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Are more restrictive food cadmium standards justifiable health safety measures or opportunistic barriers to trade? An answer from economics and public health

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ABSTRACT

In the past, Cd regulations have imposed trade restrictions on foodstuffs from some developing countries seeking to access markets in the developed world and in recent years, there has been a trend towards imposing more rigorous standards. This trend seems to respond more to public and private sectors strategies in some developed countries to create disguised barriers to trade and to improve market competitiveness for their industries, than to scientifically justified health precautions (sanitary and phytosanitary measures) and/or technical barriers to trade acceptable under the Uruguay Round Agreement of the WTO. Applying more rigorous Cd standards in some developed countries will not only increase production costs in developing countries but it will also have a large impact on their economies highly dependent on international agricultural markets. In the current literature there are large uncertainties in the cause–effect relationship between current levels of Cd intakes and eventual health effects in human beings; even the risk of Cd to kidney function is under considerable debate. Recent works on the importance of zinc:Cd ratio rather than Cd levels alone to determine Cd risk factors, on the one hand, and on the declining trends of Cd level in foods and soils, on the other, also indicate a lack of scientific evidence justifying more restrictive cadmium standards. This shows that developing countries should fight for changing and making more transparent the current international structures and procedures for setting sanitary and phytosanitary measures and technical barriers to trade.

1. Introduction

Cadmium (Cd) inputs are mainly from atmospheric deposition, application of biosolids, use of phosphate fertilizers, and from effluents from cadmium-using and recycling industries (Syers and Gochfeld, 2000).

While the sources of Cd emissions to the environment have been listed in some detail in many reports (Nriagu and Pacyna, 1998; Jackson and MacGillivray, 1993; WHO, 1992; Cook and Morrow, 1995; Jensen and Bro-Rasmussen, 1992), there have been very few attempts to determine human Cd exposure to its various sources. One such effort is reported by Van Assche and Ciarletta (1993) and Van Assche (1998), who developed a model for Cd exposure for human beings and allocated this exposure to the various sources. The model estimated that the relative importance of various cadmium sources to human exposure is as follows (Van Assche, 1998): phosphate fertilizers 41.3%, fossil fuel combustion 22%, iron and steel production 16.7%, natural sources 8%, non-ferrous metals 6.3%, cement production 2.5%, cadmium products 2.5% and incineration 1%.

Recently, there has been an increasing concern, mainly in the developed world, about exposures, intakes and absorption

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of Cd by humans, where increasingly affluent populations are demanding a cleaner environment in general, and reductions in the amounts of contaminants reaching people as a result of increasing human activities. A practical implication of this trend in the developed countries has been the imposition of new and more restrictive regulations, which prohibit or restrict the production, uses and/or ways of disposing of goods, services and byproducts and wastes. Such changes also increase the costs of acquiring, using, enjoying or discarding products. Another implication is the potential and/or real distortion created by these regulations in different markets, which sometimes extend to the international trade and affect not only the developed countries issuing such regulations but also the markets and producers in the developing countries.

This paper analyzes the effects that more restrictive cadmium standards can have for the developing countries in the future.

2. Cadmium and people

Food products account for most of the human exposure to cadmium, except in the vicinity of cadmium-emitting industries (ExtoxNet, 2003). The average cadmium levels in food range from 2 to 40 ppb. The level of cadmium in most drinking water supplies is less than 1 ppb. Air levels normally range from 5 to 40 ng/m^3 (EBI, 2003). For the general population, the average person ingests about 30 micrograms (μg) of cadmium from food each day. The intake from inhaled air is small because the Cd concentration is usually below 0.01 μg/m^3 (WHO, 1972). For smokers, cigarette smoke is a large potential source of Cd exposure, their intake can be an additional 1 to 4 μg per day from cigarettes, assuming that 20 cigarettes per day may lead to an inhalation of 2–4 μg Cd of which 25% can be absorbed (WHO, 1972). Average cadmium levels in cigarettes range from 1000 to 3000 parts per billion (ppb).

Cadmium is taken up through the roots of plants to edible leaves, fruits and seeds. During the growth of grains such as wheat and rice, cadmium taken from the soil is concentrated in the core of the kernel, while zinc (Zn) is found mostly in the germ and bran. With processing Zn is lost, increasing the Cd:Zn ratio. Refined flours, rice, and sugar all have relatively higher ratios of cadmium to zinc than do the whole foods. Cadmium will also accumulate in animal milk and fatty tissues (Kaneta et al., 1986). Therefore, people are exposed to cadmium when consuming plant- and animal-based foods. Seafood, such as mollusks and crustaceans, can be a source of cadmium, as well. In fact, most foods, including shellfish, have trace amounts of contaminants and heavy metals. For most species the levels of these contaminants are well below established standards at which adverse health effects might occur. However, Canadian authorities advise consumers to be aware of elevated levels of cadmium found in British Columbia oysters and whole scallops, because exposure to elevated levels of cadmium over an extended period of time may result in damage to the kidneys (CFIA, 2003).

Cadmium concentrations in most foods range from about 0.01 to 0.05 mg/kg, although higher levels were found in nuts and oil seeds, mollusks, and offal (especially liver and kidney) (JECFA, 2003). In a recent study regarding the major dietary sources of cadmium in several countries, the Food and Agriculture Organization/World Health Organization (FAO/WHO) Joint Expert Committee on Food Additives (JECFA) determined that the following foods contribute 10% or more to the Provisional Tolerable Weekly Intake (PTWI) in at least one of the GEMS/Food regions: rice, wheat, starchy roots/tubers, and mollusks. Vegetables (excluding leafy vegetables) contribute >5% to the PTWI in two regions.

Table 1 shows that the daily intake of Cd appears to be of the order of 50 μg in some European countries and the United States, whereas in unpolluted areas of Japan the level is higher. The accuracy of these data is supported by data on the Cd content of faeces, because the fecal output of Cd is about 90% of the amount ingested. In West Germany, the mean daily fecal output of Cd was found to be 31 μg; 42 μg in three American individuals; and 57 μg in Japanese subjects (WHO, 1972). In Table 1 it is possible to see that in other European

Table 1 – Daily intake of cadmium from food; different countries

Country	Daily intake (μg/day)	Reference
Australia	4.9–15.4 [a]	FSANZ (2002)
	5.6 – 16.8 [b]	Satarug et al. (2002)
	20–30	Hardy (1998)
	22	Satarug et al. (2003)
Basque Country (Spain)	11 [c]	Jalón et al. (1997)
Canada	13	Dabeka and McKenzie (1995)
Canary Island (Spain)	11.2 [c]	Rubio et al. (2006)
Catalonia (Spain)	15.7 [d]	Llobet et al. (2003)
Croatia	17.3	Sapunar-Postruznik et al. (1996)
Czech Republic	15 [c]	Ruprich (1998)
Europe	10–30	Nasreddine and Parent-Massin (2002)
Finland	14.5	Louekari et al. (1991)
Germany	25.9 [c]	Wilhelm et al. (2002)
	2.6 [e]	Wilhelm et al. (2005)
	48	Essing et al. (1969)
Hong Kong	21.4 [f]	HKSAR (2002)
Italy	19–46 [g]	Coni et al. (1992)
Japan	59–113	JPHA (1970)
	41	Tsuda et al. (1995)
Lebanon	12 [c]	Nasreddine et al. (2006)
New Zealand	28	NZTDS (2000)
Poland	15–21 [g]	Marzec and Bulinski (1991)
Romania	38–64	Rautu and Sporn (1970)
Several countries	7–63	JECFA (2003)
Slovak Republic	12–14 [c]	Krizova et al. (2005)
United States	4–60	Schroeder and Balassa (1961)
UK	16 [c]	MAFF (1999)

Source: elaborated with data from WHO (1972) and the additional mentioned sources.
[a] For a 70 kg-female of 25–34 years.
[b] For a 70 kg-male of 25–34 years.
[c] For an adult of 70 kg.
[d] Male adult.
[e] Child of 8 kg.
[f] For an average secondary student of 60 kg. Those above the 95 percentile of highest showed an intake 2.3 times higher.
[g] Average person.

Table 2 – International regulation and recommendations on cadmium consumption

Country	Concept	Level
United States	Environmental Protection Agency (EPA)	
	Drinking water	
	Current standard	5 ppb
	Interim maximum contaminant level (MCL)	0.01 mg/l
	Proposed max. contaminant level goal (MCLG)	0.005 mg/l (5 μg/1)
	Food and Drug Administration (FDA)	
	Food colors maximum	15 mg/k
	Fish meat	0.05 mg/kg
Canada	Federal government	
	Drinking water	0.005 mg/l
	Ontario Water Quality Objectives	
	Interim objective under development	0.01 mg/l (hardness 0–100 mg/l $CaCO_3$) 0.0005 mg/l (hardness > 100 mg/l $CaCO_3$)
Hong Kong	Food adulteration (metallic contamination) regulations[a]	
	Cereals and vegetables	0.1 ppb
	Fish, crab-meat, oysters, prawns and shrimps	2 ppb
	Meat of animal and poultry	0.2 ppb
Norway	Fish meat	0.05 mg/kg
Chile	Table salt[b]	0.5 mg/kg
	Table mineral water[b]	0.01 mg/l
	Potable water[c]	0.01 mg/l
European Communities	Meat of bovine animals, sheep, pig and poultry	0.05 mg/kg wet weight
	Horsemeat	0.2 mg/kg wet weight
	Liver of cattle, sheep, pig and poultry	0.5 mg/kg wet weight
	Kidney of cattle, sheep, pig and poultry	1.0 mg/kg wet weight
	Muscle meat of fish excluding those in the next two bullets[d]	0.05 mg/kg wet weight
	Muscle meat of the following fish: anchovy (*Engraulis* species), bonito (*Sarda sarda*), common two-banded seabream (*Diplodus vulgaris*), eel (*Anguilla anguilla*), grey mullet (*Mugil labrosus labrosus*), horse mackerel or scad (*Trachurus species*), louvar or luvar (*Luvarus imperialis*), sardine (*Sardina pilchardus*), sardinops (*Sardinops species*), tuna (*Thunnus species*, *Euthynnus species*, *Katsuwonus pelamis*), wedge sole (*Dicologoglossa cuneata*)[d]	0.1 mg/kg wet weight
	Muscle meat of swordfish (*Xiphias gladius*)[d]	0.3 mg/kg wet weight
	Crustaceans, excluding brown meat of crab and excluding head and thorax meat of lobster and similar large crustaceans (*Nephropidae* and *Palinuridae*)[d]	0.5 mg/kg wet weight
	Bivalve mollusks	1.0 mg/kg wet weight
	Cephalopods (without viscera)	1.0 mg/kg wet weight
	Cereals, excluding bran, germ, wheat grain and rice	0.1 mg/kg wet weight
	Soybeans	0.2 mg/kg wet weight
	Vegetables and fruits as defined in Article 1 of Directive 90/642/EEC, excluding leafy vegetables, fresh herbs, all fungi, stem vegetables, root vegetables and potatoes	0.05 mg/kg wet weight
	Leafy vegetables, fresh herbs, celeriac and all cultivated fungi	0.02 mg/kg wet weight
	Stem vegetables, root vegetables and potatoes, excluding celeriac. For potatoes the maximum level applies to peeled potatoes	0.1 mg/kg wet weight
New Zealand	Kidneys	2.5 mg/kg
	Liver	1.25 mg/kg
	Meat flesh	0.05 mg/kg
	Leafy vegetables	0.1 mg/kg
	Root and tuber vegetables	0.1 mg/kg
	Wheat	0.1 mg/kg
Sweden	Cereals	0.08 mg/kg Swedish Seal of Quality

[a]Maximum limit to import, consign, deliver, manufacture or sell, for human consumption.
[b]Food Sanitary Regulation (Supreme Decree 177/96, modified 30/7/2000.
[c]Chilean Norm 409, 1992.
[d]Commission regulation (EC) No. 78/2005 of 19 January 2005.

counties, such as Spain, Croatia, Czech Republic, Finland, Poland and the Slovak Republic de daily intake of Cadmium is in the range of 15 μg.

In 2003, in its 61st meeting, the FAO/WHO Joint Expert Committee on Food Additives (JECFA) updated its previous review of dietary intake of Cd by including new information from Australia, Croatia, France, Greece, Japan, Lithuania, Nigeria, Slovakia, Spain, and the European Union. Estimates of mean intake of Cd based on national studies ranged from 0.7 to 6.3 μg/kg of body weight per week (or 49 to 441 μg/week for an adult of 70 kg). Mean dietary intakes derived from the five WHO GEMS/Food Regional Diets (based on food balance sheets) and average cadmium concentrations in those regions range from 2.8 to 4.2 μg/kg of body weight per week (i.e., 196 to 294 μg/week for an adult of 70 kg). These estimates constitute approximately 40 to 60% of the current PTWI of 7 μg/kg of body weight (JECFA, 2003). The seven commodity groups that contributed significantly to total intake of Cd included rice, wheat, root vegetables, tuber vegetables, leafy vegetables, other vegetables, and mollusks. These commodities accounted for 40–85% of the total intake of Cd in the five GEMS/food regions (WHO, 2004).

3. International recommendations and standards for cadmium

At the 16th meeting of the FAO/WHO Joint Expert Committee on Food Additives, the Committee allocated a Provisional Tolerable Weekly Intake (PTWI) of 400–500 μg of cadmium per person; and, at its subsequent three meetings, the Committee retained this PTWI, but expressed it in terms of the weekly intake of cadmium per kg of body weight (7 μg per kg of body weight) (JECFA, 2003).

In June 2003, the JECFA concluded that the risk of excess renal tubular dysfunction in the population would be negligible below a urinary cadmium excretion of 2.5 μg/g of creatinine. At its 55th meeting, the Committee had decided that the prevalence of renal tublar dysfunction could serve as a reasonably basis for risk assessment. In June 2003, however, the Committee noted that these estimates are based on a model that is dependent on the values assumed for key parameters (e.g. dietary bioavailability, age dependency of the intake/excretion ratio). Although new information indicated that a proportion of the general population may be at increased risk of tubular dysfunction at the current PTWI of 7 μg/kg body weight (bw) (or 1 μg/kg bw per day), in its 61st meeting the Committee maintained the PTWI at this value because of lack of precision in the risk estimates (JECFA, 2003).

Various agencies have established limits for the discharge of Cd to air and water and the content of Cd in drinking water and ceramic plates and cups. The European Community has established the regulations for the Cd content for a number of different agricultural, meat and seafood products. These regulations, as explained in the next section, are causing an increasing number of rejections of imports of these products to the EU from different countries, especially developing countries. Some of these regulations as related to foodstuffs are shown in Table 2.

In the recent years, some developed countries have been proposing stricter cadmium standards for foods. In February of 2005, the JECFA held in Rome its sixty-fourth meeting devoted to the evaluation of food contaminants and, responding to a previous request of the Codex Committee on Food Addit Contam (CCFAC), evaluated the impact of different maximum levels (MLs) for cadmium in commodities that contribute significantly to intake. The assessment took into account the potential impact of different MLs on the distribution of concentrations of cadmium in each commodity (i.e. how eliminating samples containing Cd concentrations greater than the ML affected the mean value of the resulting distribution, and the proportion of samples containing Cd at concentrations greater than the ML) and the dietary intakes of cadmium from each individual commodity (i.e. how the mean concentration of Cd for each ML, affected mean intake of Cd).

The JECFA concluded that the effect of different MLs on overall intake of cadmium would be very small. At the proposed Codex MLs, mean intake of Cd would be reduced by approximately 1% of the PTWI. The imposition of stricter MLs, one level lower, would result in potential reductions in intakes of Cd of no more than 6% (wheat grain, potatoes) of the PTWI. Thus, the JECFA concluded, that a variation of these magnitude attributable to the use of the propose Codex MLs, and one level higher or lower, is of no significance in terms of risk to human health (WHO, 2006).

4. Effects of current standards for cadmium on developing countries

The enforcement of current Cd standards in developed countries has affected developing countries mainly through rejections of their export products. In fact, many developed countries have prohibited access to their markets of foreign products containing more cadmium than the levels accepted by their regulations.

The Health and Consumer Protection Directorate General of the European Commission has its Rapid Alert System for Food and Feed (RASFF), which provides European control authorities with an effective tool for exchanging information on measures taken to ensure food safety. The RASFF was established in 1979 as a network involving the Member States (EU+EFTA/EEA), the Commission and the European Food and Safety Authority (EFSA). By this system, whenever a member of the network has any information relating to the existence of a serious direct or indirect risk to human health, this information is immediately notified to the Commission, which immediately transmits the information to the members of the network (RASFF, 2003).

The RASFF produces information under two different headings: alert notifications and information notifications. Alert notifications are sent when the food or feed presenting the risk is on the market and when immediate action is required. Alerts are triggered when a member state detects a problem and has initiated the relevant measures, such as withdrawal/recall. Products subject to an alert notification have been withdrawn or are in the process of being withdrawn from the market. Information notifications, in turn, concern a food or feed for which a risk has been identified, but for which the other members of the network do not have to take immediate action because the product has not reached their market. These notifications mostly concern food and feed consignments that have been tested and rejected at the external borders of the EU.

In 2005, heavy metals were the cause of 4.7% of the 927 alert notifications and of 16% of the 1997 information notifications issued by the RASFF. Moreover, among heavy metals, cadmium was the cause with the largest number of notifications, followed by mercury.

To avoid the recurrence of a problem that has been detected, the RASFF informs their countries of origin in a systematic way via the Commission Delegations. Moreover, when a problem has been detected on several occasions, a letter is sent to the competent authority in the country concerned. As a consequence of these letters, countries concerned took measures such as delisting of establishments, suspension of exports, intensification of controls and changes of legislation. Also, EC Member States intensified checks at import. In addition to that, when the guarantees received were not sufficient, the Commission took measures such as prohibition of import, systematic control at the EU borders, mandatory presentation of health certificates, etc. Additionally, the Food and Veterinary Office uses, among other criteria, the information transmitted through the RASFF to identify the priorities for its inspections program (RASFF, 2003).

Table 3 summarizes the number of alert and information notifications issued between 1999 and 2006. As the table shows, there has been a rapid and large increase in the number of both alert and information notifications, since compared with the 1999–2000 biannual period, alert notifications increased 819% for the biannual period of 2005–2006, while information notifications increased in 696%. Moreover, the fact that during the 2003–2006 period most of the RASFF Notifications based on food cadmium content were issued by countries heavily involved in the production and commercialization of fishing products in the European market supports the argument that Cd levels are used as unjustifiable barriers to free trade. However, this statement must be qualified by the comment that there could be a sample selection problem involved in the numbers just mentioned. Nonetheless when the RASFF notifications are examined in detail, they show that by far the largest proportion of them affects developing countries. The consequences of this type of measure based on cadmium standards are large economic losses for companies in developing countries because an alert

Table 3 – European Communities Rapid Alert System for Food and Feed (RASFF) Alert and Information Notifications; 1999–2003

Year	Alerts	Informations	Total
1999 [a]	97	263	360
2000 [b]	133	340	473
2001 [b]	302	406	708
2002 [b]	434	1092	1526
2003 [b]	454	1856	2310
2004 [b]	692	1897	2589
2005 [b]	956	2202	3158
2006 [c]	927	1997	2924
Increase 1999/2000–2005/2006	819%	696%	730%

[a] Data from RASFF (2004).
[b] Data from RASFF (2005).
[c] Own calculation with data from RASFF (2007).

and/or an information notification issued by the RASFF implies rejection of an export product, which often causes economic damage to the country of origin of such products. The economic losses can be considerable because exporters lose not only the value of the product but also the shipping and handling costs.

As early as 1989, several containers of canned razor clams from Chile were rejected in Spain due to the level of Cd (Figueroa, 1994). The larger than acceptable Cd content was due to the fact that in some coastal areas of Chile, the Pacific sea naturally contains high levels of Cd due to weathered material from the Andean mountains and eroded soils. Recently, Meador et al. (2005) analyzed concentrations of Cd, mercury (Hg) and lead (Pb) in sea sediments and fish from several locations and found that differences in fish species are less important than the unique geochemical features at each sea site that control bioavailability and bioaccumulation and the potential sources for each element. And Lee and Lee (2005) studied in the laboratory the bioavailability of sediment-associated Cd, Zn and nickel (Ni) and their toxicity to polychaetes *Neanthes arenaceodentat* and found that bioavailability and toxicity of metals in sediments was not well predicted by sediment metal concentrations only, but considering the influence of geochemical factors (acid volatile sulfides) on the metal bioavailability improved the prediction of toxicity. There are also indications that human activities, such as mining and industrial processing of ores and metals, have contributed to the heavy metal content of some specific sites of the Chilean Pacific ocean (De Gregori et al., 1994a, 1996). As a result of this, shellfish and seafood living in these waters accumulate Cd to levels higher than those in other parts of the world, especially in their intestines since they are filtering living organisms (De Gregori et al., 1992, 1994b).

In the late 1980s, the immediate direct monetary loss caused to a Chilean exporter by the rejection to enter his canned razor clams to the European market was approximately US$50,000 per each container rejected. The consequence of this was that at least four small and medium size Chilean companies producing and exporting this product had serious economic problems after suffering the rejection of several containers and the closure of a large market for their products.

Aware of these difficulties and to comply with cadmium standards, Chilean exporters sought to implement a special treatment for razor clams and other mollusks to extract their intestines before canning them. However, this new processing method implied increased production costs and a reduction of the competitive advantage of Chilean exporters in the Spanish and European markets.

More recently, in the mid 1990s, the Seychelles was encouraged to develop a swordfish industry with a grant from the EC. By 2002, a fleet of 12 small vessels and 3 exporters was established. However, following a number of alerts for Cd in European countries, pressure from the European Commission Directorate General for Health and Consumer Affairs (DG SANCO) on the Seychelles authorities resulted in a suspension of certain exports to Europe. This caused economic distress as there are few alternative markets and, in consequence, much of the fleet switched to unsustainable shark fishing (James, 2004).

James (2004) analyzed the limits for cadmium set by the European Commission for different food and compared the cadmium level set for swordfish (0.05 ppm) with those set for other products, such as crustacean and livers of cattle, pigs and sheep (0.5 ppm), kidneys of these species and mollusks (1 ppm), and concluded that "clearly restrictions of swordfish cannot be claimed as a consumer protection measure".

In fact, the lack of strong scientific evidence about the effects of cadmium on human health and the many uncertainties remaining about the cause–effect relationship between the Cd content of food or between Cd intake and some human health problems described in the literature as provoked by Cd, indicate that cadmium restrictions set by the EC and in other developed countries, seems to be more a disguised protectionism from free trade than sanitary and phytosanitary (SPS) measures or technical barriers to trade (TBT) scientifically justified or in accordance with the World Trade Organization (WTO) Uruguay Round Agreement.

For instance, the existing evidence on cadmium's risk for kidney function, which according to the current knowledge probably corresponds to its most critical health effect, both for the general population and for occupational exposed workers (NCM, 2003), it is not conclusive, is under considerable debate and most of the time it is anecdotal or based on a very limited number of cases (even on only one individual case, like in Garry et al., 1986). Other times, the evidence on Cd responsibility for causing kidney problems is contaminated by the interaction of concomitant toxic agents, like in studies reporting renal dysfunction in workers exposed to arsenic and cadmium (Hong et al., 2003) and lead and cadmium (Gerhardson et al., 1998), or it is largely speculative as in Garcon et al. (2004). Moreover, there is inconclusive and even contradictory evidence on the correlation between cadmium exposure estimates and Cd concentrations found in kidney tissue in workers of smelters and of a factory of nickel cadmium batteries (Kazantzis and Armstrong, 1984; Gerhardson et al., 2002; Borjesson et al., 1997).

5. More restrictive standards for cadmium and developing countries

Many developing countries face various problems to comply with sanitary and phytosanitary measures and technical barriers to trade (SPS/TBT), not only in the fishery sector but also in other export sectors, and stricter enforcement of the regulations, particularly at the early stages of the supply chain, could marginalize small producers in developing countries from export markets altogether (Bostock et al., 2004). The restrictions based on Cd levels constitute only one of such problems, since more restrictive cadmium standards would lead to greater compliance costs for producers in developing countries which will make them less competitive in world markets, and therefore will decrease their participation in those markets.

On the other hand, there are clear indications that some developed countries are moving in the direction of making cadmium standards more restrictive. A clear example of this is the National Cadmium Minimization Strategy established in July 2000 by the Australian Federal Standing Committee on Agriculture and Resource Management. Moreover, in Sweden the agricultural industry and the cereal and food industry are pushing for tighter standards on cadmium.

In June 2002, in a seminar entitled "Cadmium from Plough to Plate", at the Swedish University of Agricultural Sciences in Uppsala, organized by the FOOD 21-Sustainable Food Production Program and the Swedish Cadmium Network, a prominent executive of Cerealia, a cereal company owned by Swedish Farmers indicated that "if you are a company or aim to be a market leader in your business in Northern Europe, the presence of cadmium in the food chain cannot be neglected". This put Cd on an equal footing with topics such as genetically modified organisms (GMO) and sewage sludge when referring to the key issues challenging the food industry in that part of the world (Börjesson, 2002).

In general the tone used in Northern Europe to refer to the Cd problem in food and agriculture is one of urgency and of great relevance for consumers and peoples' health. The Swedish seminar was not an exception and it went as far as to propose methods to minimize Cd in the food chain and discuss an action plan for Europe in the future (see Ivarsson et al., 2002). The measures proposed include the development of low Cd-accumulating plant cultivars, a reduction in the Cd content in arable inputs (feed, lime, fertilizers, etc.) and in additions of recycled materials to soil (manures, composts, biosolids), and a reduction in the bioavailability and crop uptake of soil Cd (application of lime on acidic soils, etc.), etc. No analysis is provided about the economic costs of these measures and therefore it is impossible to make even a very general comparison of such costs with the expected eventual benefits of the proposed measures. Moreover, the proposed measures do not take into consideration the conclusions of a risk assessment of Cd in European soils presented at the same seminar indicating that current Cd emissions to soil have decreased more than 2-fold in the EU in about the last 20 years, and that the current emissions will not result in soil Cd concentrations above the Predicted No Effect Concentration (PNEC) to protect the food chain of the general population (Smolders, 2002).

In fact, as a result of the decreasing emissions of Cd by human activities to the atmosphere a decreasing deposition on soils is expected for the future, which leads to reduced intake of cadmium by edible vegetables and crops (NCM, 2003). Five years ago already, Larsen et al. (2002) reported that cadmium, nickel mercury and selenium contents of food in Denmark were stable or declined slightly from 1988–1992 to 19993–1997. And in Belgium and the Netherlands, the Cd content of foodstuff decreased during the 1980s (OECD, 1994). Thus the current evidence seem to indicate that cadmium levels in soils and food are typically declining due to lower pollution levels, better management practices and better understanding of how cadmium moves in the food chain.

In spite of this, as well as of the already mentioned lack of conclusive evidence of a causal relationship between the usual Cd intake by humans and adverse health effects, Australia has embarked in recent years on a campaign to introduce the concept that reducing cadmium levels in agricultural products is necessary for improving human health. In fact, the Agricultural Ministry of Australia is conducting a publicity campaign to promote the production of different agricultural products with reduced Cd levels using full-color brochures that openly declare that "Australia has adopted a strategy to maintain safe levels of cadmium in its agricultural soils and produce: an important move in insuring safe food for Australians and a competitive edge for our agricultural exports." In these brochures it is stated that, together "with the effects of long-term fertilizer use", "…the practice of adding sewage biosolids and green wastes to soils in Australia…has the potential to increase the level of cadmium above the maximum concentrations acceptable to health authorities, with consequent implications for human health and international trade".

However, as an increasing body of the literature is showing, not only the cadmium levels on soils determine the transfer of soil Cd to foodstuffs, but the zinc to cadmium ratio in the soil is also very important, if not more important, than the Cd levels alone (Chaney et al., 2004a). As a result of this, the transfer of Cd risk to consumers is complex (Chaney, 2004) and it is influenced by many factors, such as fertilizer rate and time elapsed from fertilizer application (Huan et al., 2004), soil salinity, crop genotypes (Khoshgoftarmanesh et al., 2006), crop rotation pattern employed for cultivation (Khoshgoftarmanesh and Chaney, 2007) and consumers' dietary deficiencies (Chaney et al., 2004b), among others. Moreover, Cd risk management is possible in metal rich soils, applying limestone, using phytoextraction by hyperaccumulator plants such as *Thlaspi caerulescens*, a southern France plant with remarkable Cd phytoextraction capability and Cd:Zn enrichment ratio (Chaney et al., 2006a), or incorporating excess limestone plus added Zn in soils with very high Cd:Zn contamination due to previous sewage sludge application (Chaney et al., 2006b). The lack of understanding of these factors and the fact that the dietary Cd risks to humans have been inferred from toxicological studies in which Cd salts are applied to soils, or added to diets without the corresponding amount of Zn which would be present in the geogenic-contaminated environment, have raised a concern about environmental Cd much of which is based on misunderstanding of the food chain transfer and bioavailability of this heavy metal from usual contaminated soils (Chaney and Reeves, 2006).

The Australian government's marketing strategy is implemented according to the game rules dictated by developed countries, and for developing countries it will be difficult to compete in international markets with this type of advertising campaign implemented with all the financial resources of rich countries. If customers in international markets, especially in the developed world, are finally convinced by this publicity, the products from developing countries will surely lose some market share, regardless the lack of scientific basis for such marketing messages.

In this situation and considering its possible implications for the future, there is a need at the international level for a greater understanding of the impacts of Sanitary and Phytosanitary/Technical Barrier to Trade requirements on developing countries. In the specific case of cadmium standards, this need becomes ever more urgent because these standards will affect the ability of developing countries to compete in the international agricultural markets, so crucial for their economies. Moreover, there is also a need to change institutional structures and procedures relating to SPS measures and TBT standard setting, and to improve the transparency of SPS/TBT agreements. Developing countries will need to fight in international forums to achieve greater international harmonization of SPS measures and TBT standards related to Cd.

6. Conclusions

Cadmium standards in developed countries have created in the past restrictions to market access for export products from developing countries. For example, the rejection by Spain of Chilean razor clams shipments in the late 1980s, and the pressure exerted by the EC on the Seychelles that prohibited exports of swordfish in the late 1990s. These measures had significant economic costs on the industries of the affected countries.

More recently, the European Commission has imposed trade restrictions on products from developing countries based on their Cd content. Fishing products such as swordfish, cuttlefish, squid and octopus have been the most affected products. The Rapid Alert System for Food and Feed that reports alert and information notifications shows an increasing trend in the enforcement of the restrictions applied to food trade by the European Commission.

In the developed world there is a trend in recent years to push for more restrictive cadmium standards despite the scientific evidence showing that: a) Cd level in foods and soils are typically declining due to lower pollution levels, better management practices and better understanding of how Cd moves in the food chain; b) in determining Cd risks Zn:Cd ratio is as, if not more important, than Cd levels alone, a fact that, due to the generally prevailing natural soil conditions, mitigates risk of Cd exposure in certain foodstuffs; and c) the Cd risks to kidney function is under considerable debate and they may be overestimated. All of this seems to indicate that stricter Cd standards for food would imply unnecessary and costly regulatory burdens.

Analyzing Cd strategies recently adopted by some developed countries, such as the Australian Cadmium Minimization Strategy, it seems clear that the rationale for such strategies is mainly a commercial one. Indeed, it appears that in countries like Australia and Sweden, authorities and/or the private sector are using Cd standards to promote the competitive advantages of their national industries. If these strategies are successful, it will be difficult for developing countries to compete in international agricultural markets.

It will be increasingly important in the future for developing countries to fight in the international forums and organizations, such as the WTO, to transform and make more transparent the international institutions and structures setting Sanitary and Phytosanitary measures and Technical Barriers to Trade for Cd.

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