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Health risk assessment due to wastewater use in agriculture

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INTRODUCTION

The shortage of water for irrigation gives rise to the use of alternative sources. In Latin American countries, these alternative sources are affected by dumpings from the mining and metallurgical industry whose effluents contain concentrations of metals and other organic toxic substances that could have impact on human health, due to ingestion of food produced in areas irrigated with wastewater or contaminated surface waters. In addition, technological development has contributed to increase other industrial dumpings that contaminate surface waters.

At present, explosive growth of the population associated with poorly planned technological development and the increasing use of materials containing metals are producing harmful effects in the environment. In some cases natural biogeochemical cycles have been broken (WHO, 1992).

The inadequate disposal of industrial wastes has created pollution problems since this waste is disseminated in the environment or is accumulated in sediments, aquatic organisms, and water.

There are many studies on the possible effects of chemical substances on humans through laboratory experiments in animals and information is available on the incidence of cancer by prolonged exposure to toxic substances. Experiments in plants and insects, as the Drosophyla (fruit fly), demonstrate that toxic substances of chemical origin induce genetic mutations and chromosome aberrations. These experiments demonstrate that there exists a risk, but it is not simple to extrapolate these results to human beings.

The population is exposed to toxic chemical compounds through the use of wastewater in agriculture. Theoretically, wastewater of industrial origin should not be used for this purpose but in developing countries formal and clandestine industries dispose of their effluents to the municipal sewerage with or without authorization and without any treatment. This exposes the population, permanently, to relatively small quantities of chemical compounds and may produce chronic intoxications with serious consequences.

Another health hazard pose by inadequate disposal of wastewater is the use of sediments for soil improvement because they contain toxic elements that may accumulate (PAHO, 1989).

The environmental impact of chemical residues in wastewater used for irrigation and the prediction of their effects on human health are a very complex matter. In addition, it should be considered that the standards of developed countries do not apply to areas with different characteristics. The factors that influence the nature and intensity of the impact on health are: the climate, nutritional status, genetic predisposition, type of work and exposure level.

The indiscriminate use of pesticides also influences the deterioration of water quality. This resource can be contaminated by runoffs from crops, atmospheric precipitations and, to a lesser extent, by domestic sewage. Polychlorinated biphenyls (PCB), present in larger quantity in pesticides and other organochlorine compounds, are degraded very slowly in the environment and are bioaccumulative, thus, they represent a potential danger. Air and water are vehicles through which PCB are dispersed in the environment, although food also constitute an important vehicle. As a consequence, PCB residues are found in living organisms from many regions. The highest concentrations are usually present near industrial areas and electric power plants.

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Industrialization and urban development without adequate planning increase human health hazards by exposure to chemical substances through air, water, sediments, and food. The nature of this risk and its potential danger has been recognized a few years ago and its effects still have not been evaluated (PAHO, 1990).

The identification and confirmation of such effects are difficult because epidemiological studies last long, the population migrates, and exposure time is unknown. In addition, chronic diseases can have various causes and, in many cases, they are not classified correctly.

Usually, in developing countries there is not statistical information on the trends and causes of diseases produced by ingestion of chemical substances through agricultural and livestock products. However, several studies have demonstrated adsorption of heavy metals by plants, such as wheat and rice that can affect the consumers (WHO, 1992). An epidemiological evidence was the case of Toyama, Japan, where the population was affected by the ingestion of cadmium contained in rice; the origin of this element was a nearby mine that contaminated the irrigation water.

The nature of human health hazards by exposure to toxic chemical compounds varies considerably. In general, they increase birth defects, abortions and certain forms of cancer, and decrease the average weight of children at birth.

CASE STUDY: TREATMENT AND WASTEWATER USE IN AGRICULTURE IN LIMA, PERU

The study "Health risk evaluation due to wastewater use in agriculture" was conducted in four agricultural areas (Callao, San Martín de Porres, San Juan de Miraflores and Lima).

2.1 General objective of the study

To evaluate the chemical-toxicological level of contamination of the agricultural products irrigated with raw and treated wastewater.

2.2 Specific objectives

- To determine the concentration of toxic heavy metals and synthetic organic compounds (pesticides and polychlorinated biphenyls) in rivers, raw wastewater and treated wastewater used for irrigation.
- To determine the concentration of toxic heavy metals, pesticides, and polychlorinated biphenyls in agricultural and livestock products (vegetables and milk) from areas irrigated with water of rivers, raw wastewater and treated wastewater.
- To compare the potential risk associated with toxic chemical compounds present in waters of rivers, raw wastewater and treated wastewater used to irrigate agricultural and livestock products.
- To train professionals in the measurement of metallic organic toxic substances and, thus, to increase the local analytical capacity.

METHODOLOGY AND RESULTS

The study was conducted in metropolitan Lima to evaluate the presence and concentration of toxic chemical compounds in waters used for irrigation and in agricultural and livestock products from areas of reuse, a control area, and markets. In addition, soils and sludge were analyzed. The areas selected for the study were: the river Lurín in Cieneguilla (control area), San Juan de Miraflores (use of stabilization pond effluents), Callao (use of industrial and domestic wastewater and water from river) and San Martín de Porres (domestic wastewater). Analyses of metals, pesticides, and PCB were carried out in all water samples.

The following analytical procedures were applied:

a. Water

The analytical methodologies proposed by the Health and Welfare, Ottawa, Canada, National Water Research (Burlington) and by the Standard Methods (15a. edition, 1985) were used.

b. Agricultural products

The recommendations of the Health Protection Branch Laboratory, Food Laboratory, Toronto, Canada, and the analytical methodologies of CEPIS developed with the support of JICA were applied.

c. Soil and sludge

The methodologies proposed by the laboratories of the National Water Research (Burlington) and by the Standard Methods (15a. edition, 1985) were adopted.

<u>For analytical quality control</u>, measurements were subject to an analytical quality control program developed by CEPIS laboratory and the methodology used by GEMS/WATER and PRELAB.

To control the results, synthetic samples from the Environmental Protection Agency (EPA) of the United States and biological references from the National Institute for Environmental Studies (NIES) of Japan were used. Recovery tests were performed with selected samples to which known quantities of analite were added, in addition, control tests of distilled water and solvents for pesticides and PCB were done.

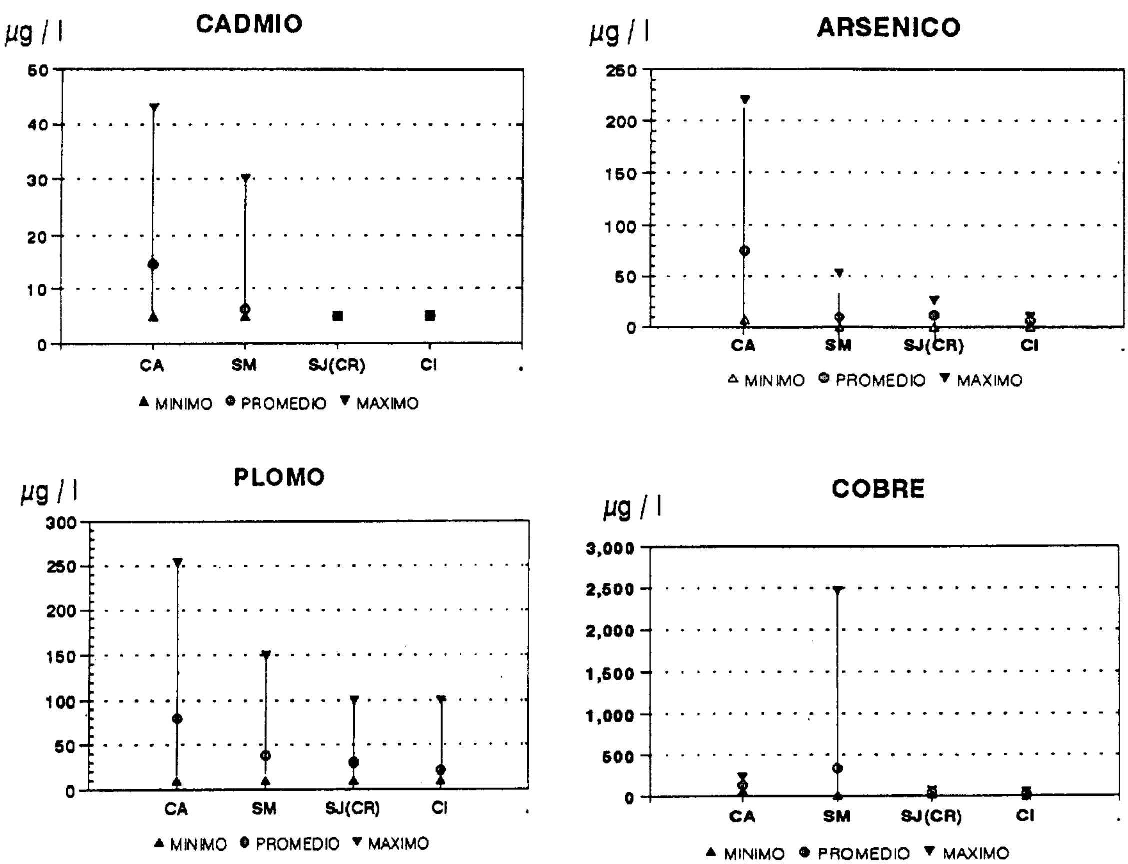

Fig. 1 Metals of toxicological interest in irrigation water.

The reference samples were: "Pepperbush", chlorella, EPA 2, EPA 3, EPA 4, and EPA 5. Clethra barbinervis is a plant that contains high values of manganese, zinc, nickel, and cadmium, among other metals.

With respect to the results, in industrial wastewater high levels of heavy metals were found: arsenic (7 to 220 μg/l), cadmium (5 to 43 μg/l), lead (10 1 253 μg/l), copper (50 to 250 μg/l), iron (1.800 to 6.400 μg/l), and zinc (60 to 2.460 μg/l) (see Figure 1). Chlorinated pesticides in different sampling points were very low (<700 ng/l). With regard to PCB, the highest value was detected in San Martín de Porres (270 μg/l). In general, removal of heavy metals, pesticides, and PCB is produced in stabilization ponds.

The agricultural and livestock products selected for the study were: corn, spinach, strawberry, potato, carrot, and milk from the areas of study and nearby markets. The highest value of lead was detected in spinach samples from markets (0,037 μg/g) (see Table 1). Cadmium does not constitute a problem in the areas studied. With respect to PCB, the highest values in milk samples were from Callao, 60 μg/l in total milk and 1000 μg/l in fat.

CONCLUSIONS

The use of industrial wastewater in agriculture and livestock represent a potential risk for health, due to the toxic nature of chemical compounds and to the concentrations to which the products are exposed.

Irrigation water with low levels of lead (around 30 μg/l) has a minimum influence in the toxicological quality of vegetables whose edible part grows beneath the soil.

Table 1 Lead and cadmium in agricultural products

Area	Sampling place	Species	Concentration	
			Pb (μg/g)	Cd (μg/g)
CALLAO *	Agricultural area	Corn	< 0,002	< 0,003
		Potato	0.002	< 0,003
		Spinach	0.014	< 0,003
		Carrot	< 0,002	< 0,003
	Market	Corn	< 0,002	< 0,003
		Potato	0.002	< 0,003
		Spinach	0.004	< 0,003
		Carrot	< 0,002	< 0,003
		Strawberry	0.002	< 0,003
SAN MARTÍN *	Agricultural area	Corn	< 0,003	< 0,003
		Spinach	< 0,009	< 0,003
	Market	Corn	0.002	< 0,003
		Potato	0.002	< 0,003
		Spinach	0.037	< 0,003
		Carrot	< 0,002	< 0,003
		strawberry	< 0,002	< 0,003
SAN JUAN *	Area Agricultural	Corn	0.003	< 0,003
CIENEGUILLA	Agricultural area	Corn	< 0,002	< 0,003
Markets of Lima	Mayorista (wholesale dealer)	Corn	< 0,002	< 0,003
		Potato	< 0,002	< 0,003
		Spinach	< 0,002	< 0,003
		Carrot	< 0,002	< 0,003
		Strawberry	< 0,002	< 0,003
	Central	Corn	< 0,002	< 0,003
		Potato	< 0,002	< 0,003
		Spinach	< 0,002	< 0,003
		Carrot	< 0,002	< 0,003
		Strawberry	< 0,002	< 0,003

* Use of wastewater without treatment.

Vegetables growing at the soil surface level may be contaminated by atmospheric emissions containing lead.

There is a direct relationship among the levels of PCB in water, sediments, and sludge samples of livestock fed in reuse areas.

For irrigation water, the permissible limit values of toxic chemical compounds should not be regarded as absolute values, but should be adapted to the local conditions considering contributions from other sources.

Wastewater treatment by means of stabilization ponds removes toxic elements when low concentrations are found in raw wastewater.

The establishment of permissible maximum limits of toxic substances should be studied for irrigation water considering conditions of soil, types of plant, and bioaccumulation.