alfthan G, Keemola P, Salminen I & Tamminen M (1996) Effect of extreme fish consumption on dietary and plasma antioxidant levels and fatty acid composition. *European Journal of Clinical Nutrition* **50**, 741–746.

Arnaud J, Favier A, Zarski JP, Rachall M, Labadie H & Beaugrand M (1988) Serum selenium in alcoholic disease. In *Selenium in Medicine and Biology*, pp. 273–276 [J Nève and A Favier, editors]. New York, NY: de Gruyter.

Arnaud J, Prual A, Preziosi P, Cherouvrier F, Favier A, Galan P & Hercberg S (1993) Effect of iron supplementation during pregnancy on trace element (Cu, Se, Zn) concentrations in serum and breast milk from Nigerian women. *Annals of Nutrition and Metabolism* **37**, 262–271.

Aro A & Alfthan G (1998) Effects of selenium supplementation of fertilizers on human nutrition and selenium status. In *Environmental Chemistry of Selenium*, pp. 81–97 [WT Frankenberger Jrand RA Engberg, editors]. New York, NY: Marcel Dekker.

Aro A, Alfthan G & Varo P (1989) Se supplementation of fertilizers has increased the Se intake and serum-Se concentration of Finnish people. In *Selenium in Biology and Medicine*, pp. 242–245 [A Wendel, editors]. New York: Springer-Verlag.

Aro A, Alfthan G & Varo P (1995) Effects of supplementation of fertilizers on human selenium status in Finland. *Analyst* **120**, 841–843.

Aro A, Kumpulainen J, Alfthan G, Voshenko A & Ivanov V (1994) Factors affecting the selenium intake of people in Transbaikalian Russia. *Biological Trace Elements Research* **40**, 277–285.

Arthur JR, Nicol F & Beckett GJ (1993) Selenium deficiency, thyroid hormone metabolism, and thyroid hormone deiodinases. *American Journal of Clinical Nutrition* **57**, 236S–239S.

Arvilommi H, Poikonen L, Jokinen I, Muukkonen O, Rasenen L, Foreman J & Huttenen JK (1983) Selenium and immune functions in humans. *Infection and Immunology* **41**, 185–189.

Ashour MN, Salem SI, El-Gadban HM, Elwan NM & Basu TK (1999) Antioxidant status in children with protein–calorie malnutrition (PEM) living in Cairo, Egypt. *European Journal of Clinical Nutrition* **52**, 669–673.

Aursnes I, Smith PB, Arnesen H & Åkesson B (1988) Correlation between plasma levels of selenium and antithrombin-III. *European Journal of Haematology* **40**, 7–11.

Azzini M, Girelli D, Olivieri O, Guarini P, Stanzial AM, Frigo A, Milanino R, Bambara LM & Carrocher R (1995) Fatty acids and antioxidant micronutrients in psoriatic arthritis. *Journal of Rheumatology* **22**, 103–108.

Backovic D, Marinkovic J, Jorga J, Pavlica M, Maksimovic Z & Nikolic M (1999) Environmental factors, health-related habits, and serum selenium levels in cancer patients and healthy controls. *Biological Trace Elements Research* **67**, 55–62.

Barclay MNI, MacPherson A & Dixon J (1995) Selenium content of a range of UK foods. *Journal of Food Composition and Analysis* **8**, 307–318.

Barrington JW, Lindsay P, James D, Smith S & Roberts A (1996) Selenium deficiency and miscarriage: a possible link? *British Journal of Obstetrics and Gynaecology* **103**, 130–132.

Beck MA (1997) Rapid genomic evolution of a non-virulent Coxsackievirus B3 in selenium-deficient mice. *Biomedical and Environmental Science* **10**, 307–315.

Beck MA, Kolbeck PC, Rohr LH, Morris VC & Levander OA (1994*a*) Benign human enterovirus becomes virulent in selenium-deficient mice. *Journal of Medical Virology* **43**, 166–170.

Beck MA, Kolbeck PC, Shi Q, Rohr LH, Morris VC & Levander OA (1994*b*) Increased virulence of a human enterovirus (Coxsackievirus B3) in selenium-deficient mice. *Journal of Infectious Diseases* **170**, 351–357.

Beck MA, Shi Q, Morris VC & Levander OA (1995) Rapid genomic evolution of a non-virulent Coxsackievirus B3 in selenium-deficient mice results in selection of identical virulent isolates. *Nature Medicine* **1**, 433–436.

Beguin Y, Bours V, Delbrouck JM, Robave G, Roelands I, Bury J, Fillet G & Weber G (1989) Relationship of serum selenium levels to tumor activity in acute and non-lymphocytic leukemia. *Carcinogenesis* **10**, 2089–2091.

Behne D, Kyriakopoeulos A, Weiss-Nowak C, Kalckloesch M, Westphal C & Gessner H (1996) Newly found selenium-containing proteins in the tissues of the rat. *Biological Trace Elements Research* **55**, 99–110.

Behne D & Wolters W (1979) Selenium content and glutathione peroxidase activity in the plasma and erythrocytes of non-pregnant and pregnant women. *Journal of Clinical Chemistry and Clinical Biochemistry* **17**, 133–135.

Bellisola G, Perona G, Galassini S, Moschini G & Guidi GC (1993) Plasma selenium and glutathione peroxidase activities in individuals living in the Veneto region of Italy. *Journal of Trace Elements and Electrolytes in Health and Disease* **7**, 242–244.

Beker D, Romíc Z, Kršnjavi H & Zima Z (1992) A contribution to the world selenium map. *Biological Trace Elements Research* **33**, 43–49.

Benemariya H, Robercht H & Deestra H (1993) Daily dietary intake of copper, zinc and selenium by different population groups in Burundi, Africa. *Science of the Total Environment* **136**, 49–76.

Bergmann S, Neumeister V, Siekmeier R, Mix C, Wahrburg U & Jaross W (1998) Food supply abundant increase of serum selenium concentrations in middle-aged Dresden women between 1990 and 1996. *Toxicology Letters* **96 – 97**, 181–187.

Berry MJ, Bannu L, Harney JW & Larsen PR (1993) Functional characterization of the eukaryotic SECIS elements which direct selenocysteine insertion at UGA codons. *EMBO Journal* **12**, 3315–3322.

Bibow K, Meltzer H, Holm H & Norheim G (1989) Blood selenium levels of Norwegians compared to their Se intakes. In *Selenium in Biology and Medicine*, pp. 234–237 [A Wendel, editors]. New York, NY: Springer-Verlag.

Bibow K, Meltzer H, Mundal H, Paulsen I & Holm H (1993) Platelet selenium as indicator of wheat selenium intake. *Journal of Trace Elements and Electrolytes in Health and Disease* **7**, 171–176.

Bird SM, Uden PC, Tyson JF, Block E & Denoyer E (1997) Speciation of selenoamino acids and organoselenium compounds in selenium-enriched yeast using high-performance liquid chromatography-inductively coupled mass spectrometry. *Journal of Analytical Atomic Spectrometry* **12**, 785–788.

Bjørneboe G, Johnson J, Bjørneboe A, Bach-Wiig J, Mørland J &

Drevon CA (1988) Diminished serum concentration of vitamin E in alcoholics. *Annals of Nutrition and Metabolism* **32**, 56–61.
Blot WJ, Li JY, Taylor PR, Guo W, Dawsey S, Wang GQ, Yang CS, Zheng SF, Gail M, Li GY, Liu BQ, Tangrea J, Sun YH, Liu F, Fraumeni F Jr, Zhang YH & Li B (1993) Nutrition intervention trials in Linxian, China: supplementation with specific vitamin/mineral combinations, cancer incidence, and disease-specific mortality in the general population. *Journal of the National Cancer Institute* **85**, 1483–1490.
Bonomini M, Forster S, Manfrini V, De Risio F, Steiner MI, Vidovich MI, Klinkmann H, Ivanovich P & Albertazzi A (1996) Geographic factors and plasma seleniumin uremia and dialysis. *Nephron* **72**, 197–204.
Bonomini M, Manfrini V, Marini A, De Risio F, Niri L, Klinkmann H & Albertazzi A (1995) Hemodialysis with regenerated cellulosic membrane does not reduce plasma selenium levels in chronic uremic patients. *Artificial Organs* **19**, 81–85.
Borglund M & Åkesson B (1987) Effect of selenium supplementation on the distribution of selenium in plasma proteins of healthy subjects. *International Journal of Vitamin and Nutrition Research* **58**, 97–102.
Bortoli A, Fassin G, Marchiori M, Mellow R, Brugiolo R & Martelli F (1990) Selenium status and effects of selenium supplementation in a group of elderly women. *Journal of Trace Elements and Electrolytes in Health and Disease* **5**, 19–21.
Bratakos MS & Ioannou P (1989) The regional distribution of selenium in Greek cereals. *Science of the Total Environment* **84**, 237–247.
Bratakos MS, Kanaki H, Vasiliov-Waite A & Ioannou P (1990*a*) The nutritional selenium status of healthy Greeks. *Science of the Total Environment* **96**, 161–176.
Bratakos MS, Vouterakos TP & Ioannou PV (1990*b*) Selenium status of cancer patients in Greece. *Science of the Total Environment* **92**, 207–222.
Brätter P, Negretti V, Rosick V, Jaffé W, Menez H & Tovar G (1984) Effect of selenium intake in man at high dietary levels of seleniferous areas of Venezuela. In *Trace Element Analytical Chemistry in Medicine and Biology*, vol. 3, pp. 29–46 [P Brätter and P Schramel, editors]. New York, NY: de Gruyter.
Bro S, Berendtsen H, Norgaard J, Host A & Norgensen P (1988) Serum selenium concentration in maternal and umbilical cord blood. Relation to course and outcome and pregnancy. *Journal of Trace Elements and Electrolytes in Health and Disease* **2**, 165–169.
Brtková A, Magálová T, Babinská K & Béderová A (1994) Serum selenium levels in Slovak population. *Biological Trace Elements Research* **46**, 163–171.
Brune D, Samsahl K & Wester PO (1996) A comparison between the amounts of As, Au, Br, Cu, Fe, Mo, Se and Zn in normal and uraemic human whole blood by means of neutron activiation analysis. *Clinica Chimica Acta* **13**, 285–291.
Bukkens S, de Vos N, Kok F, Schouten E, de Bruijin A & Hofman A (1990) Selenium status and cardiovascular risk factors in healthy Dutch subjects. *Journal of the American College of Nutrition* **9**, 128–135.
Burguera J, Burguera M, Gallignani M, Alarcon O & Burguera J (1990) Blood serum selenium in the province of Merida, Venezuela, related to sex, cancer incidence and soil selenium content. *Journal of Trace Elements and Electrolytes in Health and Disease* **4**, 73–77.
Burk RF (1986) Selenium and cancer: meaning of serum selenium levels. *Journal of Nutrition* **116**, 1584–1586.
Burk KE, Bedford RG, Combs GF Jr, French I & Skeffington DR (1992) The effect of topical L-selenomethionine on minimal erythema dose of ultraviolet irradiation in humans. *Photodermatology, Photoimmunology Photomedicine* **9**, 1–6.
Burk RF, Pearson WN, Wood RP & Viteri F (1967) Blood selenium levels and in vitro red blood cell uptake of 75Se in kwashiorkor. *American Journal of Clinical Nutrition* **20**, 723–733.
Burrini C, Ghinassi A, Borghi G & Fuzzi G (1993) Determination of normal levels of selenium in blood serum by GFAAS. *Giornale Ital in Chimica Clinica* **18**, 27–33.
Butler J, Thomson C, Whanger P & Robinson M (1991) Selenium distribution in blood fractions of New Zealand women taking organic or inorganic selenium. *American Journal of Clinical Nutrition* **53**, 748–754.
Cai XJ, Uden PC, Block E, Zhang X, Sullivan JJ & Quimby BD (1994) Allium chemistry: identification of natural abundance organoselenium compounds volative from garlic, elephant garlic, onions, Chinese chives by headspace gas chromatography with atomic emission detection. *Journal of Agricultural and Food Chemistry* **42**, 2081–2084.
Cai XJ, Block E, Uden PC, Zhang X, Sullivan JJ & Quimby BD (1995) Allium chemistry: identification of selenoamino acids in ordinary and selenium-enriched garlic, onion and broccoli using gas chromatography with atomic emission detection. *Journal of Agricultural and Food Chemistry* **43**, 1754–1757.
Calautti P, Moschine G, Stievano BM, Tomio L, Calzarava F & Perona G (1980) Serum selenium levels in malignant lymphoproliferative diseases. *Scandinavian Journal of Haematology* **23**, 63–66.
Calomme M, Hu J, van den Branden K & van den Berghe DA (1995*a*) Seleno-Lactobaccillus. An organic selenium source. *Biological Trace Elements Research* **47**, 379–383.
Calomme M, van den Branden K & Van den Berghe DA (1995*b*) Selenium and Lactobaccillus species. *Journal of Applied Bacteriology* **79**, 331–340.
Cao Y, Liu H, Xiang C & Zhou X (1997) Preparation of instant gruel for selenium supplement. *Faming Sheqing Gongkai Shoumingshu* CN, 1,135,850. Cl. A23L1/164.
Casaril M, Stanzial AM, Menini C, Olivieri O, Girelli D, Corso F, Gandini G, Pinto F & Corrocher R (1995) Serum selenium in a healthy population in the Venetian region: relationships with age, sex, weight and alcohol intake. *European Journal of Medicine* **3**, 35–39.
Casiot C, Vacchina V, Chassaigne H, Szpunar J, Potin-Gautier M & Lobinski R (1999) An approach to the identification of selenium species in yeast extracts using pneumatically-assisted electrospray tandem mass spectrometry. *Analytical Communications* **36**, 77–80.
Ceballos-Picot I, Merad-Boudia M, Nicole A, Thevenin M, Hellier G, Legrin S & Berr C (1996) Peripheral antioxidant enzyme activities and selenium in elderly subjects and in dementia of Alzheimer's type-place of the extracellular glutathione peroxidase. *Free Radicals in Biology and Medicine* **20**, 579–587.
Cenac A, Simonoff M, Moretto P & Djibo A (1992) A low plasma selenium is a risk factor for peripartum cardiomyopathy: A comparative study in Sahelian Africa. *International Journal of Cardiology* **36**, 57–59.
Chaitchik S, Shenberg C, Nir-El Y & Mantel M (1988) The distribution of selenium in human blood samples of Israeli population-comparison between normal and breast cancer cases. *Biological Trace Elements Research* **15**, 205–212.
Chen CK, Liaw JM, Juang JC & Lin TH (1997) Antioxidant enzymes and trace elements in hemodialyzed patients. *Biological Trace Elements Research* **58**, 149–157.
Chen L (1999) Effect of selenium fertilizer on selenium amount and quality of kiwifruit. *Jishou Daxue Xuebao, Ziran Kexueban* **20**, 50–52.
Chou HT, Yang HL, Tsou SS, Ho RK, Pai PY & Hsu HB (1998) Status of trace elements in patients with idiopathic dilated

cardiomyopathy in central Taiwan. *Chug Hua I Hsueh Tsa Chih* **61**, 193–198.

Chu YJ, Liu QY, Hou C & Yu SY (1984) Blood selenium concentration in residents of areas in China having a high incidence of lung cancer. *Biological Trace Elements Research* **6**, 133–137.

Clark LC, Combs GF Jr, Turnbull BW, Slate E, Alberts D, Abele D, Allison R, Bradshaw J, Chalker D, Chow J, Curtis D, Dalen J, Davis L, Deal R & Dellasega M, *et al.* (1996) The nutritional prevention of cancer with selenium 1983–1993: a randomized clinical trial. *Journal of the American Medical Association* **276**, 1957–1963.

Clark LC, Dalkin B, Krongrad A, Combs GF Jr, Turnbull BW, Slate EH, Witherington R, Herlong JH, Janosko E, Carpenter D, Borosso C, Falk S & Rounder J (1998) Decreased incidence of prostate cancer with selenium supplementation: Results of a double-blind cancer prevention trial. *British Journal of Urology* **81**, 730–734.

Clark L, Hixon L, Combs G Jr, Patel N, Reid M & Sampliner R (1993) Plasma selenium concentrations predict the rate of colorectal neoplastic polyps. *Cancer Epidemiology, Biomarkers and Prevention* **2**, 41–46.

Clausen J, Nielsen SA & Kristensen M (1989) Biochemical and clinical effects of an antioxidant supplementation of geriatric patients: A double blind study. *Biological Trace Elements Research* **20**, 135–151.

Combs GF Jr (1989) Selenium. In *Nutrition and Cancer Prevention*, pp. 389–420 [T Moon and M Micozzi, editors]. New York, NY: Marcel Dekker.

Combs GF Jr (1994) Essentiality and toxicity of selenium: a critique of the recommended dietary allowance and the reference dose. In *Risk Assessment of Essential Elements*, pp. 167–183 [W Mertz, CO Abernathy and SS Olin, editors]. Washington, DC: ILSI Press.

Combs GF Jr & Clark LC (1999) Selenium and cancer. In *Nutritional Oncology*, pp. 215–222 [D Heber, GL Blackburn and VLW Go, editors]. New York, NY: Academic Press.

Combs GF Jr & Combs SB (1986*a*) Selenium in the environment. In *The Role of Selenium in Nutrition*, pp. 15–40, New York, NYAcademic Press.

Combs GF Jr & Combs SB (1986*b*) Selenium in foods and feeds. In *The Role of Selenium in Nutrition*, pp. 41–126, New York, NYAcademic Press.

Combs GF Jr & Combs SB (1986*c*) The biological availability of selenium in foods and feeds. In *The Role of Selenium in Nutrition*, pp. 127–177, New York, NYAcademic Press.

Combs GF Jr & Combs SB (1986*d*) Effects of selenium excesses. In *The Role of Selenium in Nutrition*, pp. 463–525, New York, NYAcademic Press.

Combs GF Jr & Gray WP (1998) Chemopreventive agents: selenium. *Pharmacology and Therapeutics* **79**, 179–192.

Combs GF Jr & Lü J (2001) Mechanisms of selenium anticarcinogenesis. *Physiological Reviews* (In the Press).

Coudry C, Roussel A, Arnaud J & Favier A (1997) EVA Study Group Selenium and antioxidant vitamin and lipoperoxidation levels in preaging French population. *Biological Trace Elements Research* **57**, 183–190.

Cser MA, Sziklai-Laszlo I, Menzel H & Lombeck I (1992) Elevated selenium and erythrocyte glutathione peroxidase activities correlate with HDL-cholesterol and triglycerides in juvenile diabetes. *Proceedings of the Fifth International Symposium on Selenium in Biology and Medicine*, Vanderbilt University, p. 127 (abstract).

Cser MA, Sziklai-Laszlo I, Menzel H & Lombeck I (1996) Selenium and glutathione peroxidase activity in Hungarian children. *Journal of Trace Elements in Medicine and Biology* **10**, 167–173.

Cumming F, Fardy JJ & Woodward DR (1992) Selenium and human lactation in Australia: Milk and blood selenium levels in lactating women and selenium intakes of their breast-fed infants. *Acta Paediatrica Scandinavica* **81**, 292–295.

Damyanova AA, Akanle OB & Spyrov M (1987) Changes in the elemental content of blood components by selenium supplementation in humans. *Journal of Radioanalytical and Nuclear Chemistry* **113**, 431–436.

Darling G, Mathias P, O'Regan M & Naughten E (1992) Serum selenium levels in individuals on PKU diets. *Journal of Inherited Metabolic Disease* **15**, 769–773.

Darlow BA, Inder TE, Graham PJ, Sluis KB, Malpas TJ, Taylor BJ & Winterborn CC (1995) The relationship of selenium status to respiratory outcome in the very low birth weight infant. *Pediatrics* **96**, 314–319.

Dastych M, Koutnik V & Docekalova H (1997) Selenium in human and food chain in south Moravian region. *Klinische Biochemishe und Metabolism* **5**, 233–236.

Demirci A & Pometto AL (1999) Production of organically bound selenium yeast by continuous fermentation. *Journal of Agriculture and Food Chemistry* **47**, 2491–2495.

Dhindsa HS, Bergmingham MA, Mierzwa J & Sullivan D (1998) Plasma selenium concentrations in a Sikh population in Sydney, Australia. *Analyst* **123**, 885–887.

Dickson R & Tomlinson R (1967) Selenium in blood and human tissues. *Clinica Chimica Acta* **16**, 311–321.

Djujic I, Djujic B & Trajkovic L (1995) Dietary intake of selenium in Serbia: results for 1991. *Naucni Skupovi (Srpska Akademija Nauka i Umetnosti). Odeljenje Prirodno-Matematickih Nauka* **6**, 81–87.

Drobner C, Röhrig B, Anke M & Thomas G (1997) Selenium intake of adults in Germany depending on sex, time, living area and type of diet. In *Trace Elements in Man and Animals-9*, pp. 158–159 [PWF Fischer, MR L'Abbé, KA Cockell and RS Gibson, editors]. Ottawa: NRC Research Press.

Duan Y & Fu T (1997) Absorption of Se by garlic and effects of Se on growth of garlic. *Guangdong Weiliang Yuansu Kexue* **4**, 52–55.

Dubois F, Nicholas B, Hoffman R, Belleville F, Paysant P, Kessler M, Jonon B & Cao-Huu T (1988) Blood selenium, glutathione peroxidase and cadmium in chronic renal failure patients. In *Selenium in Medicine and Biology*, pp. 289–292 [J Nève and A Favier, editors]. New York, NY: de Gruyter.

Ducros V, Faure P, Ferry M, Couzy F, Biajoux I & Favier A (1997) The sizes of the exchangeable pools of selenium in elderly women and their relation to institutionalization. *British Journal of Nutrition* **78**, 379–396.

Duffield AJ & Thomson CD (1999) A comparison of methods of assessment of dietary selenium intakes in Otago, New Zealand. *British Journal of Nutrition* **82**, 131–138.

Dutta SK, Miller PA, Greenberg LB & Levander OA (1983) Selenium and acute alcoholism. *American Journal of Clinical Nutrition* **38**, 713–718.

Dworkin B, Newman LJ, Berezin S, Rosenthal WS, Schwarz SM & Weiss L (1987) Low blood selenium levels in patients with cystic fibrosis compared to controls and healthy adults. *Journal of Parenteral and Enteral Nutrition* **11**, 38–41.

Dworkin BM & Rosenthal WS (1984) Selenium and the alcoholic. *Lancet* **31**, 1015–1022.

El-Amri FA, El-Saltani HA, Dogadkin NN & Ashour IA (1994) Determination of trace elements in normal and diabetic whole blood by neutron activation analysis. *Biological Trace Elements Research* **43–45**, 383–388.

El-Bayoumy K (1991) The role of selenium in cancer prevention. In *Practice of Oncology*, 4th ed., pp. 1–15 [VT DeVita, S Hellman and SS Rosenberg, editors]. Philadelphia, PA: Lippincott.

Ellis N, Lloyd B, Lloyd RS & Clayton BE (1984) Selenium and vitamin E, in relation to risk factors for coronary heart disease. *Journal of Clinical Pathology* **37**, 200–206.

Ermakov VV (1992) Biogeochemical regioning problems and the biochemical selenium provinces of the former USSR. *Biological Trace Element Research* **33**, 171–185.

Feldman DS & Smith DK (1987) Comparison of selenium status in healthy patients from a low-selenium area with that of multiple sclerosis. In *Selenium in Biology and Medicine*, vol. B, pp. 985–991 [GF Combs Jr, JE Spallholz, OA Levander and JE Oldfield, editors]. Westport, CN: AVI Publishing Co.

Fernandez-Banares F, Dolz C, Mingorance MN, Cabre E, Lachica M, Abda-Lacruz A, Gil A, Estreve M, Gine J & Gassul M (1990) Low serum selenium concentration in a healthy population resident in Catalunya: a preliminary report. *European Journal of Clinical Nutrition* **44**, 225–229.

Ferrer E, Alegria A, Barbera R, Farre R, Lagarda MJ & Monleon J (1999) Whole blood selenium content in pregnant women. *Science of the Total Environment* **227**, 139–143.

Finley JW (1999) The retention and distribution by healthy young men of stable isotopes of selenium consumed as selenite, selenate or hydroponically-grown broccoli are dependent on the isotopic form. *Journal of Nutrition* **129**, 865–871.

Fleming GA (1962) Selenium in Irish soils and plants. *Soil Science* **94**, 28–35.

Fleming GA & Walsh T (1957) Selenium occurrence in certain Irish soils and its toxic effect on animals. *Royal Irish Academy Proceedings* **58**, 151–156.

Fleming C, Lie J, McCall J, O'Brien J, Baille E & Thistle JL (1982) Selenium deficiency and fatal cardiomyopathy in a patient on home parenteral nutrition. *Gastroenterology* **83**, 689–693.

Foote JW, Hinks LJ & Lloyd B (1987) Reduced plasma and white blood cell selenium levels in haemodialysis patients. *Clinica Chimica Acta* **164**, 323–328.

Forrer R, Gautschi K & Lutz H (1991) Comparative determination of selenium in serum of various animal species and humans by means of electrothermal atomic absorption spectrometry. *Journal of Trace Elements and Electrolytes in Health and Disease* **5**, 101–113.

Gambhir JK & Lali P (1996) Blood selenium levels in Indians: Delhi area. *Journal of Clinical Biochemistry* **11**, 148–151.

Ganther HE (1999) Selenium metabolism, selenoproteins and mechanisms of cancer prevention: complexities with thioredoxin reductase. *Carcinogenesis* **20**, 1657–1666.

Gasmi A, Garnier R, Galliot-Guilley M, Gaudillat C, Quartenoud B, Buisine A & Djebbar D (1997) Acute selenium poisoning. *Veterinary and Human Toxicology* **39**, 304–308.

Gebre-Medhin M, Gustavson KH, Gamstorp I & Plantin LO (1985) Selenium supplementation in X-linked muscular dystrophy. *Acta Paediatrica Scandinavica* **74**, 886–890.

Gerber M, Richardson S & Chappuis P (1998) Selenium and other antioxidants in breast cancer. In *Selenium in Medicine and Biology*, pp. 263–266 [J Nève and A Favier, editors]. New York, NY: de Gruyter.

Gibson RS, Martinez O & MacDonald A (1985) The zinc, copper and selenium status of a selected sample of Canadian elderly women. *Gerontology* **40**, 26–30.

Gissel-Nielsen G (1975) Selenium concentration in Danish forage crops. *Acta Agricultura Scandinavica* **25**, 216–220.

Gissel-Nielsen G (1998) Effects of selenium supplementation of field crops. In *Environmental Chemistry of Selenium*, pp. 99–112 [WT Frankenberger Jr and RA Engberg, editors]. New York, NY: Marcel Dekker.

Gladyshev VN, Jeang KT, Wooton JC & Hatfield DL (1998) A new human selenium-containing protein. Purification, characterization and cDNA sequence. *Journal of Biological Chemistry* **273**, 8910–8915.

Glattre E, Thomassen Y, Thoresen S, Haldorsen T, Lund-Larsen P, Theodorsen L & Aaseth J (1989) Prediagnostic selenium in a case-control study of thyroid cancer. *International Journal of Epidemiology* **18**, 45–49.

Golubkina NA (1994) Selenium intake of Briansk region population living in radionuclide-contaminated areas. *Voprosy Pitania* **4**, 3–6.

Golubkina NA (1997) Selenium content in wheat and rye flour of Russia, CSC and Baltic. *Voprosy Pitania* **7**, 17–20.

Golubkina NA & Alfthan GV (1999) The human selenium status in 27 regions of Russia. *Journal of Trace Elements in Medicine and Biology* **13**, 15–20.

Golubkina NA, Baturin AK, Shagova MV & Martinchik AN (1998*a*) Human selenium status in Altay region. *Voprosy Pitania* **8**, 16–18.

Golubkina NA, Mal'tsev G, Bogdanov NG, Vlaskina S, Alekseeva IA & Khotimchenko SA (1995) Selenium status of the inhabitants in the Kaluga region. *Voprosy Pitania* **5**, 13–15.

Golubkina NA, Parfenova EO & Rehsetnik LA (1998*b*) The human selenium status in Irkutsk region. *Voprosy Pitania* **8**, 24–26.

Golubkina NA, Shagova MV & Spirichev VB (1996) Selenium status of different population groups of the Bashkortostan Republic. *Voprosy Pitania* **6**, 3–5.

Golubkina NA, Shagova MV, Spirichev VB, Khristenko PP, Alfthan D, Laaksonsen P, Muratov IM & Vachaeva NN (1992) The selenium content of food products and the blood of inhabitants of Norilsk. *Voprosy Pitania* **2**, 43–45.

Golubkina NA & Sokolov IA (1997) Level of selenium supply for inhabitants of the Northern economic area of Russia. *Gigiena I Sanitariia* **3**, 22–24.

Golubkina NA, Sokolov YA, Hotimchenko SA, Tutelyan VA, Zolotov PA, Olezhko-Ozhevsky YP, Zhminchenko VM, Amanova IY & Mepenzina OL (1996) Selenium-enriched yeast Saccharomyces cerevisiae. *Bioteckhnologiya* **5**, 52–56.

Gondi F, Pantó G, Fehér J, Bogye G & Alfthan G (1992) Selenium in Hungary: The rock-soil-human system. *Biological Trace Elements Research* **35**, 299–306.

Goodwin WJ, Lane HW, Bradford K, Marshall MV, Griffen AC, Geopfert H & Jesse RH (1983) Selenium and glutathione peroxidase in patients with epidermoid carcinoma of the oral cavity and oropharynx. *Cancer* **51**, 110–115.

Grandjean P, Nielsen G, Jorgensen P & Hormer H (1992) Reference intervals for trace elements in blood: significance of risk factors. *Scandinavian Journal of Clinical and Laboratory Investigation* **52**, 321–337.

Griffiths NM & Thomson CD (1974) Selenium in whole blood of New Zealand residents. *New Zealand Medical Journal* **80**, 199–202.

Güneral F & Sunguroğlu (1995) Fluorometric determination of selenium in plasma, erythrocytes and urine. *Tropical Journal of Medical Science* **23**, 151–154.

Guo P, Xu JH, Chang SY, Xu SJ & Wang K (1997) Hydrogen peroxide production in chondrocytes induced by fulvic acid and inhibited by selenium. *Shengwu Huaxue Zazhi* **13**, 103–107.

Guvenoc H, Karataos F & Guvenoc M (1995) Low levels of selenium in mothers and their newborns in pregnancies with a neural tube defect. *Pediatrics* **95**, 879–882.

Hai VD, Thuy DH, Bao DT & Vuong DH (1984) First investigation on blood selenium of Vietnamese. *Reviews in Pharmacology* **24**, 8–11.

Hansen JC, Kromann N, Wulf HC & Albøge K (1984) Selenium and interrelationship with mercury in whole blood and hair in an east Greenlandic population. *Science of the Total Environment* **38**, 33–40.

Hardell L, Danell M, Ängqvist CA, Marklund SL, Fredriksson M, Zakari A & Kjellgren A (1993) Levels of selenium in plasma and glutathione peroxidase in erythrocytes and the risk of breast cancer: A case-control study. *Biological Trace Elements Research* **36**, 99–108.

Hardell L, Degerman A, Tomic R, Marklund SL & Bergors M (1995) Levels of selenium in plasma and glutathione peroxidase in erythrocytes in patients with prostate cancer or benign hyperplasia. *European Journal of Cancer Prevention* **4**, 91–95.

Harrison I, Littlejohn D & Fell GS (1996) Distribution of selenium in human blood plasma and serum. *Analyst* **121**, 189–194.

Hatano S, Aihara K, Nishi Y & Usui T (1985) Trace elements (copper, zinc, manganese, and selenium) in plasma and erythrocytes in relation to dietary intake during pregnancy. *Journal of Pediatric Gastroenterology and Nutrition* **4**, 87–92.

He S (1996) Health margarine containing gamma-linoleic acid and selenium. *Faming Sheqing Gongkai Shoumingshu* CN, 1,126,042. Cl. A23L1/19.

Hegoczki J, Suhajda A, Janzso B & Vereczky G (1997) Yeast enriched with trace elements as a new type of trace element source. *Elelmezesi Ipar* **51**, 338–341.

Hill KE, Lloyd RS, Yang JG, Read R & Burk RF (1991) The cDNA for rat selenoprotein P, contains 10 TGA codons in the open reading frame. *Journal of Biological Chemistry* **266**, 10050–10053.

Hill KE, Xia Y, Åkesson B, Boeglin ME & Burk RF (1996) Selenoprotein P, concentration in plasma is an index of selenium status in selenium-deficient and selenium-supplemented Chinese subjects. *Journal of Nutrition* **126**, 138–145.

Hinks LJ, Inwards KD, Lloyd B & Clayton B (1988) Reduced concentrations of selenium in mild Crohn's disease. *Journal of Clinical Pathology* **41**, 198–201.

Hu X & Ding R (1998) Production of selenium-rich tea in selenium-low plantation. *Turang (Nanjing)* **30**, 31–35.

Huang Y, Yan G, Wang G, Chen Y & Luo Q (1997) Selenium contents in Se-rich mushroom. *Yunnan Daxue Xuebao, Ziran Kexueban* **19**, 341–343.

Hughes K & Ong CN (1998) Vitamins, selenium, iron and coronary heart disease risk in Indians, Malays and Chinese in Singapore. *Journal of Epidemiology Community Health* **57**, 181–185.

Hussein L & Bruggeman J (1999) Selenium analysis of selected Egyptian foods and estimated daily intakes among a population group. *Food Chemistry* **65**, 527–532.

Imai H, Kashiwazaki H, Suzuki T, Kabuto M, Himeno S, Watanabe C, Moji K, Kim SW, Rivera JO & Takemoto TI (1995) Selenium levels and glutathione peroxidase activities in blood in an Andean high-altitude population. *Journal of Nutritional Science and Vitaminology* **41**, 349–361.

Imai H, Suzuki T, Kashiwazaki H, Takemoto T, Izumi T & Moji K (1990) Dietary habit and selenium concentrations in erythrocyte and serum in a group of middle-aged and elderly Japanese. *Nutrition Research* **10**, 1205–1214.

Ip C (1998) Lessons from basic research in selenium and cancer prevention. *Journal of Nutrition* **128**, 1845–1854.

Ip C, Birringer M, Block E, Kotrebai M, Tyson JF, Uden PC & Lisk DJ (2000*a*) Chemical speciation influences comparative activity of selenium-enriched garlic and yeast in mammary cancer prevention. *Journal of Agricultural and Food Chemistry* **48**, 2062–2070.

Ip C & Ganther H (1990*b*) Activity of methylated forms of selenium in cancer prevention. *Cancer Research* **50**, 1206–1211.

Ip C & Ganther H (1993) Novel strategies in selenium cancer chemoprevention research. In *Selenium in Biology and Human Health*, pp. 170–180 [RF Burk and , editor]. New York, NY: Springer-Verlag.

Ip C & Lisk D (1994) Characterization of tissue selenium profiles and anticarcinogenic responses in rats fed natural sources of selenium-rich products. *Carcinogenesis* **15**, 573–576.

Ip C, Lisk DJ & Stoewsand GS (1992) Mammary cancer prevention by regular garlic and selenium-enriched garlic. *Nutrition and Cancer* **17**, 279–286.

Ip C, Thompson HJ, Zhu Z & Ganther HE (2000*c*) In vitro and in vivo studies of methylselenic acid: evidence that a monomethylated selenium metabolite is critical for cancer chemoprevention. *Cancer Research* **60**, 2882–2886.

Iwanier K & Zachara BA (1995) Selenium supplementation enhances the element concentration in blood and seminal fluid but does not change the spermatozoal quality characteristics in subfertile men. *Journal of Andrology* **16**, 441–447.

Iyengar GV (1984) Reference values for elemental concentrations in some human samples of clinical interest: A preliminary evaluation. *Science of the Total Environment* **38**, 125–131.

Jacobson S & Plantin LO (1985) Concentration of selenium in plasma and erythrocytes during total parenteral nutrition in Crohn's disease. *Gut* **26**, 50–54.

Janghorbani M, Xia YM, Whanger PD, Butler JA, Olesik JW & Grunwald E (1999) Effect of dietary selenium restriction on selected parameters of selenium status in men with high lifelong intake. *Journal of Nutrition Biochemistry* **10**, 564–572.

Jiang Y & Xu G (1989) The relativity between some epidemiological characteristics of Kaschin-Beck disease and selenium deficiency. In *Selenium in Biology and Medicine*, pp. 263–269 [A Wendel, editors]. New York, NY: Springer-Verlag.

Jochum F, Terwolbeck K, Meinhold H, Behne D, Menzel H & Lombeck I (1999) Is there any health risk of low dietary selenium supply in PKU-children? *Nutrition Research* **19**, 349–360.

Joint Food Safety and Standards Group (1999) *Food Surveillance Information Sheet: Dietary Intake of Selenium, no. 126*, LondonMinistry of Agriculture, Fisheries and Food.

Judson GJ & Reuter DJ (1998) *Soil Analysis: An Interpretation Manual*, pp. 325–329, UrrbraeSouth Australia Research and Development Institute.

Kadrabová J, Madaric A & Ginter E (1998) Determination of the daily selenium intake in Slovakia. *Biological Trace Elements Research* **61**, 277–286.

Kadrabová J, Madárič A, Kováčiková Z & Ginter E (1995) Selenium status, plasma zinc, copper and magnesium in vegetarians. *Biological Trace Elements Research* **50**, 13–24.

Kadrabová J, Madárič A, Kováčiková Z, Podivínsky F & Ginter E (1996*a*) Gazdík Selenium status is decreased in patients with intrinsic asthma. *Biological Trace Elements Research* **50**, 241–248.

Kadrabová J, Madárič A, Šustrová M & Ginter E (1996*b*) Changed serum trace element profile in Down's syndrome. *Biological Trace Elements Research* **54**, 201–206.

Kant AK, Moser-Veillon PB & Reynolds RD (1989) Dietary intakes and plasma concentrations of zinc, copper, iron, magnesium and selenium of young, middle-ages and older men. *Nutrition Research* **9**, 717–724.

Kantola M, Mand E, Viitak A, Juravskaja J, Purkunen R, Vartianen T, Saarikoski S & Pasanen M (1997) Selenium contents of serum and human milk from Finland and neighboring countries. *Journal of Trace Elements in Experimental Medicine* **10**, 225–232.

Karlsson J, Lundgren G & Rρnneberg R (1996) Plasma selenium in healthy man before and after nutratherapy. *International Journal of Vitamin and Nutrition Research* **67**, 27–33.

Kasperek K, Lombeck I, Keim J, Iyengar GV, Wang YX, Feinendegen LE & Bremer HJ (1982) Platelet selenium in children with normal and low selenium intake. *Biological Trace Elements Research* **4**, 29–34.

Kauppila A, Mäkilä U, Korpela H, Viinikka L & Yrjänheikki E (1987) Relationship of serum selenium and lipid peroxidation in preeclampsia. In *Selenium in Biology and Medicine*, Vol. B, pp. 996–1001 [GF Combs Jr, JE Spallholz, OA Levander and JE Oldfield, editors]. Westport, CN: AVI Publishing Co.

Kauppila A, Sundström H, Korpela H, Viinikka L & Yrjänheikki E (1984) Serum selenium and gynecological cancer: Effect of selenium supplementation on plasma malondialdehyde and serum glutathione peroxidase. In *Icosanoids and Cancer*, pp. 263–266 [H Thaler-Dao, editor]. New York, NY: Raven Press.

Kavas-Ogly AA, Lutfullaev FE, Rafiev AN, Onishenko VA, Abbasova BA & Rish MA (1995) Selenium intakes by inhabitants of the Samarkland oasis. In *Mengen-Spurenelem., Arbeitstag 18th*, pp. 395–399 [M Anke, editor]. Leipsig: Verlag Harald Schubert.

Keshan Disease Research Group (1979) Observations on effect of sodium selenite in prevention of Keshan Disease. *Acta Academia Medica Sinica* **1**, 75–83.

Kivelä SL, Mäenpää P, Nissinen A, Alfthan G, Punsar S, Enlund H & Puska P (1989) Vitamin A, vitamin, E, and selenium status in an aged Finnish male population. *International Journal of Vitamin and Nutrition Research* **59**, 373–380.

Klapec T, Mandic ML, Grigic J, Primorac L, Ikic M, Lovric T, Grigic Z & Herceg Z (1998) Daily dietary intake of selenium in eastern Croatia. *Science of the Total Environment* **217**, 127–136.

Knekt P, Aromaa A, Maatela J, Alfthan G, Aaran RK, Hakama M, Hakulinen T, Peto R & Teppo L (1990) Serum selenium and subsequent risk of cancer among Finnish men and women. *Journal of the National Cancer Institute* **82**, 864–868.

Kocyigit A, Erel O, Gurel MS, Avci S & Aktepe N (1998) Alterations of serum selenium, zinc, copper and iron concentrations and some related antioxidant activities in patients with cutaneous Leishmaniasis. *Biological Trace Elements Research* **65**, 271–281.

Koehler H, Peters H, Pankau H & Duck HJ (1988) Selenium in cardiology and angiology. *Biological Trace Elements Research* **15**, 157–166.

Kok FJ & Hofman A (1989) Selenium status and cardiovascular disease: Dutch epidemiologic data. In *Selenium in Biology and Medicine*, pp. 214–218 [A Wendel, editors]. New York, NY: Springer-Verlag.

Kopsell DA & Randall WM (1999) Selenium accumulation in a rapid-cycling Brassica oleracea population responds to increasing sodium selenate concentrations. *Journal of Plant Nutrition* **22**, 927–937.

Korpela H, Loueniva R, Yrajanheikki E & Kauppila A (1984) Selenium concentration in maternal and umbilical cord blood, placenta and amniotic membranes. *International Journal of Vitamin and Nutrition Research* **54**, 257–261.

Korpela H, Nuutinen LS & Kumpulainen J (1989) Low serum selenium and glutathione peroxidase activity in patients receiving short-term total parenteral nutrition. *International Journal of Vitamin and Nutrition Research* **59**, 80–84.

Koranova V, Skodova Z, Dedina J, Valenta Z, Parizek, Pisa Z & Styblo M (1993) Serum selenium in adult Czechoslovakia (Central Bohemia) population. *Biological Trace Elements Research* **37**, 91–100.

Köse K, Dogan P, Kardas Y & Saraymen R (1996) Plasma selenium levels in rheumatoid arthritis. *Biological Trace Elements Research* **53**, 51–56.

Kotrebai M, Birringer M, Tyson JH, Block E & Uden PC (2000*a*) Selenium speciation in enriched and natural samples by HPLC–ICP–MS and HPLC–ESI–MS with perfluorinated carboxylic acid ion-pairing agents. *Analyst* **125**, 71–78.

Kotrebai M, Tyson JH, Block E & Uden PC (2000*b*) High-performance liquid chromatography of selenium compounds utilizing perfluorinated carboxylic acid ion-pairing agents and inductively coupled plasma and electrospray ionization mass spectrometric detection. *Journal of Chromatography* **866**, 51–63.

Koyama H, Watanabe C, Satoh H, Hosokai H & Tamura S (1995) Consistent relationship between selenium and apolipoprotein A-II concentrations in the sera of fasting middle-aged male abstainers and regular consumers of alcohol. *Biological Trace Elements Research* **50**, 33–42.

Krämer K, Look MP, Chrissafidou A, Karsten S & Areads J (1996) Selen und tumarerkrankugen (Selenium and tumourigenesis. *Aktuelle Ernahrungsmedizin* **21**, 103–113.

Krajčovičová-Kudláčková M, Šimončič R, Babinska K, Béderová A, Brtková A, Magálová T & Grančičová E (1995) Selected vitamins and trace elements in blood of vegetarians. *Annals of Nutrition and Metabolism* **39**, 334–339.

Krsnjavi H, Grgurevic-Batinica A, Beker D, Romic Z & Krsnjavi A (1992) Selenium and fertility in men. *Trace Elements in Medicine* **9**, 107–108.

Kurahashi K, Inoue S, Yonekura S, Shimoshi Y & Toei K (1980) Determination of selenium in human blood by gas chromatography with electron-capture detection. *Analyst* **105**, 690–695.

Kvíčala V, Zamrazil H & Čermák J (1994) Levels of some trace elements in serum of Prague inhabitants measured by INAA. *Biological Trace Elements Research* **43–45**, 497–502.

Kvíčala V, Zamrazil , Čeřovska J, Bednář J & Janda J (1995) Evaluation of selenium supply and status of inhabitants of three selected rural and urban regions of the Czech Republic. *Biological Trace Elements Research* **47**, 365–375.

Kyriakopoulos A, Rothlein D, Pfeifer H, Gessner H & Behne D (1998) Selenium-containing compounds in baker's yeast (Saccharomycese cerevisiae). In *Mengen-Spurenelem., Arbeitstag 18th*, pp. 740–745 [M Anke, editor]. Leipsig: Verlag Harald Schubert.

Lag J (1998) Germedical aspects of selenium: Norwegian investigations. *Journal of Environmental Pathology, Toxicology and Oncology* **17**, 229–232.

Lahermo P, Alfthan G & Wang D (1998) Selenium and arsenic in the environment in Finland. *Journal of Environmental Pathology, Toxicology and Oncology* **17**, 205–216.

Lal M, Joseph D, Choudhury KK, Bajpai HN, Gauba I, Lokeshwar MR & Wagle CS (1991) Studies of blood lead levels in children by proton-induced X-ray emission (PIXE). *Science of the Total Environment* **103**, 209–214.

Lamand M, Tressol JC & Bellanger J (1994) The mineral and trace element composition in French food items and intake levels in France. *Journal of Trace Elements and Electrolytes in Health and Disease* **8**, 195–202.

Lane HW, Barroso AO, Dudrick SJ, Englert DA & MacFadyen BV (1982) Selenium status of seven IVH patients. In *Trace Element Metabolism in Man and Animals*, pp. 30–33 [J McHowell and CL White, editors]. New York, NY: Springer-Verlag.

Lane HW, Lotspeich CA, Moore CE, Ballard J, Dudrick SJ & Warren DC (1987) The effect of selenium supplementation on selenium status of patients receiving total parenteral nutrition. *Journal of Parenteral and Enteral Nutrition* **11**, 177–182.

Lane HW, Warren DC, Martin E & McCowan J (1983*a*) Selenium status of industrial workers. *Nutrition Research* **3**, 805–817.

Lane HW, Warren DC, Taylor BJ & Stool E (1983*b*) Blood selenium and glutathione peroxidase levels and dietary selenium of free-living and institutionalized elderly subjects. *Proceedings of the Society for Experimental Biology and Medicine* **173**, 87–95.

Lee AM, Huel G, Godin J, Hellier G, Sahuquillo J, Moreau T & Blot P (1995) Inter-individual variation of selenium in maternal plasma, cord blood and placenta. *Science of the Total Environment* **159**, 119–127.

Lee GP & Park KW (1999) Quality improvement of 'Seoul' celery by selenium in the nutrient solution culture. *Acta Horticultura* **483**, 185–192.

Lemoyne M, van Gossum A, Kurian R & Jeejeebhoy KN (1988) Plasma vitamin E, and selenium and breath pentane in home parenteral nutrition patients. *American Journal of Clinical Nutrition* **48**, 1310–1315.

Levander OA, Alfthan G, Arvilommi H, Gref CG, Huttunen JK, Kataja M, Koivistoinen P & Pikkarainen J (1983) Bioavailability of selenium to Finnish men as assessed by platelet glutathione peroxidase activity and other blood parameters. *American Journal of Clinical Nutrition* **37**, 887–897.

Levander OA & Morris VC (1984) Dietary selenium levels needed to maintain balance in North American adults consuming self-selected diets. *American Journal of Clinical Nutrition* **39**, 809–815.

Levander OA, Moser PB & Morris VC (1987) Dietary selenium intake and selenium concentrations of plasma, erythrocytes, and breast milk in pregnant and postpartum lactating and nonlactating women. *American Journal of Clinical Nutrition* **46**, 694–698.

Levander OA, Sutherland B, Morris VC & King JC (1981) Selenium metabolism in human nutrition. In *Selenium in Biology and Medicine*, pp. 256–268 [JE Spallholz, JL Martin and HE Ganther, editors]. Westport, CN: AVI Publishing Co.

Li JY, Taylor PR, Li B, Blot WJ, Guo W, Dawsey S, Wang GQ, Yang CS, Zheng SF, Gail M, Li GY, Liu B, Tangrea J, Sun Y, Liu F, Fraumeni F Jr & Zhang YH (1993) Nutrition intervention trials in Linxian, China. *Journal of the National Cancer Institute* **85**, 1492–1498.

Lin TH, Tseng WC & Cheng SY (1998) Direct determination of selenium in human blood plasma and seminal plasma by graphite furnace atomic absorption spectrophotometry and clinical application. *Biological Trace Elements Research* **64**, 133–149.

Liou JJ, Chen WL, Chen RLC & Yang JPW (1998) Screening and cultivation of a yeast strain with high organoselenium yields. *Taiwan Tangy Yangjiuso Yanjiu Huibao* **162**, 51–63.

Liu S (1997) Selenium-containing anticancer beer. *Faming Sheqing Gongkai Shoumingshu* CN, 1,160.079. Cl. C12C5/02.

Liu BS & Li SS (1987) Primary study of relationship between endemic selenosis and fluorosis. In *Selenium in Biology and Medicine*, vol. B, pp. 708–711 [GF Combs Jr, JE Spallholz, OA Levander and JE Oldfield, editors]. Westport, CN: AVI Publishing Co.

Liu CH, Lu ZH, Su Q & Duan YQ (1987) Regional selenium deficiency of feeds in China. In *Selenium in Biology and Medicine*, vol. B, pp. 47–52 [GF Combs Jr, JE Spallholz, OA Levander and JE Oldfield, editors]. Westport, CN: AVI Publishing Co.

Lloyd B, Holt RS & Delves HT (1983) The determination of selenium in plasma and whole egg. In *Trace Element Analytical Chemistry in Medicine and Biology*, vol. 2, pp. 1129–1141 [P Brätter and P Schramel, editors]. New York, NY: de Gruyter.

Lloyd B, Lloyd RS & Clayton BE (1983*b*) Effect of smoking, alcohol and other factors on the selenium status of a healthy population. *Journal of Epidemiology and Community Health* **37**, 213–217.

Lombeck I, Kasperek K & Menzel H (1987*a*) Selenium status of pediatric patients. In *Selenium in Biology and Medicine*, vol. B, pp. 619–630 [GF Combs Jr, JE Spallholz, OA Levander and JE Oldfield, editors]. Westport, CN: AVI Publishing Co.

Lombeck I, Menzel H & Frosch D (1987*b*) Acute selenium poisioning of a 2-year-old child. *European Journal of Pediatrics* **146**, 308–312.

Longnecker MP, Taylor PR, Levander OA, Howe SM, Veillon C, McAdam PA, Patterson KY, Holden JM, Stampfer MJ, Morris JS & Willett WC (1991) Selenium in diet, blood and toenails in relation to human health in a seleniferous area. *American Journal of Clinical Nutrition* **53**, 1288–1294.

Lü JZ, Zhang BZ & Milner JA (1994) Dietary selenite modifies glutathione metabolism and 7,12-dimethylbenz(a)anthracene conjugation in rats. *Journal of Nutrition* **124**, 172–180.

Lundberg AC, Åkesson A & Åkesson B (1992) Dietary intake and nutritional status in patients with systemic sclerosis. *Annals of Rheumatic Diseases* **51**, 1143–1148.

Luo X, Wei H, Yang C, Xing J, Qiao C, Feng Y, Liu J, Liu Z, Wu Q, Liu Y, Stoecker BJ, Spallholz JW & Yang SP (1985) Selenium intake and metabolic balance of 10 men from a low selenium area of China. *American Journal of Clinical Nutrition* **42**, 31–37.

Luoma PV, Korpela H, Sotaniemi EA & Kumpaulainen J (1985) Serum selenium, glutathione peroxidase, lipids, and human liver microsomal enzyme activity. A double-blind controlled trial of selenium supplementation. *Biological Trace Elements Research* **8**, 113–121.

Lux O & Naidoo D (1995) The assessment of biological variation components of copper, zinc and selenium. *Journal of Nutritional Biochemistry* **6**, 43–47.

McAdam PA, Smith DK, Feldman EB & Hames C (1984) Effect of age, sex and race on selenium status of healthy residents of Augusta, Georgia. *Biological Trace Elements Research* **6**, 3–9.

McConnell KP, Broghamer WL Jr, Blotcky AJ & Hurt OJ (1975) Selenium levels in human blood and tissues in health and in disease. *Journal of Nutrition* **105**, 1026–1031.

McConnell KP, Jager RR, Bland KI & Blotcky AJ (1980) The relationship of dietary selenium and breast cancer. *Journal of Surgery and Oncology* **15**, 67–70.

McCray CWR & Hurwood ID (1963) Selenosis in northwestern Queensland associated with a marine cretaceous formation. *Queensland Journal of Agricultural Science* **20**, 475–498.

McKenzie RL, Rea HM, Thomson CD & Robinson MF (1978) Selenium concentration and glutathione peroxidase activity in blood of New Zealand infants and children. *American Journal of Clinical Nutrition* **31**, 1413–1418.

McOrist GD & Fardy JJ (1989) Selenium status in the blood of Australians using neutron activation analysis. *Journal of Radioanalytical and Nuclear Chemistry* **134**, 65–72.

MacPherson A, Barclay MNI, Scott R & Yates RWS (1997) Loss of Canadian wheat imports lowers selenium intake and status of the Scottish population. In *Trace Elements in Man and Animals-9*, pp. 203–205 [PWF Fischer, MR L'Abbé, KA Cockell and RS Gibson, editors]. Ottawa: NRC Research Press.

Madaric A, Kadrabova J & Ginter A (1994) Selenium concentration in plasma and erythrocytes in a healthy Slovak population. *Journal of Trace Elements and Electrolytes in Health and Disease* **8**, 43–47.

Magalova T, Be'no I, Brtkova T, Meki'nova D, Volkovona KM, Staruchova M & Tatara M (1997) Levels of Cu, Zn, Se and their relation to levels of ceruloplasmin and the activity of antioxidant enzymes. *Bratisl Lek Listy* **7**, 988–1011.

Mahalingam TR, Vijayalakshmi S, Krishna Prabhu S, Thiruvengadasami A, Murthy KSR, Sen D, Mathews CK & Shanmugasundarum KR (1997) Studies of some trace and minor elements in blood. A survey of the Kalpakkam (India) population Part II: reference values for plasma and red cells, and correlation with coronary risk index. *Biological Trace Elements Research* **57**, 207–221.

Maier KJ, Nelson CR, Bailey FC, Klaine SJ & Knight AW (1998) Accumulation of selenium in aquatic biota of a watershed treated with seleniferous fertilizer. *Bulletin of Environmental Contamination and Toxicology* **60**, 409–416.

Mäkelä AL, Nänto V & Mäkelä Wang W (1993) The effect of nationwide selenium-enrichment of fertilizers on selenium status of healthy Finnish medical students living in south-western Finland. *Biological Trace Elements Research* **36**, 121–157.

Maksimovíc ZJ, Djujić I, Jović V & Ršumović M (1992) Selenium deficiency in Yugoslavia. *Biological Trace Elements Research* **33**, 187–196.

Maksimovíc ZJ, Jović V, Djujić I & Ršumović M (1992) Selenium deficiency in Yugoslavia and possible effects on health. *Environmental Geochemistry and Health* **14**, 107–111.

Maksimovíc ZJ, Rsumovic M, Jović , Kosanovic M & Jovanovic T (1998) Selenium in soil, grass, and human serum in the Zlatobor mountain area (Serbia): geomedical aspects. *Journal of Environmental Pathology, Toxicology and Oncology* **17**, 221–227.

Maksimovíc Z, Vlimirovic D, Djujić I, Radosevic P, Bukvic D, Maric I & Ršumović M (1995) Selenium status in patients with Balkan Endemic Nephropathy in Serbia. *Naucni Skupovi Srpske Akademije Nauka i Umetnosti,Odeljenje prirodno-matematickih nauka* **6**, 177–181.

Mao WJ, Li Y, Li BF & Liu YH (1997) Study on biological activity of selenium-enriched mussel extract. *Chinese Journal of Oceanology and Limonology* **15**, 304–307.

Marchante-Gayon JM, Sanchez-Uria JE & Sanz-Medel A (1996) Serum and tissue selenium contents related to renal disease and colon cancer as determined by electrothermal atomic absorption spectrometry. *Journal of Trace Elements in Medicine and Biology* **10**, 229–236.

Marinov B, Tsachev K & Koleva V (1998) The concentration of selenium in the maternal serum in cases of missed abortion. *Akush Ginekologia (Sophia)* **37**, 15–16.

Marklund SL, Repo H & Koskimies S (1987) Superoxide dismutase isoenzymes, glutathione peroxidase and selenium in blood from HLA-B27-positive and -negative subjects. *Acta Pathologica Microbiologica et Immunologica Scandanavia* Sec **C95**, 107–111.

Marzec Z (1999) Analytical and estimated values of chromium, nickel and selenium intakes with adult daily food rations. *Bromatologi Chemicale Toksykologi* **32**, 185–189.

Masiak M & Herzyk D (1984) Behaviour of microelements in lung cancer patients. *Fresenius Z. Analytical Chemistry* **317**, 661–662.

Mask G & Lane HW (1993) Selected measures of selenium status in full-term and pre-term neonates and their mothers and non-pregnant women. *Nutrition Research* **13**, 901–911.

Matsuda A, Kimura M & Itokawa Y (1997) Selenium level and glutathione peroxidase activity in plasma, erythrocytes and platelets of healthy Japanese volunteers. *Journal of Nutritional Science and Vitaminology* **43**, 497–504.

Maxia V, Meloni S, Rollier MA, Brandone A, Patwardhan VN, Waslien CI & El Shami S (1972) Selenium and chromium assay in Egyptian foods and in blood of Egyptian children by activation analysis. In *Nuclear Activation Techniques in the Life Sciences*, pp. 527–550, ViennaInternational Atomic Energy Agency.

Mazzella GL, Sinfurianai E, Savoldi F, Allagrine M, Lanzola E & Scelsi R (1983) Blood cells glutathione peroxidase activity and selenium in multiple sclerosis. *Experimental Neurology* **22**, 442–446.

Meissner D (1997) Reference values for blood and serum selenium in the Dresden area. *Medicine Klinische* **92**, Suppl. 3, 41–42.

Meltzer HM, Bibow K, Paulsen IT, Mundal H, Norheim G & Holm H (1993) Different bioavailability in humans of wheat and fish selenium as measured by blood platelet response to increased dietary Se. *Biological Trace Elements Research* **36**, 229–241.

Meltzer HM & Huang E (1995) Oral intake of selenium has no effect on the serum concentrations of growth hormone, insulin-like growth factor-1, insulin-like growth factor-binding proteins 1 and 3 in healthy women. *European Journal of Clinical Biochemistry* **33**, 411–415.

Menditto A, Chiodo F, Giampaoli S & Morisi G (1995) Association of serum selenium with selected cardiovascular risk factors. *Microchemical Journal* **51**, 170–180.

Menkes MS, Comstock GW, Vuilleumier JP, Helsing KJ, Rider AA & Brookmeyer R (1986) Serum beta-carotene, vitamin, A and, E, selenium and the risk of lung cancer. *New England Journal of Medicine* **315**, 1250–1254.

Michaelsson G, Berne B, Calmark B & Strand A (1989) Selenium in whole blood and plasma is decreased in patients with moderate and severe psoriasis. *Acta Dermatologica et Venerologica* **69**, 29–34.

Mihailovic M, Lindberg P, Janovic I & Antic D (1992) Selenium status of patients with Balkan endemic nephropathy. *Biological Trace Elements Research* **33**, 771–777.

Mikac-Dević ZJ, Vukelić N & Kljaić J (1992) Serum selenium level in patients with colorectal cancer. *Biological Trace Elements Research* **33**, 87–94.

Miller L, Mills BJ, Blotcky AJ & Lindeman RD (1983) Red blood cell and serum selenium concentrations as influenced by age and selected diseases. *Journal of the American College of Nutrition* **4**, 331–341.

Milly K, Wit L, Diskin C & Tulley R (1992) Selenium in renal failure patients. *Nephron* **61**, 139–144.

Monget AL, Galan P, Preziosi P, Keller H, Bourgeois C, Arnaud J, Favier A & Hercberg S (1996) Micronutrient status in elderly people. Geriatrie/Min. Vit. Aux Network. *International Journal of Vitamin and Nutrition Research* **66**, 71–76.

Moreno MA, Marin C, Vinagre F & Ostapczuk P (1999) Trace element levels in whole blood samples from residents of the city of Badajoz, Spain. *Science of the Total Environment* **229**, 209–215.

Moore JA, Noiva R & Wells IC (1984) Selenium concentration in plasma of patients with arteriographically defined coronary atherosclerosis. *Clinical Chemistry* **30**, 1171–1173.

Morisi G, Patriarca M & Menotti A (1988) Improved determination of selenium in serum by Zeeman atomic absorption spectrometry. *Clinical Chemistry* **34**, 127–130.

Morris JS, Stampfer MJ & Willett W (1983) Dietary selenium in humans. Toenails as an indicator. *Biological Trace Elements Research* **5**, 529–537.

Mosulishvili LM, Shonia NI, Ginturi EN, Efremova EY & Kharabadze NE (1985) INAA results for metal traces in human whole blood. Frequency and age characteristics of the distribution. *Journal of Radioanalytical and Nuclear Chemistry* **88**, 121–134.

Munz B, Frank S, Hubner G, Olsen E & Werner S (1997) A novel type of glutathione peroxidase: expression and regulation during wound repair. *Biochemical Journal* **326**, 579–585.

Murphy C, Golden B, Ramdath D & Golden M (1988) Selenium status during recovery from malnutrition: Effect of selenium supplementation. In *Trace Element Metabolism in Man and Animals*, vol. 6, pp. 11–14 [LS Hurley, CL Keen, B Lönnerdal and RB Rucker, editors]. New York, NY: Plenum Press.

Mutanen M (1984) Dietary intake and sources of selenium in young Finnish women. *Human Nutrition: Applied Nutrition* **38**A, 265–269.

Mutanen M, Viita L & Mykkänen H (1989) Selenium supplementation does not alter platelet activation in subjects with normal selenium status. *International Journal of Vitamin and Nutrition Research* **59**, 309–313.

Nakamura H, Kudo H, Muramatsu H, Masago K & Murakami Y (1980) Activation analysis of trace elements in the human blood serum of some specific diseases. In *Trace Element Analytical Chemistry in Medicine and Biology*, pp. 365–380 [P Brätter and P Schramel, editors]. New York, NY: de Gruyter.

National Research Council (1983) *Selenium in Nutrition*, revised ed., p. 24. Washington, DCNational Academy Press.

Navarro-Alarcon M, De La Serrana HL, Perez-Valero V & Lopez-Martinez C (1998) Serum selenium levels as indicators of body status in cancer patients and their relationships with other nutritional and biochemical markers. *Science of the Total Environment* **212**, 195–202.

Navarro-Alarcon M, Lopez G, De La Serrana HL, Perez-Valero V & Lopez-Martinez C (1999) Serum and urine selenium concentrations as indicators of body status in patients with diabetes mellitus. *Science of the Total Environment* **228**, 79–85.

Nève J (1995) Human selenium supplementation as assessed by changes in blood selenium concentration and glutathione peroxidase activity. *Journal of Trace Elements in Medicine and Biology* **9**, 65–73.

Nève J, Chamart S, van Erum S, Vertongen F & Dramaix M (1988*a*) Selenium status in humans as investigated by the effects of supplementation with Se-enriched yeast tablets. In *Selenium in Medicine and Biology*, pp. 315–320 [J Nève and A Favier, editors]. New York, NY: de Gruyter.

Nève J, Molle L, Hanocq M, Sinet PM & van Geffel R (1983*a*) Erythrocyte and plasma trace element levels in clinical assessments. Zinc, copper and selenium in normals and patients with Down's syndrome and cystic fibrosis. *Biological Trace Elements Research* **5**, 75–79.

Nève J, Sinet PM, Molle L & Nicolle A (1983*b*) Selenium, zinc and copper in Down's syndrome (trisomy 21): blood and relations with glutathione peroxidase and superoxide dismutase. *Clinica Chimica Acta* **133**, 209–214.

Nève J, Vertongen F & Capel P (1988*b*) Selenium supplementation in healthy Belgian adults: response in platelet glutathione peroxidase activity and other blood indices. *American Journal of Clinical Nutrition* **48**, 139–143.

Nève J, Vertongen F, Thonnart N & Carpentier YA (1984) Assessment of selenium status in patients receiving long-term total parenteral nutrition. In *Trace Element Analytical Chemistry in Medicine and Biology*, vol. 3, pp. 139–149 [P Brätter and P Schramel, editors]. New York, NY: de Gruyter.

Noble RM & Barry GA (1982) Survey of selenium concentrations in wheat, sorghum and soybean grains, prepared poultry feeds and feed ingredients from Queensland. *Queensland Journal of Agricultural and Animal Sciences* **39**, 1–8.

Nomura AMY, Lee J, Stemmermann GN & Combs GF Jr (2000) Serum selenium and subsequent risk of prostate cancer. *Cancer Prevention Biomarkers* **9**, 883–887.

Oldfield JE (1999) *Selenium World Atlas*, BrusselsSelenium Tellurium Development Association.

Olivieri O, Girelli D, Azzini M, Stanzial AM, Russo C, Ferroni M & Corrocher R (1995) Low selenium status in the elderly influences thyroid hormones. *Clinical Science* **89**, 637–642.

Olivieri O, Stanzial A, Girelli D, Trevisan M, Guarini P, Terzi M, Caffi S, Fontana F, Casaril M, Ferrari S & Corrocher R (1994) Selenium status, fatty acids, vitamins A and E, and aging: the Nove Study. *American Journal of Clinical Nutrition* **60**, 510–517.

Olmsted L, Schrauzer GN, Flores-Arce M & Dowd J (1989) Selenium supplementation of symptomatic human immunodeficiency virus infected patients. *Biological Trace Elements Research* **20**, 59–65.

Ojo OJ, Oluwolfe AF, Durosinmi AM, Ogunsola OJ, Akanle OA & Spyrou NM (1994) Baseline levels of elemental concentrations in whole blood, plasma and erythrocytes of Nigerian subjects. *Biological Trace Elements Research* **46**, 461–469.

Orack H & Yanavdag R (1996) Selenium content of milk and milk products of Turkey. Part I. *Chimica Acta Turcica* **24**, 239–243.

Oster O, Drexler M, Schenk J, Meinertz T, Kasper W, Schuster CJ & Prellwitz W (1986) The serum selenium concentration of patients with acute myocardial infarction. *Annals of Clinical Research* **18**, 36–42.

Oster O & Prellwitz W (1982) A methodological comparison of hydride and carbon furnace atomic absorption spectroscopy for the determination of selenium. *Clinica Chimica Acta* **124**, 277–291.

Oster O & Prellwitz W (1990*a*) Selenium and cardiovascular disease. *Biological Trace Elements Research* **24**, 91–103.

Oster O & Prellwitz W (1990*b*) The renal excretion of selenium. *Biological Trace Elements Research* **24**, 119–146.

Oster O, Prellwitz W, Kasper W & Meinertz T (1983) Congestive cardiomyopathy and the selenium content of plasma. *Clinica Chimica Acta* **128**, 125–132.

Oster O, Schmiedel G & Prellwitz W (1988*a*) The organ distribution of selenium in German adults. *Biological Trace Elements Research* **15**, 23–45.

Oster O, Schmiedel G & Prellwitz W (1988*b*) Correlations of blood selenium with hematological parameters in West German adults. *Biological Trace Elements Research* **15**, 47–81.

Overvad K, Wang D, Olsen J, Allen D, Thorling E, Bulbrook R & Hayward J (1991) Selenium in human mammary carcinogenesis: a case-control study. *European Journal of Cancer* **27**, 900–902.

Ozata M, Salik M, Aydin A, Sayin S, Oktenu C, Beyhan Z, Isimer A & Ozdemir IC (1999) Iodine and zinc, but not selenium and copper, deficiency exists in a male Turkish population with endemic goiter. *Biological Trace Elements Research* **69**, 211–216.

Panel on Dietary Antioxidants and Related Compounds (2000) *Dietary Reference Intakes for Vitamin, C, Vitamin, E, Selenium and Beta-Carotene and other Carotenoids*, Washington, DCNational Academy Press.

Pawlowicz Z, Zachara BA, Trafikowska U, Maciag A, Marchaluk E & Nowicki A (1991) Blood selenium concentrations and glutathione peroxidase activities in patients with breast cancer and with advanced gastrointestinal cancer. *Journal of Trace Elements and Electrolytes in Health and Disease* **5**, 275–277.

Pearn J & McCay CRW (1979) Blood selenium in chronic spinal muscular atrophy. *Journal of Neurological Science* **42**, 199–202.

Peleg I, Morris S & Hames CG (1985) Is serum selenium a risk factor for cancer? *Medical Oncology and Tumor Pharmacotherapy* **2**, 157–163.

Peng A, Wang WH, Wang CX, Wang ZJ, Rui HF, Wang WZ & Yang ZW (1999) The role of humic substances in drinking water in Kaschin-Beck diesease in China. *Environmental Health Perspectives* **107**, 293–296.

Peng A, Xu Y, Lu JH & Wang ZJ (2000) Study on the dose–effect relationship of selenite with the growth of wheat. *Biological Trace Elements Research* **76**, 175–181.

Peretz A, Nève J, Desmedt J, Duchateau J, Dramaix M & Famaey JP (1991) Lymphocyte response is enhanced by supplementation of elderly subjects with selenium-enriched yeast. *American Journal of Clinical Nutrition* **53**, 1323–1328.

Peretz A, Nève J, Fontaine J, Vertongen F & Famaey JP (1988) Effects of corticosteroid treatment on selenium status in man and animal. In *Selenium in Medicine and Biology*, pp. 93–96 [J Nève and A Favier, editors]. New York, NY: de Gruyter.

Perona G, Guidi GC, Piga A, Cellerino R, Milani G, Colautti B, Moschini G & Stievano BM (1979) Neonatal erythrocyte glutathione peroxidase deficiency as a consequence of selenium imbalance during pregnancy. *British Journal of Haematology* **42**, 567–574.

Piccinini L, Borella P, Bargellini A, Medici CI & Zoboli A (1996) A case-control study on selenium, zinc and copper in plasma and hair of subjects affected by breast and lung cancer. *Biological Trace Elements Research* **51**, 23–29.

Pleban PA, Munyani A & Beachum J (1982) Determination of selenium concentration and glutathione peroxidase activity in plasma and erythrocytes. *Clinical Chemistry* **28**, 311–316.

Poirier KA (1994) Summary of the derivation of the reference dose for selenium. In *Risk Assessment of Essential Elements*, pp. 157–166 [W Mertz, CO Abernathy and SS Olin, editors]. Washington, DC: ILSI Press.

Prieto MA, Naranjo CC, Lui GP, de la Cruz GM, de la Fe Napoles C & Mestre PF (1994) Determination of selenium in blood and serum of patients with epidemical neuritis by ETAAS. *Quimica Analitica* **13**, 182–186.

Primm P, Anderson HD & Morris JS (1979) The effects of dialysis time on selenium loss from human blood sera. *Transactions of the Missouri Academy of Sciences* **23**, 117–124.

Pucheu S, Coudray C, Vanzetto G, Favier A, Machecourt J & de Leiris J (1995) Time-course of changes in plasma levels of trace elements after thrombolysis during the acute phase of myocardial infarction in humans. *Biological Trace Elements Research* **47**, 171–181.

Raines DA, Kinsara AJ, Fawzy ME, Vasudevan S, Mohamed GE, Legayada ES, Al-Rawithi S & Al-Yazigi A (1999) Plasma and urinary selenium in Saudi Arabian patients with dilated cardiomyopathy. *Biological Trace Elements Research* **69**, 59–68.

Ravaglia G, Forti P, Mailoli F, Bastagli L, Facchini A, Mariani E, Savarino L, Sassi S, Cucinotta D & Lenaz G (2000) Effect of micronutrient status on natural killer cell immune function in healthy, free-living subjects aged >90 y. *American Journal of Clinical Nutrition* **71**, 590–598.

Rayman MP (1997) Dietary selenium: time to act. *British Medical Journal (Clinical Research Edition)* **314**, 387–388.

Rayman MP (2000) The importance of selenium to human health. *Lancet* **356**, 233–241.

Rayman MP, Abou-Shakra FA, Ward NI & Redman CWG (1996) Comparison of selenium levels in pre-eclamptic and normal pregnancies. *Biological Trace Elements Research* **55**, 9–20.

Rea HM, Thomson CD, Campbell DR & Robinson MF (1979) Relation between erythrocyte selenium concentrations and glutathione peroxidase (*EC* 1.11.1.9) activities of new Zealand residents and visitors to New Zealand. *British Journal of Nutrition* **42**, 201–208.

Reilly C (1998) Selenium: a new entrant into the functional food arena. *Trends in Food Science and Technology* **9**, 114–118.

Reinhold U, Blitz H, Bayer W & Schmidt KH (1989) Serum selenium levels in patients with malignant melanoma. *Acta Dermatologica et Venereologica (Stockholm)* **69**, 132–136.

Ribalta J, Reyes H, Hernandez I, Fuentes O, Baez M, Gonzales M & Palma J (1995) Can a selenium deficiency affect the pathogenesis of cholestasis in pregnancy? *Gastroenterology and Hepatology* **18**, 114–120.

Richard MJ, Arnaud J, Koukay N, Favier A, Jurkovits C, Dechelette E, Hachache T, Meftahi H, Foret M & Laporte DF (1988) Lipid peroxidation, relationship with selenium and glutathione peroxidase activities in patients with chronic renal failure. In *Selenium in Medicine and Biology*, pp. 283–288 [J Nève and A Favier, editors]. New York, NY: de Gruyter.

Ringstad J, Kildebo S & Thamassen Y (1993*a*) Serum selenium, copper, and zinc concentrations in Crohn's disease and ulterative colitis. *Scandinavian Journal of Gastroenterology* **28**, 605–608.

Ringstad J, Knutsen SF, Nilssen OR & Thomassen Y (1993*b*) A comparative study of serum selenium and vitamin E levels in a population of male risk drinkers and abstainers: A population-based matched-pair study. *Biological Trace Elements Research* **36**, 65–71.

Robberecht HJ & Deelstra HA (1994) Factors influencing blood selenium concentrations: a literature review. *Journal of Trace Elements and Electrolytes in Health and Disease* **8**, 129–143.

Robberecht HJ, Hendrix P, Van Cauwenbergh R & Deelstra HA (1994) Actual daily dietary intake of selenium in Belgium, using duplicate portion sampling. *Zeitschrift fur Lebensmittel-Untersuchung und Forschung* **199**, 251–254.

Robinson MF, Campbell DR, Stewart RDH, Rea HM, Thomson CD, Snow PG & Squires IHW (1981) Effect of daily supplements of selenium on patients with muscular complaints in Otago and Canterbury. *New Zealand Medical Journal* **93**, 289–292.

Robinson MF, Campbell DR, Sutherland HF, Herbison GP, Paulin JM & Simpson FO (1983*a*) Selenium and risk factors for cardiovascular disease in New Zealand. *New Zealand Journal of Medicine* **96**, 755–762.

Robinson MF, Godfrey PJ, Thomson CD, Rea HM & van Rij AM (1979) Blood selenium and glutathione peroxidase activity in normal subjects and in surgical patients with and without cancer in New Zealand. *American Journal of Clinical Nutrition* **32**, 1477–1485.

Robinson MF & Thomson CD (1987) Status of the food supply and residents of New Zealand. In *Selenium in Biology and Medicine*, vol. B, pp. 631–644 [GF Combs Jr, JE Spallholz, OA Levander and JE Oldfield, editors]. Westport, CN: AVI Publishing Co.

Robinson MF, Thomson CD & Huemmer PK (1985) Effect of a megadose of ascorbic acid, a meal and orange juice on the absorption of selenium as sodium selenite. *New Zealand Medical Journal* **98**, 626–628.

Robinson MF, Thomson CD, Jenkins P, Luzhen G & Whanger PD (1997) Long-term supplementation with selenate and seleno-methionine: urinary excretion by New Zealand women. *British Journal of Nutrition* **77**, 551–563.

Robinson MF, Thomson CD, Ong LK & Huemmer P (1983*b*) Effects of supplementation with high-selenium yeast wheat bread on glutathione peroxidase and related enzymes in women. *Proceedings of the Nutrition Society* **43**, 17A.

Rosenfeld I & Beath OA (1964) *Selenium: Geobotany, Biochemistry, Toxicology and Nutrition*, New York, NYAcademic Press.

Rotruck JT, Ganther HE, Swanson AB, Hafeman DG & Hoekstra WG (1972) Selenium: Biochemical role as a component of glutathione peroxidase. *Science* **179**, 588–590.

Rudolph N & Wong SL (1978) Selenium and glutathione peroxidase activity in maternal and cord plasma and red cells. *Pediatric Research* **12**, 789–792.

Rukgauer M, Klein J & Kruse-Jarres JD (1997) Reference values for the trace elements copper, manganese, selenium and zinc in the serum/plasma of children, adolescents and adults. *Journal of Trace Elements in Medicine and Biology* **11**, 92–98.

Saeed K, Thomassen Y & Langmyr FJ (1979) Direct electro-thermal atomic absorption spectrometric determination of selenium in serum. *Analytica Chimica Acta* **110**, 285–289.

Saint-Georges M, d'Auzac CL, Bonnefont D, Bourely B, Jaudon MC & Galli A (1988) Implication of selenium and glutathione peroxidase deficiency in the pathology of hemodialyzed patients. In *Selenium in Medicine and Biology*, pp. 293–296 [J Nève and A Favier, editors]. New York, NY: de Gruyter.

Salbe AD, Hill CH, Veillon C, Howe SM, Longnecker MR, Taylor PR & Levander OA (1993) Relationship between serum somatomedin C levels and tissue selenium content among adults living in a seleniferous area. *Nutrition Research* **13**, 399–405.

Salonen JT, Alfthan G, Huttunen JK, Pikkarainen J & Puska P (1982) Association between cardiovascular death and myocardial infarction and serum selenium as a matched-pair longitudinal study. *Lancet* **2**, 175–179.

Salonen T, Halme M, Sarna S, Westermarck T, Nordberg UR & Bayer W (1988) Selenium status improved among elderly due to selenium-enrichment of fertilizers in Finland. In *Trace Element Metabolism in Man and Animals*, vol. 6, pp. 19–20 [LS Hurley, CL Keen, B Lönnerdal and RB Rucker, editors]. New York, NY: Plenum Press.

Salvini S, Hennekens CH, Morris JS, Willett WC & Stampfer MJ (1995) Plasma levels of the antioxidant selenium and risk of myocardial infarction among US physicians. *American Journal of Cardiology* **76**, 1218–1221.

Samir M & El-Awady MY (1998) Serum selenium levels in multinodal goiter. *Clinical Otolaryngology* **23**, 512–514.

Sanchez-Ocampo A, Torres-Perez J & Jimeniz-Reyes M (1996) Selenium levels in the serum of workers in a rubber tire repair shop. *American Industrial Hygiene Association Journal* **57**, 72–75.

Saraymen R, Soylak M, Elci L & Dogan M (1997) Blood serum selenium level of adults living in the province of Kayseri-Turkiye. *Fresenius Environmental Bulletin* **6**, 694–698.

Schramel P, Hasse S & Ovcar-Pavlu J (1988) Selenium, cadmium, lead and mercury concentrations in human breast milk, in placenta, maternal blood and the blood of the newborn. *Biological Trace Elements Research* **15**, 111–124.

Schrauzer GN, Molenaar T, Mead S, Luehn K, Yamamoto H & Araki E (1985) Selenium in the blood of Japanese and American women with and without breast cancer and fibrocystic disease. *Japanese Journal of Cancer Research (Gann)* **76**, 374–377.

Schrauzer GN, Rhead WJ & Evans GA (1973) Selenium and cancer: Chemical interpretation of a plasma 'cancer test'. *Bioinorganic Chemistry* **2**, 329–340.

Schrauzer GN & White DA (1978) Selenium in human nutrition: Dietary intakes and effects of supplementation. *Bioinorganic Chemistry* **8**, 303–318.

Schubert A, Holden JM & Wolf WR (1987) Selenium content of a core group of foods based on a critical evaluation of published analytical data. *Journal of the American Dietetic Association* **87**, 285–292.

Schwarz K, Bieri JG, Briggs GM & Scott ML (1957) Prevention of exudative diathesis in chicks by factor 3 and selenium. *Proceedings of the Society for Experimental Biology and Medicine* **95**, 621–626.

Schwarz K & Foltz CM (1957) Selenium as an integral part of factor 3 against dietary necrotic liver degeneration. *Journal of the American Chemical Society* **79**, 3292–3293.

Scieszka M, Danch A, Machalski M & Drozdz M (1997) Plasma selenium concentration in patients with stomach and colon cancer in the Upper Silesia. *Neoplasma* **44**, 395–397.

Scott R, MacPherson A & Yates R (1997) Selenium supplementation in sub-fertile human males. In *Trace Elements in Man and Animals-9*, pp. 458–459 [PWF Fischer, MR L'Abbé, KA Cockell and RS Gibson, editors]. Ottawa: NRC Research Press.

Segal I, Gut A, Schofield D, Shiel N & Braganza JM (1995) Micronutrient antioxidant status in black South Africans with chronic pancreatitis: opportunity for prophylaxis. *Clinica Chimica Acta* **239**, 71–79.

Sekulovic D, Maksimovic S, Jakovljevic M, Kresovic M & Mihajlov M (1996) Application of Se-fertilizers in cultivated mint and chamomile production in order to improve their pharmacological properties. *Journal of Science and Agricultural Research* **57**, 93–99.

Sesama G, Baj A, Toffoletto F, Sega R & Ghezzi L (1992) Plasma selenium levels of the general population of an area of northern Italy. *Science of the Total Environment* **120**, 97–102.

Shamberger RJ, Rukovena E, Longfield AK, Tytko SA, Deadbar S & Willis CE (1973) Antioxidants and cancer: I. Selenium in the blood of normal and cancer patients. *Journal of the National Cancer Institute* **50**, 863–870.

Shin WS, Hong SI, Jung MR, Kim JH & Na HB (1991) The study on concentration of serum selenium in patients with hepatoma. *Korean Journal of Nutrition* **24**, 506–515.

Shortt CT, Duthie GC, Robertson JD, Morrice PC, Nicol F & Arthur JR (1997) Selenium status of a group of Scottish adults. *European Journal of Clinical Nutrition* **51**, 400–404.

Shrift A (1964) selenium cycle in nature? *Nature* **201**, 1304–1305.

Sima A & Pfannhauser W (1998) Selenium levels in foods produced in Austria. In *Mengen-Spurenelem., Arbeitstag 18th*, pp. 197–204 [M Anke, editors]. Leipsig: Verlag Harald Schubert.

Sinet PM, Nève J, Nicole A & Molle L (1984) Low plasma selenium in Down's syndrome (trisomy 21). *Acta Paediatrica Scandinavica* **73**, 275–277.

Sippola J (1979) Selenium in content of soil and timothy (Phleum pratense) in Finland. *Annals of Agriculture in Finland* **18**, 182–187.

Slejkovec Z, van Elteren JT, Wordoniecka UD, Kroon KJ, Falnoga I & Byrne AR (2000) Preliminary study on the determination of selenium compounds in some selenium-accumulating mushrooms. *Biological Trace Elements Research* **75**, 139–155.

Sluis KB, Darlow BA, George PM, Mogridge N, Dolamore BA & Winterbourn CC (1992) Selenium and glutathione peroxidase levels in premature infants in a low selenium community (Christchurch, New Zealand). *Pediatric Research* **32**, 189–194.

Smith AM, Chang MPH & Medeiros LC (2000) Generational differences in selenium status of women. *Biological Trace Elements Research* **75**, 157–165.

Smith JC Jr, Lewis S, Holbrook S, Seidel K & Rose K (1987) Effect of heparin and citrate on measured concentrations of various analytes in plasma. *Clinical Chemistry* **33**, 814–816.

Snook JT, Palmquist DL, Moxon AL, Cantor AH & Vivian WM (1983) Selenium status of a rural (predominantly Amish) community living in a low-selenium area. *American Journal of Clinical Nutrition* **38**, 620–630.

Squali H, Arnaud J, Richard MJ, Renversez JC & Favier A (1997) Evaluation of oxidative stress and antioxidant defenses in malnourished Moroccan children. *Annals of Nutrition and Metabolism* **41**, 149–159.

Srikumar TS, Johansson GK, Öckerman PA, Gustafsson JA & Åkesson B (1992) Trace element status in healthy subjects switching from a mixed to a lactovegetarian diet for 12 mo. *American Journal of Clinical Nutrition* **55**, 885–890.

Stadtman TC (1996) Selenocysteine. *Annual Review of Biochemistry* **65**, 83–100.

Stead NW, Bishop SL & Carroll RM (1984) Selenium (Se) balance in the dependent elderly. *American Journal of Clinical Nutrition* **39**, 677.

Stewart RDH, Griffiths NM, Thomson CD & Robinson MF (1978) Quantitative selenium metabolism in normal New Zealand women. *British Journal of Nutrition* **40**, 45–54.

Stoewsand GS, Andrews JL, Munson L & Lisk DJ (1989) Effect of dietary Brussels sprouts with increased selenium content on mammary carcinogenesis in the rat. *Cancer Letters* **45**, 43–48.

Stork A, Jury WA & Frankenberger WT Jr (1999) Accelerated volatilization of selenium from different soils. *Biological Trace Element Research* **69**, 217–234.

Strain JJ, Bokje E, Van't Veer P, Coulter J, Stewart C, Logan H, Odling-Smee W, Spence RAJ & Steele K (1997) Thyroid hormones and selenium status in breast cancer. *Nutrition and Cancer* **27**, 48–52.

Suadicani P, Hein HO & Gyntelberg F (1992) Serum selenium concentation and risk of ischemic heart disease in a prospective cohort study of 3000 males. *Atherosclerosis* **96**, 33–42.

Sullivan JF, Blotcky AJ, Jetton MM, Hahn HKJ & Burch RE (1979) Serum levels of selenium, calcium, copper, magnesium, manganese and zinc in various human diseases. *Journal of Nutrition* **109**, 1432–1437.

Sundström H, Yrjanheikki E & Kauppila A (1986) Serum selenium and thromboxane in patients with gynecological cancer. *Carcinogenesis* **5**, 1051–1052.

Sune X & Zhou Y (1997) Selenium-rich vinegar. *Faming Sheqing Gongkai Shoumingshu* CN 1,148,089. Cl. C12J1/00.

Suzuki T, Hongo T, Ohba T, Kobayashi K, Imai H, Ishida H & Suzuki H (1989) The relation of dietary selenium to erythrocyte and plasma selenium concentrations in Japanese college women. *Nutrition Research* **9**, 839–848.

Suzuki T, Imai H & Kobatashi K (1988) Dietary intake of selenium in Japanese: an estimation by analyzed and reported values in foodstuffs and cooked dishes. *Journal of the Japanese Society of Nutrition and Food Science* **41**, 91–102.

Swaine DJ (1955) The trace element content of soils. *Commonwealth Bureau of Soil Science Technical Committee* **48**, 1–157.

Swanson CA, Longnecker MP, Veillon C, Howve SM, Levander OA, Taylor PR, McAdam PA, Brown C, Stampfer MJ & Willet WC (1990) Selenium intake, age, gender and smoking in relation to indices of selenium status of adults residing in a seleniferous area. *American Journal of Clinical Nutrition* **52**, 852–862.

Tan JA, Zheng DZ, Hou SF, Zhu WY, Li RB, Zhu ZY & Wang WY (1987) Selenium in ecological and chemicogeography and endemic Keshan and Kaschin-Beck disease in China. In *Selenium in Biology and Medicine*, vol. B, pp. 859–876 [GF Combs Jr, JE Spallholz, OA Levander and JE Oldfield, editors]. Westport, CN: AVI Publishing Co.

Tanner AR, Bantock I, Hinks L, Lloyd B, Turner NR & Wright R (1986) Depressed selenium and vitamin E, levels in an alcoholic population. Possible relationship to hepatic injury through increased lipid peroxidation. *Digestive Diseases and Sciences* **31**, 1307–1312.

Tarp U, Hansen JC & Overvad K (1986) Blood selenium concentrations during long-term supplementation. *Nutrition Research* **6**, 853–855.

Tarp U, Thorling EB & Hansen JC (1990) Longitudinal study of changes in blood selenium among Danish blood bank donors (1974–1988). *Nutrition Research* **10**, 1171–1176.

Terrier F, Hida H, Favier A & Marconnet P (1995) Muscle GSH-Px activity after prolonged exercise, training, and selenium supplementation. *Biological Trace Elements Research* **47**, 279–285.

Terry N, Zayed AM, de Souza MP & Tarum AS (2000) Selenium in higher plants. *Annual Review of Plant Physiology and Plant Molecular Biology* **51**, 401–432.

Thérond P, Marchand M, Biou D, Demelier JF, Auzépy P & Richard C (1988) Plasma selenium and cardiomyopathy. In *Selenium in Medicine and Biology*, pp. 277–279 [J Nève and A Favier, editors]. New York, NY: de Gruyter.

Thérond P, Marchand M, Biou D, Demelier JF, Brion F, Foucaud P & Navarro J (1988) Selenium and vitamin E supplementation in cystic fibrosis. In *Selenium in Medicine and Biology*, pp. 333–336 [J Nève and A Favier, editors]. New York, NY: de Gruyter.

Thiele R, Schuffenhauer M, Winnefled K, Dawcnski H, Pleissner J & Pfeifer R (1995) Selenium level in patients with acute myocardial infarct and in patients wth severe angina pectoris without myocardial infarct. *Medicine Klinische* **90**, Suppl. 1, 45–48.

Thilly CH, Swennen B, Bourdoux P, Ntambue K, Moreno-Reyes R, Gillies J & Vanderpas JB (1993) The epidemiology of iodine-deficiency disorders in relation to goitrogenic factors and thyroid-stimulating hormone regulation. *American Journal of Clinical Nutrition* **57**, Suppl., 267S–270S.

Thilly CH, Vanderpas JB, Beba N, Ntambue K, Contempre B, Swennen B, Moreno-Reyes R, Bourdoux P & Delange F (1992) Iodine deficiency, other trace elements, and goitrogenic factors in the etiopathogeny of iodine deficiency disorders. *Biological Trace Elements Research* **32**, 229–243.

Thomson CD, Ong LK & Robinson MF (1985) Effects of supplementation with high-selenium wheat bread on selenium, glutathione peroxidase and related enzymes in blood components of New Zealand residents. *American Journal of Clinical Nutrition* **41**, 1015–1022.

Thomson CD & Robinson MF (1986) Urinary and fecal excretions and absorption of a large supplement of selenium: superiority of selenate over selenite. *American Journal of Clinical Nutrition* **44**, 659–663.

Thomson CD & Robinson MF (1993) Long-term supplementation with selenate and selenomethionine: selenium and glutathione peroxidase (*EC* 1.11.1.9) in blood components of New Zealand women. *British Journal of Nutrition* **69**, 577–588.

Thomson CD & Robinson MF (1996) The changing selenium status of New Zealanders. *European Journal of Clinical Nutrition* **50**, 107–114.

Thomson CD, Robinson M, Butler J & Whanger P (1993) Long-term supplementation with selenate and selenomethionine: selenium and glutathione peroxidase in blood components of New Zealand residents. *British Journal of Nutrition* **69**, 577–588.

Thomson CD, Robinson MF, Campbell DR & Rea HM (1982) Effect of prolonged supplementation with daily supplements of selenomethionine and sodium selenite on glutathione peroxidase activity in blood of New Zealand residents. *American Journal of Clinical Nutrition* **36**, 24–31.

Thomson CD, Robinson MF & Whanger PD (1989) Selenium (Se) and glutathione peroxidase (GSH-Px) in blood components of NZ women during long-term supplementation with selenate or selenomethionine (Semet). In *Selenium in Biology and Medicine*, pp. 254–257 [A Wendel, editor]. New York, NY: Springer-Verlag.

Thomson CD & Stevens SM (1988) The absence of adaptive changes in tissue activities of glutathione-S-transferase, superoxide dismutase and catalase following selenium and vitamin, E supplementation in subjects of low selenium status. *Biochemistry International* **16**, 83–92.

Thomson CD, Stevens SM, van Rij AM, Wade CR & Robinson MF (1988) Selenium and vitamin E supplementation: Activities of glutathione peroxidase in human tissues. *American Journal of Clinical Nutrition* **48**, 316–323.

Thorngren M & Åkesson B (1987) Effect of dietary fish on plasma selenium and its relation to haemostatic changes in healthy adults. *International Journal of Vitamin and Nutrition Research* **57**, 429–435.

Thorling EB, Overvad K & Geboers J (1986) Selenium status in Europe – Human data a multicenter study. *Annals of Clinical Research* **18**, 3–7.

Thorling EB, Overvad K, Heerfordt A & Fooldspang A (1985) Serum selenium in Danish blood bank donors. *Biological Trace Elements Research* **8**, 65–73.

Thuluvath PJ & Triger DR (1992) Selenium and chronic liver disease. *Journal of Haematology* **14**, 176–182.

Thuong T, Auzépy P, Blondeau M & Richard C (1986*a*) Decrease of the serum level of selenium in chronic alcoholics with or without dilated cardiomyopathy. *Presse Médicine* **15**, 693–696.

Turan B, Delilbaşi E, Dalay N, Sert Ş, Afrasyap L & Sayal A (1992) Serum selenium and glutathione-peroxidase activities and their interaction with toxic metals in dialysis and renal transplantation patients. *Biological Trace Elements Research* **33**, 95–102.

Tiran B, Tiran A, Petck W, Rossipol E & Wawschinek O (1992) Selenium status of healthy children and adults in Styra (Austria) Investigation of a possible undersupply in the Styrian population. *Trace Elements in Medicine* **9**, 75–79.

Tolonen M, Sarna S, Halme M, Tuominen SE, Westermarck T, Nordberg UR, Keinonen M & Schrijver J (1988) Anti-oxidant supplementation decreases TBA reactants in serum of elderly. *Biological Trace Element Research* **17**, 221–228.

Torra M, Rodamilans M, Montero F & Corbella J (1997) Serum selenium concentration of a healthy northwest Spanish population. *Biological Trace Elements Research* **58**, 127–133.

Trelease SF (1945) Selenium in soils, plants and animals. *Soil Science* **60**, 125–132.

Uehara S, Honjo K, Hirano F, Sakai N, Hirayama A & Jin K (1988) Clinical significance of selenium levels in chronic pancreatitis. *Journal of Clinical Biochemistry and Nutrition* **5**, 201–207.

United States Department of Agriculture (1999) Nutrient database for standard reference. http://www.nal.usda.gov/fnic/foodcomp/Data/SR13/sr13.html

United States Environmental Protection Agency (EPA), Integrated Risk Information System (IRIS) (1991) *Reference dose (RfD) for Oral Exposure for Selenium*. Online: Input pending (verification date 3/27/91). Cincinnati, OH: Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office.

Valentine JL, Faraju B & Akashi K (1988) Selenium and glutathione peroxidase in mothers experiencing sudden infant death syndrome. In *Trace Element Metabolism in Man and Animals*, vol. 6, pp. 13–15 [LS Hurley, CL Keen, B Lönnerdal and RB Rucker, editors]. New York, NY: Plenum Press.

Valentine JL, Kang HK & Spivey GH (1978) Selenium levels in human blood, urine, and hair in response to exposure via drinking water. *Environmental Research* **17**, 347–355.

Välimäki M, Alfthan G, Pikkarainen G, Ylikahri R & Salaspuro M (1987) Blood and liver selenium concentrations in patients with liver diseases. *Clinica Chimica Acta* **166**, 171–176.

Välimäki M, Harju KJ & Ylikahri R (1983) Decreased serum selenium in alcoholics – a consequence of liver dysfunction. *Clinica Chimica Acta* **13**, 291–296.

Van Cauwenbergh R, Robbercht H, Deelstra H, Picramenos D & Kostakopoulos A (1994) Selenium concentrations in serum of healthy Greek adults. *Journal of Trace Elements and Electrolytes in Health and Disease* **8**, 99–109.

Vanderpas JB, Contrempre B, Duale N, Deckx H, Bebe N, Longombe AO, Thilly CH, Diplock AT & Dumont JE (1993) Selenium deficiency mitigates hypothyroxinemia in iodine-deficient subjects. *American Journal of Clinical Nutrition* **57**, 271S–275S.

Vanderpas JB, Contrempre B, Duale N, Goosens W, Bebe N, Thorpe R, Ntambue K, Dumont J, Thilly CH & Diplock AT (1990) Iodine and selenium deficiency associated with cretinism in northern Zaire. *American Journal of Clinical Nutrition* **57**, 271S–275S.

van der Torre H, van Dokkum W, Schaafsma G, Wedel M & Ockhuizen T (1991) Effects of various levels of selenium in wheat and meat on blood selenium status indices and on selenium balance in Dutch men. *British Journal of Nutrition* **65**, 69–80.

van Gossum A, Closset P, Noel E, Cremer M & Nève J (1996) Deficiency in antioxidant factors in patients with alcoholic-related chronic pancreatitis. *Digestive Diseases and Sciences* **41**, 1225–1231.

van Gossum A & Nève J (1995) Low selenium status in alcoholic cirrhosis is correlated with aminopyrine breath test. Preliminary effects of selenium supplementation. *Biological Trace Elements Research* **47**, 201–207.

van Rij AM, McKenzie JM, Thomson CD & Robinson MF (1981) Selenium supplementation in total parenteral nutrition. *Journal of Parenteral and Enteral Nutrition* **5**, 120–124.

van't Veer P, van der Weilen RP, Kok FJ, Hermus RJ & Sturmans F (1990) Selenium in diet, blood and toenails in relation to breast cancer: a case-control study. *American Journal of Epidemiology* **131**, 987–994.

Vendeland SC, Beilstein MA, Yeh JY, Ream W & Whanger PD (1995) Rat skeletal muscle selenoprotein W: cDNA clone and mRNA modulation by dietary selenium. *Proceedings of the National Academy of Sciences of the United States of America* **92**, 8749–8753.

Verlinden M, van Sprundel M, Van der Auwera JC & Eylenbosch WJ (1983) The selenium status of Belgian population groups. I. Healthy adults. *Biological Trace Elements Research* **5**, 103–113.

Vernie L, de Vries M, Benckhuijsen C, de Goeij J & Zegers C (1983) Selenium levels in blood and plasma, and glutathione peroxidase activity in blood of breast cancer patients during adjuvant treatment with cyclophosphamide, methotrexate and 5-fluorouracil. *Cancer Letters* **18**, 283–289.

Vertongen F, Nève J, Cauchie P & Molle L (1984) Zinc, copper, selenium and glutathione peroxidase in plasma and erythrocytes of Down's sundrome (trisomy 21) patients. Interpretation of some variations. In *Trace Element Analytical Chemistry in Medicine and Biology*, vol. 3, pp. 175–181 [P Brätter and P Schramel, editors]. New York, NY: de Gruyter.

Vézina D, Mauffette F, Roberts KD & Bleau B (1996) Selenium-vitamin E, supplementation in infertile men. Effects on semen parameters and micronutrient levels and distribution. *Biological Trace Elements Research* **53**, 65–83.

Viegas-Crespo AM, Nève J, Monteiro ML, Amorin MF, Paulo OS & Halpern MJ (1994) Selenium and lipid parameters in plasma of Portuguese subjects. *Journal of Trace Elements and Electrolytes in Health and Disease* **8**, 119–112.

Virtamo J, Valkeila E, Alfthan G, Punsar S, Huttunen JK & Karvor MJ (1987) Serum selenium and risk of cancer. A prospective follow-up of nine years. *Cancer* **10**, 145–148.

Waiyaki B (2000) Status of cadmium, lead and selenium in the soils of selected African countries and perspectives of their effects on human and environmental health. In *Soils Groundwater Pollution Remediatic*, pp. 347–374 [PM Huang, IK Islander and IK Lewis, editors]. Boca Raton, FL: Lewis.

Wallaeys B, Cornelis R, Mees L & Lameire N (1986) Trace elements in patients with renal insufficiency on continuous ambulatory peritoneal dialysis. *Acta Physiologica et Toxicologica* **59**, 435–437.

Wang GY, Zhou RH, Sun SZ, Yin TA, Wang HZ, You DQ & Yang GQ (1979) The difference in blood and hair selenium contents in residents of Keshan disease endemic and non-endemic areas: correlation between blood selenium and hair selenium. *Chinese Journal of Preventive Medicine* **13**, 204–209.

Ward KP, Arthur JR, Russell G & Aggett PJ (1984) Blood selenium content and glutathione peroxidase activity in children with cystic fibrosis, coeliac disease, asthma and epilepsy. *European Journal of Pediatrics* **142**, 21–24.

Wasowicz W, Wolkanin P, Bednarski M, Gromadzinska J, Sklodowska M & Grzybowska K (1993) Plasma trace elements (Se, Zn, Cu) concentrations in maternal and umbilical cord

blood in Poland. Relation with birth weight, gestational age and parity. *Biological Trace Elements Research* **38**, 205–215.
Wasowicz W & Zachara BA (1987) Selenium concentrations in the blood and urine of a healthy Polish sub-population. *Journal of Clinical Chemistry Clinical Biochemistry* **25**, 409–412.
Watkinson JH (1974) The selenium status of New Zealanders. *New Zealand Medical Journal* **80**, 202–205.
Watkinson JH (1987) Annual topdressing of pasture with selenate pellets to prevent selenium deficiency in grazing stock: Research and farming practice in New Zealand. In *Selenium in Biology and Medicine*, vol. B, pp. 783–792 [GF Combs Jr, JE Spallholz, OA Levander and JE Oldfield, editors]. Westport, CN: AVI Publishing Co.
Wei A (1996) Soybean sprout. *Zhengzhou Liangshi Xueyuan Xuebao* **17**, 67–70.
Wells N (1967) *Total selenium in top soils*, New Zealand Soil Bureau Atlas, maps 89 and 90. WellingtonGovernment Printer.
Wen Z, Chen X, Fu P, Qian P, Liu R & Huang J (1987) Effect of long-term selenium supplementation on the incidence of Keshan disease. In *Selenium in Biology and Medicine*, vol. B, pp. 902–904 [GF Combs Jr, JE Spallholz, OA Levander and JE Oldfield, editors]. Westport, CN: AVI Publishing Co.
Westermarck T (1977) Selenium content of tissues in Finnish infants and adults with various diseases, and studies on the effects of selenium supplementation in neuronal ceroid lipofuscinosis patients. *Acta Pharmacologica et Toxicologica* **41**, 121–128.
Whanger PD, Beilstein MA, Thomson CD, Robinson MF & Howe M (1988) Blood selenium and glutathione peroxidase activity of populations in New Zealand, Oregon and South Dakota. *FASEB Journal* **2**, 2996–3002.
Whanger PD, Xia Y & Thomson CD (1994) Protein technics for selenium speciation in human body fluids. *Journal of Trace Elements and Electrolytes in Health and Disease* **8**, 1–7.
Wilke B, Vidailhet M, Guillemin C, Favier A, Ducros Y, Arnaud J & Richard MJ (1988) Plasma and erythrocyte selenium (Se), glutathione peroxidase (GSH-Px), malondialdehyde (MDA) and plasma lipid hydroperoxides (LH) as a function of Se supplementation in 12 treated phenylketonuric (PKU) children. In *Selenium in Medicine and Biology*, pp. 337–340 [J Nève and A Favier, editors]. New York, NY: de Gruyter.
Wikström J, Westermarck T & Palo J (1976) Selenium, vitamin, E, and copper in multiple sclerosis. *Acta Neurologica Scandinavica* **54**, 287–290.
Willett WC, Polk BF, Morris JS, Stampfer MJ, Pressel S, Rosner B, Taylor JO, Schneider K & Hames CG (1983) Prediagnostic serum selenium a risk factor for cancer? *Medical Oncology and Tumor Pharmacotherapy* **2**, 157–163.
World Health Organization (1996) Selenium. In *Trace Elements in Human Nutrition and Health*, pp. 105–122, GenevaWHO.
Xia Y, Paio J, Hill KE & Burk RF (1992*a*) Biochemical changes in a selenium-deficient population in China. *Proceedings of the Fifth International Symposium on Selenium in Biology and Medicine*, Vanderbilt University, p. 36 (abstract).
Xia Y, Zhao X, Zhu L & Whanger PD (1992*b*) Distribution of selenium in erythrocytes, plasma and urine of Chinese men of different selenium status. *Journal of Nutritional Biochemistry* **3**, 211–216.
Xia YM, Hill KE & Burk RF (1989) Biochemical studies of a selenium-deficient population in China: measurement of selenium, glutathione peroxidase and other antioxidant defense indices in blood. *Journal of Nutrition* **119**, 1318–1326.
Xian G, Cai H, He Y & Li C (1997) Study of nutrition of Ca, P, Fe, Zn and Se of old people in Guangzhou city. *Guangdong Weiliang Yuansu Kexue* **4**, 38–41.
Xiong Y, Mo D, Bi H, Li S, Guo X, Yu Z, Luo Y, Feng J, Zhang L & Yang J (1998) Effect of selenium on lesion of articular cartilage fed on T-2 toxin in Chinese mini-pigs with experimental Kaschin-Beck disease. *Xi'an Yike Daxue Xuebao* **19**, 523–525.
Xu B, Chia SE & Ong CN (1994) Concentrations of cadmium, lead, selenium and zinc in human blood and seminal plasma. *Biological Trace Elements Research* **40**, 49–57.
Xu GL, Wang SC, Sun J, Gu BQ, Yang YX, Song HB, Tan W, Xua W, Liang WS & Zhang P (1997*a*) Role of selenium deficiency in the etiology and pathogenesis of Keshan disease. *J Xi'an Medical University* **9**, 98–106.
Xu GL, Wang SC, Gu BQ, Yang YX, Song HB, Xue HL, Liang WS & Zhang P (1997*b*) Further investigation on the role of selenium deficiency in the aetiology and pathogenesis of Keshan disease. *Biomedical and Environmental Science* **10**, 316–326.
Xu Q, Xu Y, Liu Y & Liu S (1996) Compound low sodium content health table salt. *Faming Sheqing Gongkai Shoumingshu* (CN, 1,116,505. Cl. A23L1/237).
Xue TL & Hartikainen H (2000) Association of antioxidative enzymes with the synergistic effect of selenium and, UV, irradiation in enhancing plant growth. *Agriculture and Food Science in Finland* **9**, 177–187.
Yadav S, Day JP, Mohan V, Snehalatha C & Braganza JM (1991) Selenium and diabetes in the tropics. *Pancreas* **6**, 528–533.
Yamaguchi T, Chimura K, Kurokawa Y, Hamada M, Inoue K & Shibuya N (1992) Selenium concentration and glutathione peroxidase activity in plasma and erythrocytes from human blood. *Journal of Clinical Biochemistry Nutrition* **12**, 41–50.
Yang GQ, Qian PC, Zhu LZ, Huang JH, Liu SJ & Lu MD (1987) Human selenium requirements in China. In *Selenium in Biology and Medicine*, vol. A, pp. 589–594 [GF Combs Jr, JE Spallholz, OA Levander and JE Oldfield, editors]. Westport, CN: AVI Publishing Co.
Yang GQ, Wang GY & Yin TA (1982) Relation between the distribution of Keshan disease and selenium status. *Acta Nutrimentia Sinica* **4**, 191–200.
Yang GQ, Wang S, Zhou R & Sun S (1983) Endemic selenium intoxication of humans in China. *American Journal of Clinical Nutrition* **37**, 872–881.
Yang GQ, Yin S, Zhou R, Gu L, Yan B, Liu Y & Liu Y (1989*b*) Studies of safe maximal daily dietary Se-intake in a seleniferous area in China. Part II Relation between Se-intake and the manifestations of clinical signs and certain biochemical alterations in blood and urine. *Journal of Trace Elements and Electrolytes in Health and Disease* **3**, 123–130.
Yang GQ & Zhou RH (1994) Further studies on human maximum safe dietary selenium intake and a discussion on some related problems. *Journal of Trace Elements and Electrolytes in Health and Disease* **8**, 159–165.
Yang GQ, Zhou R, Yin S, Gu L, Yan B, Liu Y & Li X (1989*a*) Studies of safe maximal daily dietary Se-intake in a seleniferous area in China. Part I Selenium intake and tissue selenium levels of the inhabitants. *Journal of Trace Elements and Electrolytes in Health and Disease* **3**, 77–85.
Yoshida M, Fukunaga K, Tsuchita H & Yasumoto K (1999) An evaluation of the bioavailability of selenium in high-selenium yeast. *Journal of Nutritional Science and Vitaminology* **45**, 119–128.
Yoshita K, Tabata M, Kimura R, Miyashita Y, Hayashi K, Sagara T & Nakagawa H (1998) Relationship between selenium intake and foods intake and nutrients intake in middle-aged men. *Eiyogaku Zasshi* **56**, 19–148.
Yu MW, Horng IS, Hsu KH, Chaing YC, Liaw YF & Chen CJ (1999) Plasma selenium levels and risk of hepatocellular carcinoma among men with chronic hepatitis virus infection. *American Journal of Epidemiology* **150**, 367–374.
Yu S, Mao B, Xiao P, Yu W, Wang Y, Huang C, Chen W &

Xuan X (1990) Intervention trial with selenium for the prevention of lung cancer among tin miners in Yunnan, China. A pilot study. *Biological Trace Elements Research* **24**, 105–108.

Yu SY, Zhu YJ & Li WG (1997) Protective role of selenium against hepatitis B virus and primary lever cancer in Qidong. *Biological Trace Elements Research* **56**, 117–124.

Zachara BA, Rybakowski J, Borowska K, Pilaczycska E, Zamorski R & Stefaniak B (1988) Blood selenium concentration and glutathione peroxidase activity in male patients with alcohol dependence. In *Selenium in Medicine and Biology*, pp. 269–272 [J Nève and A Favier, editors]. New York, NY: de Gruyter.

Zachara BA, Wasowicz W, Gromadzinska J, Sklodowska M & Krasomski G (1986) Glutathione peroxidase activity, selenium, and lipid peroxide concentrations in blood from a healthy Polish population. I. Maternal and cord blood. *Biological Trace Elements Research* **10**, 175–187.

Zachara BA, Wasowicz W, Sklodowska M & Gromadzinska J (1987) Selenium status, lipid peroxides concentration and glutathione peroxidase activity in the blood of power station and rubber factory workers. *Archives in Environmental Health* **42**, 223–229.

Zhou MH (1990) Influence of selenium on growth, root vigor and seed morphology of rice. *Guizhou Journal of Agricultural Science (China)* **15**, 57–59.

Zhuk LI, Kist AA, Mikolskaya IN, Osinskaya NS, Tillayev T, Tursunbayev SI & Agzamova SV (1988) Elemental blood composition of the inhabitants of Uzbekistan. *Journal of Radioanalytical and Nuclear Chemistry* **120**, 369–377.

Zhuk LI, Mikholskaya IN, Danilova EA & Kist AA (1994) Mapping using human blood composition data. *Biological Trace Elements Research* **43–45**, 371–381.

Zima T, Mestek O, N'eme'cek K & Bartova V (1998) Trace elements in hemodialysis and continuously ambulatory peritoneal dialysis patients. *Blood Purification* **16**, 253–260.

Zimmleri B, Haldimann M, Siber R, (1998) Selenium status of the Swiss population. Part 3. Changes and its causes. *Mitteilungen aus dem Gebiete der Lebensmitteluntersuchung und Hygiene* **89**, 257–293.