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# Dietary Intake of Lead and Cadmium from Foods in Tarragona Province, Spain

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For most people, the main route of exposure to heavy metals is through the diet. Lead and cadmium are ubiquitously distributed throughout the environment and it is unavoidable that traces of these metals can be detected in virtually all plant and animal organisms, and hence in our food (Sherlock et al. 1983; Piscator 1985). Lead alkyl additives in petrol are combusted and emitted into the atmosphere, and are responsible for high concentrations of lead in soil, air, water, and plants localized close to areas with heavy traffic (Webb and Burley 1962; Burguera et al. 1988; Bosque et al. 1990). On the other hand, each year considerable amounts of cadmium are deposited on agricultural lands and gardens by the application of phosphate fertilizers (Ryan et al. 1982). Also, in recent years there has been growing concern that acid rain may increase the availability of cadmium in soil and, thus, causing further increases in cadmium concentrations in agricultural products (Piscator 1985).

Evidence of the deleterious effects of lead on human health dates back to the ancient Roman and Greek civilizations (Gilfillan 1965). The presence of lead in storage vessels for water or wine, in pipes that carried water, and in cooking and eating utensils provided increased potential for lead ingestion and poisoning. Even modern-day civilizations have not entirely escaped lead ingestion since paints, gasoline, storage batteries, and certain industrial processes still represent high risks for poisoning (Thomas and Brogan 1983). With regard to cadmium, although the majority of human beings are exposed to this heavy metal via food, water, and air (Piscator 1985), it is now well established that the diet is the major source of exposure to cadmium among the general population, and that cigarette smoking is and additional source of

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non-occupational exposure to this metal (Watanabe et al. 1987; Ikeda et al. 1989).

Food reaches the consumer as the end-product of a long chain of preparation and processing operations during which it can be contaminated by heavy metals including lead and cadmium. Agricultural technology, industrial pollution, and food processing may be potential sources of contamination of foods by lead and cadmium. Thus, information about dietary intake is important in assesing risks to human health from both metals. The provisional tolerable weekly intakes (PTWI-values) of lead and cadmium established by the World Health Organization (1972) for adults are 430 μg/d and 60-70 μg/d, respectively.

Tarragona Province is an important industrial and agricultural area of Catalonia (NE Spain). The North of the province is essentially industrial, whereas the South is basically agricultural, with an additional important commercial fishing industry in both areas. Two rivers, the Ebro (South) and the Francoli (North) flow into the Mediterranean Sea at the Tarragona coastal waters, which are subjected to large loads of toxic residues including metals.

In previous studies, the average content of lead and cadmium in marine species and edible vegetables commonly consumed by the inhabitants of Tarragona was previously estimated (Bosque et al. 1990; Schuhmacher et al. 1990). The purpose of the present work was to determine lead and cadmium content in common basic items of the major food groups, as well as to calculate the daily intake of lead and cadmium by the population from Tarragona.

## MATERIALS AND METHODS

There are three methods currently used by investigators for estimating dietary intake of heavy metals and other substances: the total diet study, diary studies, and duplicate diet (Sherlock et al. 1983). The present work was carried out in accordance with the first method. In a total diet study as defined by the World Health Organization (1985), the daily contaminant intake for each food item is calculated by multiplying the contaminant concentration of a food item by the weight of that group consumed for an "average" person, and then summing these products for all food groups in each diet. Each single total diet comprises food purchased in various places of Tarragona Province; thus, the total diet study provides information on dietary intake of lead and cadmium by the "average" person in that area.

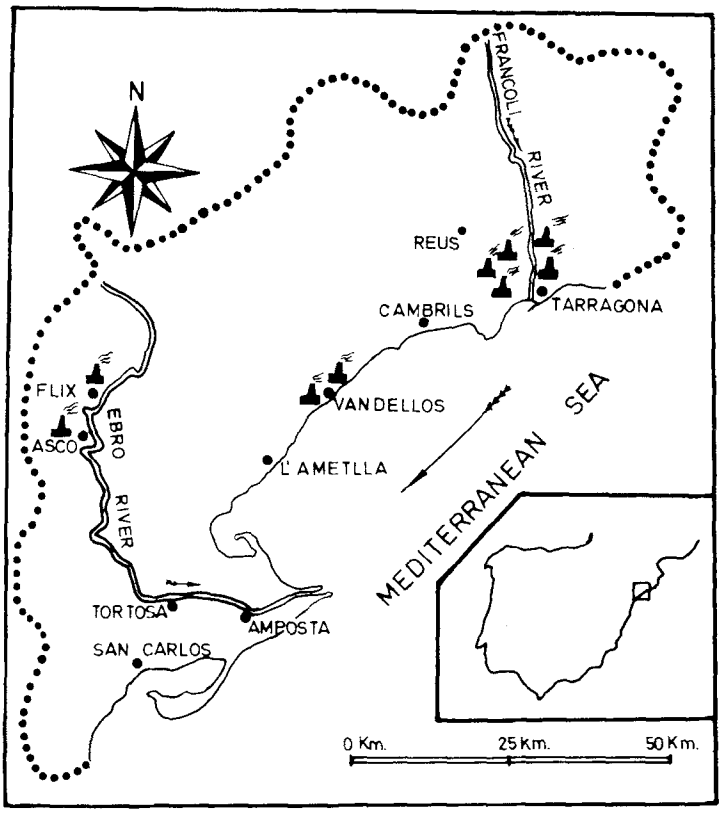


**Fig.1** Geographical location.

Food samples were obtained either directly from commercial growers or from retail outles in several sources of Tarragona Province divided into northern and southern areas (Figure 1). The total diet was divided into ten groups according to previous works by Salas et al. (1985a,b,c,): meat and offal (veal, lamb, pork, pork liver, blood sausage, and lamb brain), fish and seafood (sardine, hake, anchovy, red mullet, clam and mussel), eggs, pulses (lentils, beans, and chickpeas), bread and cereals (rice, flour and noodles), vegetables (chard, spinach, lettuce. green bean, cabbage, cauliflower, artichoke and tomato), roots and tubers (onion, potato, leek, and carrot), fruits (cherry, peach, pear, apple, plum, grape, strawberry, banana, apricot, and orange), sugar, and milk.

Lead and cadmium concentrations in fish and seafood as well as in edible vegetables were measured according to methods described previously (Bosque et al. 1990; Schuhmacher et al. 1990). To determine the amount of lead and cadmium in the remaining food items, approximately 1 g of each homogenized (or liophilized for eggs and milk) dry sample was digested with 2 ml of

65% nitric acid (Merck, Darmastadt, FRG) heating at 110 °C for 18 hr. When the fat content was high, the sample was previously heated with 1 ml of perchloric acid for 12 hr. On completion of the digestion and after adequate cooling, solutions were then made up to 10 ml with deionized water and stored in polyethylene bottles.

Lead concentrations were determined by atomic absorption spectrophotometry with a Perkin-Elmer 5100 Zeeman spectophotometer and Spectra A-30 graphite furnace. The standard addition method was employed, and $NH_4H_2PO_4$ was used as matrix modifier. cadmium concentrations were measured in a computer controlled sequential inductively coupled plasma spectrometer (Jobin Yvon JY 38 VHR) using the specifications recommended by the manufacturer. Detection limits were 0.015 μg/g for lead and 0.002 μg/g for cadmium. Three replicate determinations were made for each solution. All necessary precautions were adopted to avoid possible contamination of the samples. Lead and cadmium recoveries were assessed by analyses of Bovine Liver (National Bureau of Standards SRM 1577). The mean recovery rates obtained were 97.1% for lead and 88.7% for cadmium.

The amount of lead and cadmium intake was calculated from daily consumption for each food item (Salas et al. 1985a,b,c). The average lead and cadmium intakes were then compared with PTWI-values.

**RESULTS AND DISCUSSION**

The mean lead and cadmium concentrations in commom food items consumed by the population of Tarragona Province are shown in Figures 2 and 3. Fish and seafood, pulses and green vegetables were the groups with the highest content of both metals. In contrast, milk showed the lowest concentration of lead and cadmium.

Table 1 summarizes the total daily intake of lead and cadmium by the inhabitants of Tarragona Province. Total dietary intake (μg/d) of each metal was calculated by multiplying the concentration of lead or cadmium in a food group (μg/kg) by the weight of that group consumed for an average person (kg/d), and then summing these products for all food groups. The amount of daily intake of each food group was taken from previous studies (Salas et al. 1985a,b,c). Total daily intakes of lead and cadmium were 114.77 μg/d and 56.31 μg/d, respectively. The intake of cadmium is high when compared to the PTWI-value, which for adults is 60-70 μg/d (World Health Organization 1972). Cadmium intake

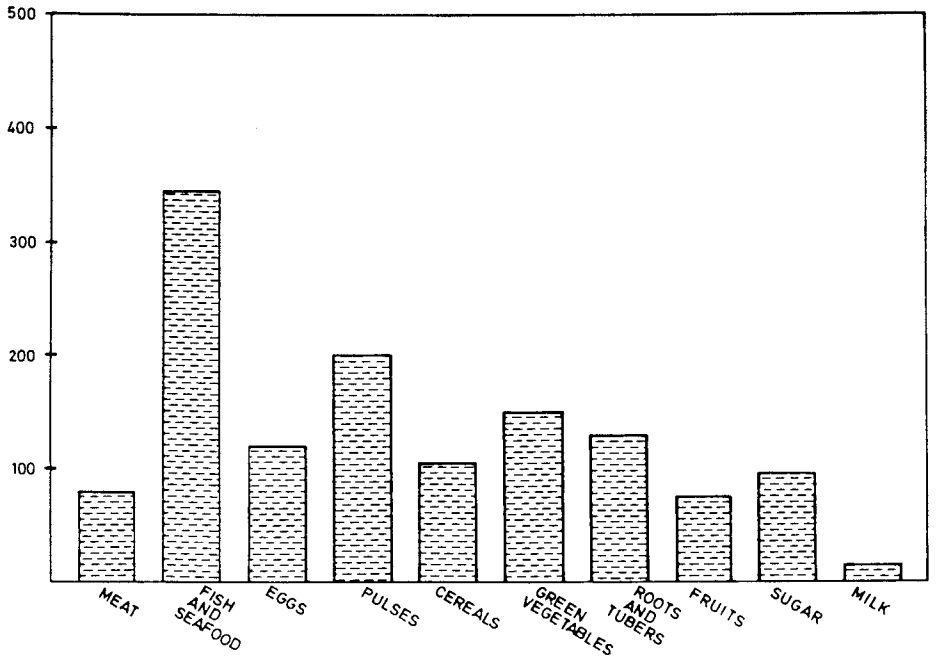


**Figure 2.** Lead concentrations (μg/kg wet weight) in some common food items from Tarragona Province, Spain.

by consumers in Tarragona Province is about three times higher than the cadmium intake in Finland, but comparable to the values reported for West Germany and Japan (Louekari and Salminen 1986).

Estimates of the daily intake of cadmium in various countries based mainly on the data on cadmium concentrations in food were summarized by Friberg et al. (1974). More recently, Piscator (1985) reviewed data on dietary intake of cadmium in several countries. The results were variable depending on the country and the method used to measure the concentration of cadmium. However, in most places the daily intake of cadmium is lower than the corresponding PTWI-value, with regional and individual variations.

Estimates from various countries show that vegetables, potatoes, and cereals provide a major portion of the cadmium intake because they are major components of the diet (Ryan et al. 1982; Pisator 1985), whereas in Tarragona Province green vegetables, fish and seafood, and fruits are the food groups that contribute substantially to the total intake of this metal.
Toxicologically it is a great concern to know the daily intake of heavy metals by consumers. It has been

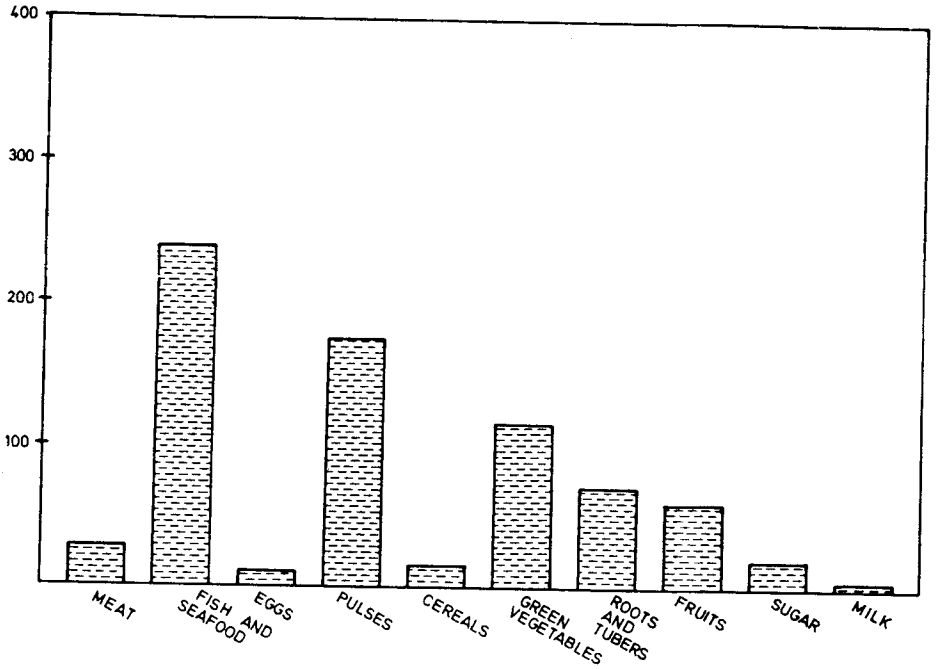


**Figure 3.** Cadmium concentrations (μg/kg wet weight) in some common food items from Tarragona Province, Spain.

reported that a cadmium concentration of about 200 mg/kg wet weight in renal cortex provokes a decrease in tubular reabsorption of proteins an increased excretion of low

molecular weight proteins (Piscator 1985). However, it has been estimated that for a 70-kg person, a daily intake of about 250 μg cadmium is needed to reach the 200 mg/kg level (Piscator 1985). According to recent results of an epidemiological study carried out in Japan, it has been reported that the total cadmium intake that produces an adverse effect on health would be approximately 2,000 mg for both men and women (Nogawa et al. 1989). Therefore, although relatively high, the average daily intake of cadmium by the population of Tarragona Province is within acceptable limits. For an intake of 56 μg Cd/day it would take 98 years to reach a toxic level of cadmium in the body. Assuming that some safety factor is deemed appropiate (5 for example), then the average person would reach the maximum tolerable level within 20 years.

On the other hand, the daily intake of lead in our area of study is lower than the mean intake in most countries, according to Horiguchi et al. (1978) who

**Table 1.** Total dietary intake of lead and cadmium by food groups in Tarragona Province, Spain.

| Food group | Consumption (kg/d) | Mean lead intake (μg/d) | Mean cadmium intake (μg/d) |
|---|---|---|---|
| Meat and offal | 0.179 | 14.14 | 4.17 |
| Fish and seafood | 0.049 | 16.98 | 11.67 |
| Eggs | 0.035 | 4.17 | 0.42 |
| Legumes | 0.015 | 2.97 | 2.61 |
| Bread and cereals | 0.186 | 19.53 | 2.98 |
| Green vegetables | 0.128 | 19.07 | 14.72 |
| Roots and tubers | 0.095 | 12.26 | 6.37 |
| Fruits | 0.157 | 11.93 | 9.89 |
| Sugar | 0.109 | 10.46 | 2.18 |
| Milk | 0.217 | 3.26 | 1.30 |
| Total intake | 1.170 | 114.77 | 56.31 |

summarized results of lead exposure in 30 countries.

Nevertheless, these authors assumed that lead content in food would be equal in all countries, which seems to be a very strong assumption. The dietary lead intake determined in the present study is lower than those reported by Louekari and Salminen (1986) in West Germany and Japan but higher than the intake in Finland. Moreover, in a recent study the dietary intake of lead among Japanese farmers was only 38.2 μg/d for

males and 32.8 μg/d for females, levels which are lower than most published values (Ikeda et al. 1989). It has been reported that vegetables and fruits are the food groups with the highest contribution to the total intake of lead (Louekari and Salminen 1986). In our study, green vegetables, bread and cereals, fish and seafood, and meat and offal were the food groups with the highest contribution to the total daily intake of this metal. In any case, the average daily intake of lead and cadmium by the population from Tarragona Province does not seem to pose a serious health risk.

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## REFERENCES


Bosque MA, Schucmacher M, Domingo JL, Llobet JM (1990) Concentrations of lead and cadmium in edible vegetables from Tarragona Province, Spain. Sci Total Environ (in press)

Burguera JL, Burguera M, Rondon C (1988) Lead in roadside soils of Mérida City, Venezuela. Sci Total Environ 77: 45-49

Friberg L, Piscator M, Nordberg GF, Kjelstrom T (1974) Cadmium in the environment, 2nd ed, CRC Press Cleveland, Ohio

Gilfillan SC (1965) Lead poisoning and the fall of Rome. J Occup Med 7: 53-60

Horiguchi S, Teramoto K, Kurono T, Ninomiya K (1978) An attempt at comparative estimate of daily intake of several metals (As, Cu, Pb, Mn, Zn) from foods in thirty countries in the world. Osaka City Med J 24: 237-242

Ikeda M, Watanabe T, Koizumi A, Fujita H, Nakatsuka H, Kasahara M (1989) Dietary intake of lead among Japanese farmers. Arch Environ Health 44: 23-29

Louekari K, Salminen S (1986) Intake of heavy metals from foods in Finland, West Germany and Japan. Food Addit Contam 3: 355-362

Nogawa K, Honda R, Kido T, Tsuritani I, Yamada Y, Ishizaki M, Yamaya H (1989) A dose-response analysis of cadmium in the general environment with special reference to total cadmium intake limit. Environ Res 48: 7-16

Piscator M (1985) Dietary exposure to cadmium and health effects: impact of environmental changes. Environ Health Perspect 63: 127-132

Ryan JA, Pahren HR, Lucas JB (1982) Controlling cadmium in the human food chain: a review and rationale based on health effects. Environ Res 28: 251-302

Salas J, Font I, Canals J, Guinovart L, Sospedra C, Martin-Hennenberg C (1985a) Consumption, nutritional habits and nutritional status of the population from Reus. II. Age and sex distribution of the consumption of meat, fish, eggs and pulses. Med Clin 84: 423-427

Salas J, Font I, Canals J, Guinovart L, Sospedra C, Martin-Hennenberg C (1985b) Consumption, nutritional habits and nutritional status of the population from Reus. III. Age and sex distribution of the consumption of milk, dairy products, visible vegetables, fats and green vegetables. Med Clin 84: 470-475

Salas J, Font I, Canals J, Guinovart L, Sospedra C, Martin-Hennenberg C (1985c) Consumption, nutritional habits and nutritional status of the population from Reus. IV. Age and sex distribution of the consumption of roots, tubercles, cereals,

sugars and fruits. Med Clin 84: 557-562
Schuhmacher M, Bosque MA, Domingo JL, Corbella J (1990) Lead and cadmium concentrations in marine organisms from the Tarragona coastal waters, Spain. Bull Environ Contam Toxicol 44: 784-789
Sherlock J, Smart GA, Walters B (1983) Dietary surveys on a population at Shiphan, Somerset, United Kingdom. Sci Total Environ 29: 121-142
Thomas JA, Brogan WC (1983) Some actions on the sperm and on the male reproductive system. Am J Ind Med 4: 127-134
Watanabe T, Abe H, Kido K, Ikeda M (1987) Relationship of cadmium levels among blood, urine, and diet in a general population. Bull Environ Contam Toxicol 38: 196-202
Webb KL, Burley JWA (1962) Contamination of vegetation by tetraethyl lead. Science 137: 765-766
World Health Organization (1972) Food Additives. WHO Technical Report Series Nº 505, World Health Organization, Geneva
World Health Organization (1985) Guidelines for the study of dietary intakes of chemical contaminats. WHO Offset Publication Nº 87, World Health Organization, Geneva

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