MERCURY EXPOSURE THROUGH FISH CONSUMPTION IN RIPARIAN POPULATIONS AT RESERVOIR GURI, USING NUCLEAR TECHNIQUES, BOLIVAR STATE, VENEZUELA

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Abstract:

The reservoir Guri located at the south of Venezuela in Bolivar State arose from daming the Caroni river and its main tributary, tha Paraguay river. It was built between the years 1963 and 1986. The reservoir, whose primary use is the electric power generation followed by others beneficial uses such as water supply and recreation, was opened to commercial fishing in recent data. The riparian population is about 8,030 inhabitants: 7,389 toward the left side (west) and 641 toward the right side (east) and it is distributed in populated centers, villages and in dispersed areas. The young population is the most conspicuous: 46 % and 52% on the right and left sides, respectively, with predominance of the masculine sex (86%). The reservoir Guri, the same as some reservoirs from other countries has shown what has been called "dam effect", term used to designate the occurrence of bioaccumulation process in reservoirs due to the high mercury levels found mainly in piscivorous fish species which are the most preferred by fish consumers. In a sample of 42 specimens of the carnivorous trophic level, the average value of total mercury was 1.90 ppm, with a maximum value of 6.04 ppm. For the detritivorous trophic level, in a sample of 17 specimens, the average value of total mercury was 0.27 ppm, with a maximum value of 0.69 ppm, while for the omnivorous trophic level, in a sample of 6 specimens, the average value of total mercury was 0.55 ppm, with a maximum value of 0.99 ppm. The source of mercury in fishes from reservoir Guri has not been determined; however, in some sectors of the flooded area there were carried out activities of exploitation of aluvional gold using metallic mercury for gold recovery and burning the amalgam at open ceiling. The objective of this research project is to determine the relationship among the ingestion of fish coming from reservoir Guri, the levels of organic mercury in hair and the appearance of signs and symptoms of neurotoxicity in a sample statistically representative of the riparian population at reservoir Guri. The information obtained related to the neurological disorders which can be found in the riparian population at reservoir Guri due to chronic exposure to organic mercury present in fishes would be of great relevance because it constitutes a sensitive point at regional level.

1. SCIENTIFIC BACKGROUND AND SCOPE OF THE PROJECT

1.1. The Reservoir Guri

The reservoir Guri located at the south of Venezuela in Bolivar State arose from damming the Caroni river and its main tributary, the Paragua river. It was built between the years 1963 and 1986 by the company "Electrificación del Caroní C.A". ("EDELCA"), which is a governmental hydroelectrical company, branch of the "Corporación Venezolana de Guayana" ("CVG"). The first flood occurred in 1968, covering an area of 800 Km^2. In 1986 the dam flooded an additional surface of 3,119 Km^2. The reservoir has a total surface of 3,919 Km^2, an useful volume of 84,720.4 x 10^6 m^3 and a level of 271 meters above the sea level, to a nominal capacity of energy generation of 9,957 MW (Figure 1)[1].

This reservoir, whose primary use is the electric power generation, followed by others beneficial uses such as water supply and recreation, was opened to commercial fishing in recent date. For this last reason, in 1995 an operative committee was created by means of a combined Resolution of the Ministries of Agriculture and, Environment and Renewable Natural Resources to guide the handling the reservoir's fishing resources. The exploitable

fishing potential in the reservoir Guri was estimated between 12.000 and 20.000 tons per year [2].

1.2. The Riparian Population

The population in the area of immediate influence of reservoir Guri is around 8,030 inhabitants: 7,389 toward the left side (west) and 641 toward the right side (east) and it is distributed in populated centers, villages and in dispersed areas. The young population is the most conspicuous: 46,4 and 52,5% on the right and left sides, respectively, with predominance of the masculine sex (89,3%) [3].

The economically active population (EAP) is about 4,737 people: 4,332 on the left side and 405 on the right side. From the EAP, 3,245 individuals (68,5 %) are into the labor power with 65,68 % being occupied and 2,64 % unoccupied. Around 30 % of the population in the economically active age is represented fundamentally by students and women dedicated to household activities [3].

On the left side of the reservoir is concentrated most of the population. In the economy primary sector almost 60 % is dedicated to agricultural activities. The additional population that integrates the primary sector is dedicated to the following activities: mining, fundamentally iron and quartz extraction, and cattle raising. In the secondary sector the population in the economically active age (around 17 %) works for the hydroelectric industry, while in the tertiary sector this population reaches about 8 percent and is dedicated fundamentally to commercial activities and services areas.

On the right side of the reservoir from the 405 inhabitants 68 % is represented by the masculine sex, this fact keeps relationship with the mining and forestry activities in this side of the reservoir. The population in the economically active age that is into the power labor represents about 71 percent, including busy and unoccupied people. In the economy primary sector almost 46 % of the population in the economically active age is dedicated to rudimentary agricultural activities and in a very few cases there are semi-intensive exploitations. The additional population that integrates the primary sector is dedicated to the following activities: mining, fundamentally quartz extraction, cattle raising and forest activities. In this side of the reservoir there is total absence of economic activities linked to the secondary sector. The tertiary sector is represented for a very few people which are dedicated to commercial activities and services areas [3].

1.3. Mercury Bioaccumulation at Reservoir Guri

The bioaccumulation of mercury in reservoirs is a phenomenon that has been recognized recently in countries such as the United States of America (USA), Canada, Sweden [4], Brazil [5] and more recently in Venezuela [5]. In most of the cases a source of specific contamination has not been identified and the problem has been attributed to global effects.

The first documentation in the literature related to the presence of mercury in fish coming from recently built reservoirs, appeared by the year 1974, when it was reported high levels of mercury in the reservoir of bay Willard in the state of Utah, USA [4]. Although a specific source of contamination was not identified, around 74% of the fish presented

mercury levels higher than 0,5 parts per million (ppm). In USA the permissible maximum content of mercury in commercial fish is 1,0 ppm and 0,5 ppm in shipments for export and domestic market, respectively [4].

The reservoir Guri, the same as some reservoirs from other countries has shown what has been called "dam effect ", term used to designate the occurrence of bioaccumulation process in reservoirs due to the high mercury levels found mainly in piscivorous fish species which are the most preferred by fish consumers.

The potential bioaccumulation of methylmercury in fish at reservoir Guri is influenced by several factors. The content of dissolved organic matter in the waters of the rivers Caroni and Paragua, which confers a dark brown coloration to these rivers increasing the bioaccumulation process. Indeed, fishes captured in darkwaters of the Amazon region almost always show bigger levels of mercury that those coming from rivers with clearer waters [5]. The bioaccumulation is also influenced by water pH, being this process bigger in waters with low pH [6] , this the case of Caroni and Paragua rivers.

By the year 1996, in a sample of 157 fish coming from the reservoir Guri, high concentrations of mercury were detected, especially in those species of predatory habits. The average concentrations of mercury in the dorsal muscle ranged from 0,17 ppm in the detritivorous trophic level (*Prochilodus rubrotaeniatus*; common name:"coporo") and 2,70 ppm in the carnivorous trophic level (*Hydrolicus scomberoides*; common name: "payara"). An interlaboratorial program was conducted by that time involving mercury analyses of ten fish samples from different trophic levels in three laboratories: two Venezuelan and one Brazilian laboratory. The correlation factor ranged from 0,96 to 0,98 among the three laboratories [5].

1.4. Project Objectives

1.4.1. General

To determine the relationship among the ingestion of fish coming from reservoir Guri, the levels of organic mercury and the appearance of signs and symptoms of neurotoxicity in a sample statistically representative of the riparian populations at reservoir Guri.

1.4.2. Specific

- To establish the nutritional profile and the characteristics of the daily ingestion of fish in a sample statistically representative of the riparian populations at reservoir Guri;
- To explore from the medical point of view a sample statistically representative of the riparian population at reservoir Guri to identify signs and symptoms of neurotoxicity;
- To verify the organic mercury levels in hair of a sample statistically representative of the riparian population at reservoir Guri.

1.5. Relevance of the Project

The information obtained related to the neurological disorders which can be found in the riparian population at reservoir Guri due to chronic exposure to organic mercury present in fishes would be of great relevance because it constitutes a sensitive point at regional level. Until now there has not been carried out any study related to the evaluation of mercury in people for the consumption of fish coming from this reservoir. In a report presented to the Government of Bolivar State for the United Nations Industrial Development Organization (UNIDO) in 1996, after the diagnosis and evaluation of the use of metallic mercury in gold mining operations, there was recommended an urgent monitoring program with the purpose of obtaining information on the population habits of fish consumption at Bolivar State, the levels of mercury in hair and, signs and symptoms of neurotoxicity in those people at risk.

This research proposal is inserted into the objectives of three regional programs conducted by the Foundation for the Development of Science and Technology of the Guyana Region: The Research Program of Occupational Health, the Research Program of Mercury, and the Research Program of Public Health. In addition, the proposed study will have the cooperation of the company "EDELCA", which has under its responsibility the integral handling of the reservoir Guri, and the Institute of Public Health of Bolivar State and, the Direction of Environment, Mining and Territory Ordination from the Regional Government of Bolivar State.

The result obtained through the present study, besides giving an answer to a regional problem, it does serve as a reference for the integral handling of some reservoirs that will be built soon in the Bolivar State.

In addition to the toxicological laboratory of the Pharmacy Faculty of the "Universidad Central de Venezuela", researchers from the laboratories (environmental and toxicological) of the "Guardia Nacional de Venezuela" will be envolved during the development of the research project.

2. METHODS

The universe of the present study is about 8,030 people living in the area of inmediate influence of reservoir Guri. Ninety two percent of the population is located on the left side, while 8% is found on the right side of the reservoir.

The required sample size with a degree of accuracy of 0.05 and a confidence level of 95 % is 366 people [7]. The sample distribution toward both sides of the reservoir will be as following: 337 to the left side and 29 people to the right side.

The study is included in the transverse, descriptive and analytic type of research. The 366 individuals of the sample statistically representative from the total population will be selected at random in each of the sectors and there will be applied a survey of the previous week's meals for the description and analysis of their respective diets. There will be determined the frequency, quantity and time of more fish consumption, especially those of the carnivorous trophic level coming from the reservoir Guri.

The levels of organic mercury in hair will be determined in all the 366 individuals. Hair samples will be collected from the occipital area and the mercury analyses will be carried out by cold vapor atomic absorption spectroscopy [8]. This method is based on the rapid conversion of mercury compounds into mercury vapor suitable for aspiration through the cell of a flameless atomic absorption monitor. By this method, total mercury and inorganic mercury may be determined, and methylmercury is then calculated as the difference. During this research efforts will be done to establish both internal and external quality control involving interlaboratory comparisons.

From the previous analyses a group will be selected from the exposed population to mercury contamination due to consumption of fish coming from the reservoir Guri. This exposed group will be evaluated from the clinical point of view which will include: personal identification aspects, epidemiological, sanitary, social, pathological, labor and personal antecedents. In the medical evaluation a special emphasis will be made on the identification of biological indicators of methylmercury effects: signs and symptoms of neurotoxicity, through a neurofunctional test battery to evaluate motor and visual function, and chromatic discrimination.

The non exposed group will be selected from the same sample of the population and it will be paired for: sex, age, socioeconomic conditions, occupation and residence sector.

The concentration of the information will be carried out by the use of the Epi-Info database [9] and for the statistical data analysis the following will be considered: descriptive sample analysis, regression analysis, and means and variances comparisons among groups.

3. RESULTS AND DISCUSSION

Inasmuch as we do not have results from this project, we will give some results from a previous work related to this co-ordinated research project.

3.1. Total Mercury Concentrations in Fishes from Reservoir Guri, Bolivar State, Venezuela (in press, 1999) [10].

A monitoring to determine mercury levels in fishes from reservoir Guri was carried out in 1998 as an activity of a program conducted by the hydroelctric company "EDELCA". The monitoring was performed by "EDELCA" personal under the advisory assistance of the "Universidad Nacional Experimental de Guayana".

Samples of 10 species of carnivorous, detritivorous, and omnivorous fishes caught at 3 different sites on reservoir Guri, were analyzed for mercury by inductively-coupled plasma (ICP) method in an equipment Jobin Yvon model JY24 using the cold vapor continuous flow technique [11]. The analytical accuracy was measured through the analysis of a reference standard certified by the National Institute of Standard and Technology of USA and the differences were not bigger than 3 percent.

No pre-impoundment data are available, however the effect of an impoundment to increase mercury concentration in fish tissue is strongly indicated. As confirmed in previous monitoring, there was found high mercury levels in fishes coming from the reservoir. In a

sample of 42 specimens of the carnivorous trophic level, the average value of total mercury was 1.90 ppm, with a maximum value of 6.04 ppm. For the detritivorous trophic level, in a sample of 17 specimens, the average value of total mercury was 0.27 ppm, with a maximum value of 0.69 ppm, while for the omnivorous trophic level, in a sample of 6 specimens, the average value of total mercury was 0.55 ppm, with a maximum value of 0.99 ppm (Table I).

TABLE I. MERCURY LEVELS IN FISH FROM RESERVOIR GURI (1998)
(Average Hg in muscles of fish)

FISH (COMMON NAME)	FISH (SCIENTIFIC NAME)	MEAN (ppm)	Hg (ppm) (MAXIMUN -MINIMUN)	n	REMARKS ON Hg LEVELS
Payara (C)	Hydrolicus scomberoides	2.48	0.90-6.04	7	VERY HIGH
Pavon (C)	Cichla temensis	0.89	0.42-1.43	4	HIGH
Aymara (C)	Hoplias macrophtalmus	2.52	1.08-4.43	3	VERY HIGH
Coporo (D)	*Prochilodus rubrotaeniatus*	0.27	0.01-0.69	17	MEDIUM
Caribe (C)	Serrasalmus rhombeus	1.67	0.20-3.82	11	HIGH
Curbinata (C)	Plagioscion squamosissimus	1.28	0.37-2.75	14	HIGH
Bagre Chola (C)	Angeneiosus brevifilis	2.57	0.96-4.19	3	VERY HIGH
Guitarrilla (O)	*Anduzedoras sp.*	0.99	0.76-1.22	2	HIGH
Bagre Yaque (O)	Leiarius marmoratus	0.54	0.41-0.67	2	HIGH
Morocoto (O)	Piaractus brachypommun	0.13	0.06-0.20	2	LOW
TOTAL	-	-	-	65	-

The natural level of mercury in fish ranges from 0,05 to 0,3 ppm and it can be lower than 0,01 ppm in herbivorous species of short life [5]. Nevertheless, the level of tolerance limit of mercury in fish, established for a weekly ingestion of 400 grams of fish, it is a variable quantity adopted by many countries to control the content of mercury in the edible parts of the fish: 0,5 ppm (humid weight) is used in USA, Canada and Brazil; 0,7 ppm in Italy; and 1,0 ppm in Finland, Sweden and Japan [5]. Venezuela does not have an official standard at this time for the permissible content of mercury in fish for human consumption; however, to fill this gap, international norms are used to cope with this matter. It is important to point out that in spite of having established the value 0,5 ppm as the safe concentration of mercury in fish for human consumption, this does not tell us anything regarding to the quantity and the frequency of the ingestion.

The source of mercury in fishes from reservoir Guri has not been determined; however, in some sectors of the flooded area there were carried out activities of exploitation of alluvial gold deposits using metallic mercury for gold recovery and burning the amalgam at open ceiling. The metallic mercury was used extensively by artisanal miners in some places that were covered by the waters and near the area of the reservoir. Before the year 1986, miners were working on mining activities along the coast line of the reservoir, the same as in the rivers that were dammed for its construction. Even in the current moments, there are miners' groups that are carried out illegal gold mining activities in some spaces of the area of immediate influence of reservoir Guri. However, it has not been determined which is the contribution to the mercury local cycle neither of the gold mining activities close to reservoir Guri nor the other ones that have been occurring in many sectors of Bolivar State.

4. PLANS FOR FUTURE WORK

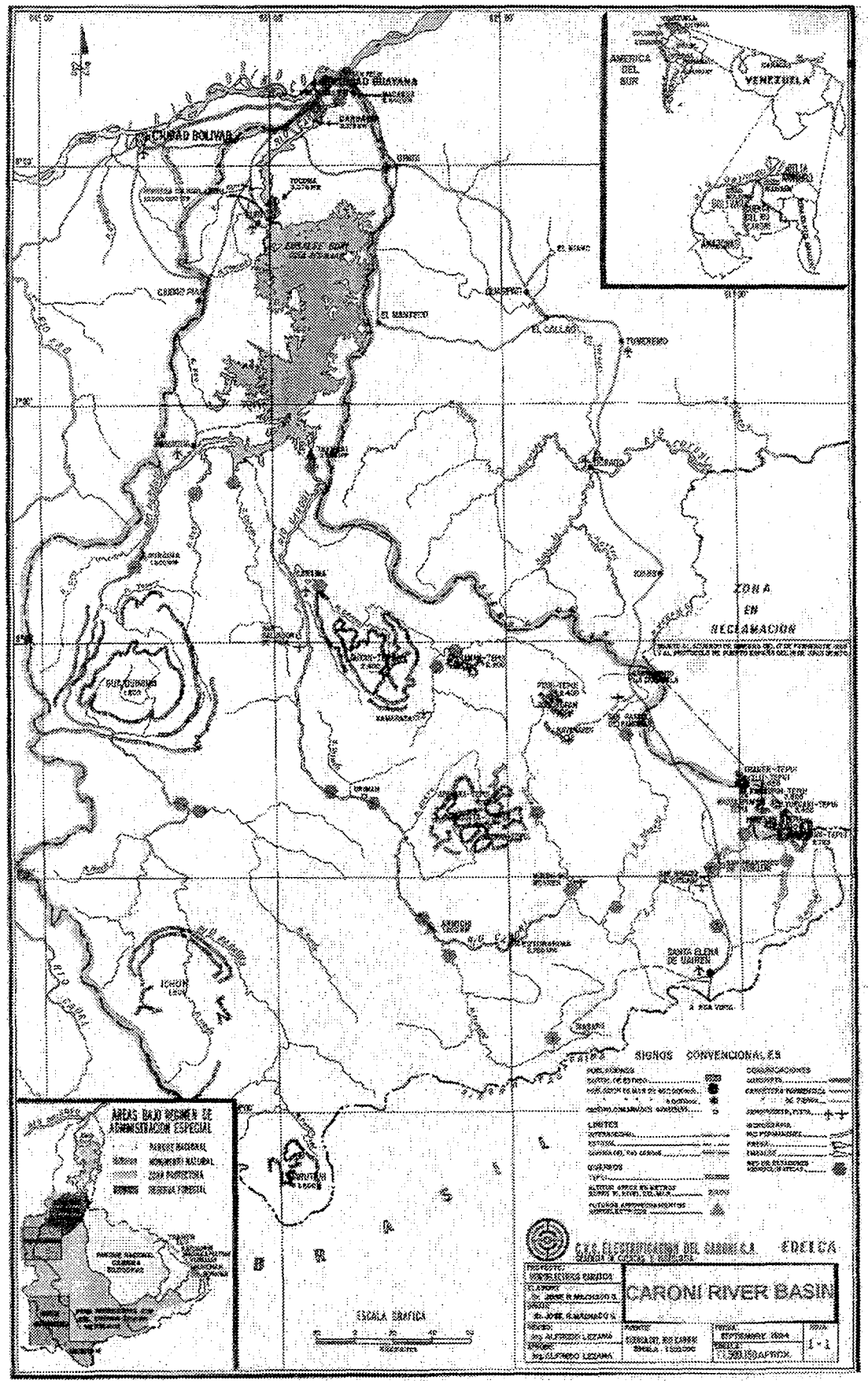
4.1. Mercury Biotransformation and Bioaccumulation at Reservoir Guri

From samples collected at reservoir Guri in the sediment and overlaying water, bacteria groups with similar biochemical characteristics will be isolated, in particular the anaerobic strict bacteria with ability to form methane or other organic compounds with similar characteristic. Laboratory experiments will be designed to study the biotransformation and bioaccumulation of mercury through the use of radioisotopes.

4.2. Export of Mercury Downstream from Reservoir Guri

It is proposed monitoring mercury levels in fish at reservoir Guri and downstream Caroni river to determine if there is an increase in mercury concentrations downstream of the reservoir. The study will be designed to identify by which compartments mercury is being transported downstream from the reservoir and to assess the amount of mercury exported. Water samples, drifting organisms and suspended particulate matters will be evaluated as important components.

Figure 1: Map of the Caroni River Basin



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