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PRESENCE OF NITRATES AND NITRITES IN WATER FOR HUMAN CONSUMPTION AND THEIR IMPACT ON PUBLIC HEALTH IN SUGARCANE-PRODUCING AREAS

[PRESENCIA DE NITRATOS Y NITRITOS EN AGUA PARA CONSUMO HUMANO Y SU IMPACTO EN LA SALUD PÚBLICA EN ZONAS CAÑERAS]

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SUMMARY

Water pollution has emerged as a consequence of human settlements, as well as from specific agricultural, forestry and industrial activities within a region. It is known that increasing use of nitrogen fertilizers also increases water pollution. Nitrates and nitrites that are dissolved in groundwater used for human consumption cause adverse health effects, such as production of nitrosamines (a cause of cancer) and decrease of oxygen carrying capacity of the blood, known as blue baby syndrome. The aim was to determine the relationship between concentration of dissolved nitrates and nitrites in drinking water, and the incidence of esophagus and stomach cancer in population living close to agricultural areas. The maximum concentration of nitrates (NO_3-) in water for human consumption was 7.5 mg L^{-1}. A total of 45 cases of esophagus and stomach cancer were identified, distributed in six agricultural municipalities studied. A weak correlation ($r = 0.46$, $p < 0.05$) was found between rational use of nitrogen in sugarcane cultivation and the number of cancer cases recorded in the area of study.

Key words: Agroecosystems; nitrogen fertilizers; water pollution; cancer.

RESUMEN

La contaminación de las aguas emerge como consecuencia de los asentamientos humanos y las actividades agrícolas, silvícolas e industriales en una región. Se conoce que al incrementarse el uso de fertilizantes nitrogenados, se produce mayor contaminación en las aguas. Los nitratos y nitritos disueltos en agua subterránea destinada al consumo humano ocasionan efectos negativos en la salud, tales como producción de nitrosaminas (causa de cáncer) y disminución de la capacidad de transporte de oxígeno en sangre, conocida como síndrome del bebé azul. El objetivo fue determinar la relación entre la concentración de nitratos y nitritos disueltos en agua de consumo humano, y la incidencia de cáncer de esófago y estómago en la población aledaña a zonas agrícolas. La concentración máxima de nitratos (NO_3-) en agua de consumo humano fue 7.5 mg L^{-1}. Se identificaron 45 casos de cáncer de esófago y estómago, distribuidos en seis municipios agrícolas. Se encontró una correlación de $r = 0.46$ ($p < 0.05$) entre el uso racional de nitrógeno en el cultivo de caña de azúcar y el número de casos de cáncer registrados en la zona de estudio.

Palabras clave: Agroecosistemas; fertilizantes nitrogenados; contaminación del agua; cáncer.

INTRODUCTION

Water is a resource essential for life, base of economic and social development of any country. Nowadays, availability of water is low in Mexico, ranking 81st worldwide. Seventy percent of the water available is used in agricultural and livestock activities, and the rest is for public and industrial use (INEGI, 2006). Veracruz is one of the states with the greatest biological and social diversity, rich in population, territory, natural resources, and livestock, agricultural and fishing activities (Borja *et al*., 1995). However, agricultural sewage and wastewater (either untreated or partially treated) are collected by bodies of water, with high levels of minerals and organic compounds, besides pesticides and fertilizers residues (EPA, 2004).

According to Stigter *et al*. (2005), the impact of agriculture on the quality of surface water and groundwater can be determined by the amount of fertilizers used, which together with irrigation cause salinization and nitrate pollution of water. The degree of groundwater pollution depends on hydrogeological factors and intensity of agricultural practices. The threat of groundwater pollution increases in irrigated sandy soils, as nitrates (NO3-) are easily leached. The amount of nitrates in agriculture is not only due to application of nitrogen fertilizers, but also to mineralization of organic nitrogen (Richards *et al*., 1996). The environmental polluting potential of this activity has been confirmed in several studies, where the more intense the agricultural activity, the more pollution of the surface water and groundwater (Lucey and Goolsby, 1993; Richards *et al*., 1996).

Mobilization and concentration of nitrates in the soil affects human and environmental health. The effect on human health can be assessed through the study of abiotic, biotic, cultural and social indicators, based on the purpose of each productive activity (Bertollo, 1998). Therefore, the aim of this study was to determine the relationship between the concentration of dissolved nitrates (NO_3^-) and nitrites (NO_2^-) in water for human consumption, derived from inadequate management of nitrogen fertilizers used in sugarcane cultivation, and the incidence of esophagus and stomach cancer cases in the population living near to the sugarcane-production areas of the Irrigation Module I-1 La Antigua, Veracruz.

MATERIALS AND METHODS

Seven sampling points were randomly established within the Irrigation Module I-1 La Antigua, Veracruz, located in Tolome, Loma Fina-El Tejón, Carretas, Faisán, La Víbora, Salmoral and La Posta, in Veracruz, Mexico. In each locality, samples of bottled water for human consumption were collected.

Diagnosis of the study area

A survey was applied based on a questionnaire, given to a sample of 130 rural producers, from a population of 1677 users. The sample size was calculated using the equation: $n = Ns^2/[(N-1)b^2/4+s^2]$, where n is the sample size, N is the population size, s^2 the variance and b the error (Scheaffer, 1987). The questionnaire provided information concerning the sources of water supply for human consumption, weekly consumption, sugarcane agroecosystem management, and type, amount and frequency of fertilizer used.

Monitoring periodicity

Three samplings were carried out on each season prevailing from March to December 2009: dry season (March-June), rainy season (July-October) and windy season (November-February) (Farías, 1991).

Sample collection

In glass flasks, 500 ml of bottled water of each of different commercial brands were collected, according to the procedures described in the Official Mexican Standard (Norma Oficial Mexicana) NOM-014-SSA1-1993, which establishes the "Sanitary procedures for the sampling of water for human use and consumption, in public and privater water supply systems". The samples were stored at 4 °C until analyzed.

Analysis protocol

In each water sample the concentration of nitrates (NO_3^-) and nitrites (NO_2^-) was determined, according to the techniques described in the Mexican Standards NMX-AA-079-SCFI-2001 and NMX-AA-099-2006, respectively. To evaluate the contamination level of the different water samples analyzed, the Official Mexican Standard NOM-127-SSA1-1994, which regulates the maximum levels allowed of the contaminants analyzed, was used as reference (SSA, 1994).

Statistical information on human health

Information related to cancer cases in population living in the surroundings of the study area, was provided by the Sanitary Jurisdiction VIII data base, at the Veracruz state Secretary of Health and Assistance. Information is organized by year of detection, patient's municipality of origin, and type of cancer. For this

research, cases of malignant tumors (cancer) in esophagus and stomach were processed, to relate them with long-time ingestion of nitrates and nitrites.

Statistical analysis

An analysis of variance was used to determine the relationship between concentration of analytes dissolved in water for human consumption and the types of cancer. Spearman's correlation non-parametric test was used to measure the association between the number of esophagus and stomach cancer cases recorded and results obtained from laboratory analysis and the survey.

RESULTS AND DISCUSSION

Diagnosis of the study area

Eighty eight percent of producers' families drink their water bottled in local or within-the study area water-purifying companies; 9 % drink tap water and the remaining 3 % drink well water. Brand names of bottled water for human consumption produced and/or distributed in the study area are Ártico, Ciel, Santorini, Bonafont, Isabel, Xallapan, San Carlos, Santa Catalina, Acuabella, Arizona, Ideal, Fuente de Vida and Ameyali. Average weekly water consumption per family is greater than 35 L. This is in agreement with the National Association of Producers and Distributors of Purified Water, who indicates that approximately 77 % of Mexican households have access to potable water and consume around 40 L of bottled water per week (El Financiero, 2008).

In the case of sugarcane management, producers use different amounts and types of fertilizer. Thirty-five percent of them use Triple 17 (N-P-K), 29 % combine it with urea, and 12 % use urea as the only source of nitrogen. A lower percentage of producers use a mixture 20-10-20 (N-P-K), as well as a mixture 10-20-20, ammonium sulfate, and 4 % of the producers use organic fertilizer. Selection of N sources used in the sugar mill supplying areas, basically depends on regional availability and fertilizers price. Thus, the criteria related to the chemical-edaphic environment must be used, since any ammonium-releasing fertilizer (ammonium sulphate and nitrate, urea, among others), will have an acid residual effect on the soil. In areas with neutral or alkaline soils, applying ammonium increases the risk of N volatilization due to transformation of ammonium into ammonia gas. This might represent significant N losses if the fertilizer is left exposed on the land surface (PRONAC, 2009b). Organic fertilizer is characterized by its low solubility, releasing more slowly the nutrients to the plants, but having a longer duration effect, diminishing its loss due to leaching (Neely *et al*., 1991; Coronado, 1997; Córdoba, 2009); in addition, its varied nutrient composition meets the plants' needs (Narea and Valdivieso, 2002), which according to Gross (1986), improves soil tillage, fertility and productivity.

Dosage of N fertilizer in sugarcane is delivered in a single application by 59.2 % of growers, and divided in two applications by the remaining 40.8 % (Figure 1). According to PRONAC (2009a, b), during rainy season in the supplying areas of La Gloria and El Modelo sugar mills, it is recommended to apply 1/3 of the fertilizer dose at the time of planting or at the start of sprouting, and the remaining 2/3 during the first cultivation labor. In areas where the beginning of the cycle is in April or May, half of the dose can be applied at the beginning of the cycle and the rest at the first labor. Fertilizer dosage and application periods are not delivered exactly as recommended by both sugar mills. Fertilizer applied per year ranges from 50 to 1570 kg ha^{-1} of N, with an average of 379.8 kg ha^{-1}. This amount of N applied is higher than that recommended for irrigated areas (200 kg ha^{-1} of N, approximately), in supplying sugar mill areas of La Gloria and El Modelo (PRONAC, 2009a, b).

Using huge amounts of N fertilizer have agronomic disadvantages: inorganic fertilizers are partially used by plants during a relatively short time, in relation to the cultivation cycle, representing great losses due to leaching caused by rain and evaporation caused by high temperature. Economically, this amount of N applied to secure the maximum use by the plant, increases production costs and decreases the benefit-cost ratio (Ascanio and Hernández, 2008).

Determination of nitrates (NO_3-) and nitrites (NO_2-) in water for human consumption

Nitrates concentration in bottled water of several brands was below the maximum level allowed (10 mg L^{-1} of NO_3-). No statistical differences were found among brand names (ANOVA, $P < 0.05$), or seasons. Local brand names Ártico, Isabel and Santa Catalina contained higher nitrate concentrations, with values of 7.5, 6.65 and 5.99 mg L^{-1} (NO_3-), respectively (Figure 2). Water of these brand names is bottled in the localities of Cardel, Zempoala and Úrsulo Galván, Veracruz. Among commercial brand names, Xallapan had the highest nitrate concentration (5.46 mg L^{-1}); this water is bottled in the municipality of La Antigua, Veracruz.

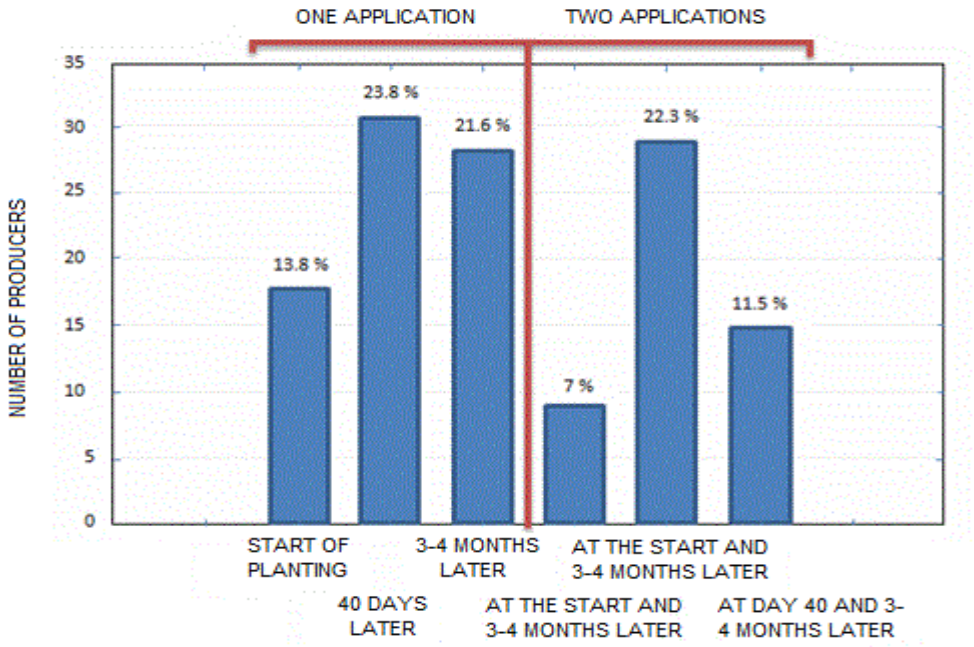

Figure 1. Dosage periods and fertilization frequency used in sugarcane produced in the Irrigation Module I-1 La Antigua, Veracruz. Mexico.

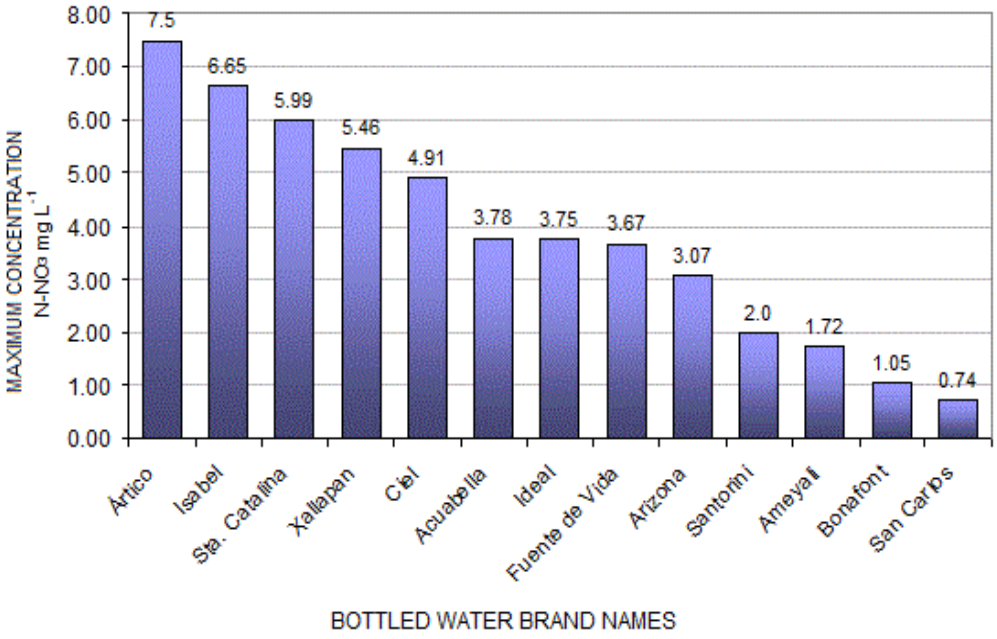

Figure 2. Maximum concentrations of nitrates (NO_3^- mg L^{-1}) present in different bottled water brands, distributed in localities from the Irrigation Module I-1 La Antigua, Veracruz. Mexico.

A lower nitrate concentration was found in Ciel (4.91 mg L^{-1}), Santorini (2.0 mg L^{-1}) and Bonafont (1.05 mg L^{-1}), however, the last two bottling plants are located outside the study area.

According to the Council for the Defense of Natural Resources (Consejo para la Defensa de los Recursos Naturales), bottled water is not necessarily cleaner or safer to drink, compared with tap water.
Some brand names might commercialize water contaminated with synthetic organic chemicals, bacteria and arsenic; a few brands even exceed the limit allowed by official standards, or by the bottled water industry (NRDC, 2007). The presence of contaminants in bottled water is also due to deficient purification processes. Nitrates in low concentrations can be retained by reverse osmosis (Riechmann, 2004), but this technology is not used in the local water bottling-purifying plants, using methods such as chlorination, ozonation and UV ray irradiation, which do not eliminate salts such as nitrates, nitrites, asbestos, among others.

Nitrite concentrations were not detectable in different localities, neither were they during different seasons. Besides being nitrate concentrations in water for human consumption, below national and international maximum level allowed, recent studies indicate that concentrations ranging from 0.1 to 870 mg L^{-1} nitrates in groundwater are mainly caused by fertilization of agricultural lands. These levels of nitrates in water for human consumption are frequently the cause of methemoglobinemia and acute infections in the respiratory airway, not only in children under one year of age, but in people of any age (Subramaniyan, 2004; Mondal *et al*., 2008).

Cancer cases

In Mexico, 514,420 deceases were recorded in the year 2007, 55.4 % were males and 44.6 % females, with malignant tumors being third place among main causes of death, having a total of 68,815 cases (13.4 %). Malignant tumor cases in esophagus and stomach were considered, due to their previous association with long-term consumption of water contaminated with nitrates and nitrites (Zaldívar and Robinson, 1973; Peter and Clough, 1983; Morales *et al*., 1995; Sandor *et al.*, 2001). The Sanitary Jurisdiction VIII, located in the city of Veracruz, Mexico, reported 338 cases of esophagus and stomach cancer in the Sotavento region from 2004 to 2009. Of these, 45 cases (13.3 %) were located in the area corresponding to the Irrigation Module I-1, distributed in the municipalities of La Antigua, Manlio F. Altamirano, Paso de Ovejas, Puente Nacional and Úrsulo Galván (Figure 3).

Statistical correlation

Based on the level of N application practiced by sugarcane growers, two statistically different categories were obtained ($P < 0.05$), which helped to classify the level of N fertilizer use into: high rational use (69.23 %; UR), given by the producers who apply a lower amount of N fertilizer, and low rational use (30.77 %), given by those who apply a higher amount of N. With this, the sugarcane UR factor in the area of study was correlated with the number of esophagus and stomach cancer cases recorded in the surrounding localities. Resulting correlation was $r = 0.46$ ($P < 0.05$), which although gives no evidence of statistical relationship between both variables during the years 2004 to 2009 in the area of Irrigation Module I-1 La Antigua, Veracruz, it also does not exclude this relationship. Cases of esophagus and stomach cancer are presented indistinctly in areas where a low or high RU is practiced, explained by fact that all the area is supplied by the same aquifer (CNA, 2009).

CONCLUSION

Nitrogen concentration as nitrates, in water for human consumption in the period and area of study did not exceed the maximum level allowed by international standards (10 mg L^{-1}). No sufficient evidence was found to attribute or exclude the incidence of esophagus and stomach cancer in the residents living in the surroundings of the Irrigation Module I-1 La Antigua, Veracruz, to the excessive use and deficient management of N fertilizer in sugarcane and by its contaminant impact in the water for human consumption.

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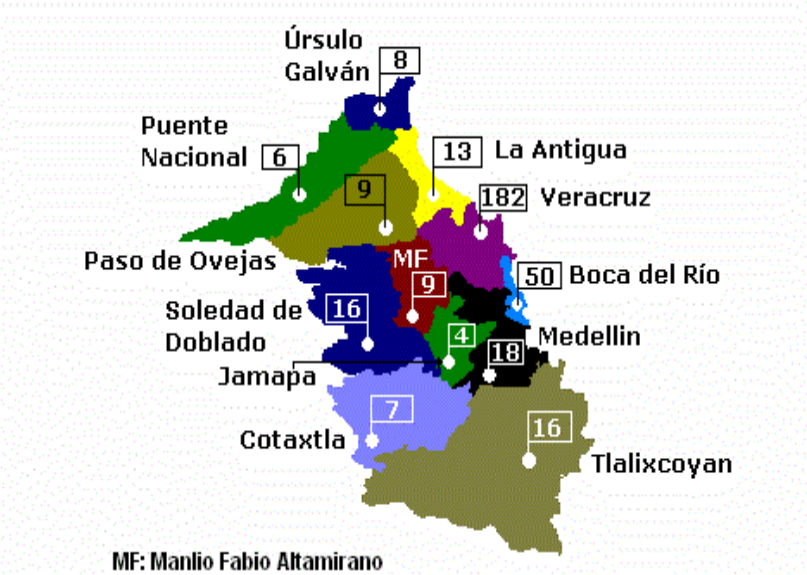

Figure 3. Number of esophagus and stomach cancer cases by municipality, detected in residents of the Sotavento region and the Irrigation Module I-1 La Antigua, Veracruz, Mexico. Years 2004-2009.

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