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Baccharis Salicifolia development in the presence of high concentrations of uranium in the arid environment of San Marcos, Chihuahua

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In humid zones and marine environments the bioindicator contaminants by trace elements are well established. However, in arid zones it is more difficult to find these tools because there is less biodiversity. The objective of this paper was to analyze the behavior of the *Baccharis salicifolia* plant in areas with high uranium concentration in arid zones, to determine the characteristics of tolerance and possible use as a biomonitor for the presence of such contaminants. For this project a uraniferous zone was selected in San Marcos, located northwest of the City of Chihuahua. A total of 8 sampling points of the plant and soil were located here. Each sample was divided into the root and the stem and leaves to determine the specific activity of the uranium in both parts of the plant and its sediments. The determination of the specific activities of the total uranium in the samples was obtained by liquid scintillation with alpha-beta separation. The results indicate a tendency for the plant to accumulate the uranium in its different parts, and to translocate it to its stem and leaves. The plant is resistant to high concentrations of uranium, not showing any specific changes in relation to non - contaminated areas that might indicate the presence of the contaminant. Therefore, its use as a biomonitor species is limited.

Keywords: Biomonitor; uranium; Baccharis Salicifolia.

En zonas húmedas y ambientes marinos están bien establecidos los bioindicadores de contaminación por elementos trazas. Sin embargo, en zonas áridas es más difícil encontrar estas herramientas, debido a que la biodiversidad es menor. El objetivo del presente trabajo fue analizar el comportamiento de la planta *Baccharis salicifolia* en sitios con altas concentraciones de uranio en zonas áridas para determinar sus características de tolerancia y posible uso como biomonitor de la presencia dicho contaminante. Para dicho estudio se seleccionó la zona uranífera de San Marcos, ubicada al noroeste de la ciudad de Chihuahua. Aquí se ubicaron 8 puntos de muestreo de la planta y suelo adyacente a la misma. Cada muestra fue seccionada en raíz y parte aérea, determinándose la actividad específica de uranio en ambas secciones de la planta y sedimentos. La determinación de las actividades específicas de uranio total en las muestras se realizó con un equipo de detección de centelleo líquido con separación alfa-beta. Los resultados indican una tendencia de la planta a acumular el uranio en sus diferentes partes, y a traslocarlo a la parte aérea de la planta. La planta es resistente a altas concentraciones de uranio, pero no muestra ningún efecto o cambio con respecto a sitios no contaminados que pueda indicar la presencia del contaminante, por lo que su uso como especie biomonitora es limitado.

Descriptores: Biomonitor; uranio; Baccharis Salicifolia.

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1. Introduction

The City of Chihuahua is located at the center of the Chihuahuan desert in México. The study area is found in the basin of the San Marcos River, where uranium deposits are found [1,2].

Organisms with concentration of metals in their tissues are often used to indicate and quantify the levels of contaminants or the bioavailability of the contaminants in the environment. A bioindicator organism contains information about the quality of the environment; a biomonitor organism contains information about the quantitative aspects of the quality of the environment [3]. In order to use an organism as a biomonitor it must be representative and abundant in the study zone, tolerate high concentrations of the contaminants, easy to identify and be analyzed, furthermore it must reflect some characteristic that allows the identification of the contaminant [4].

Previous studies in the area have shown the presence of uranium in the superficial waters, fish, and some plants [1,5]. Therefore the search for uranium contaminant biomonitors in the region may help reveal hazardous environments for crops and cattle as well as for human population. Near the study area crop land is found mainly with corn and cattle raising.

In humid areas, likens and ferns have been used as bioindicators for trace element contaminants [6,7]. In the marine environment different organisms have been used such as oysters and shrimp [4]. In México several articles have been published about biomonitors and bioindicators [8-10] but the plants are located essentially in humid areas. However, it is important to identify bioindicators in arid environments like the desert of Chihuahua due to the high contamination of these areas [11,12], considering that there are only a few species that stand the conditions of the desert [13].

The San Marcos basin spans over approximately 175 km^2. Published data about the superficial water contamination shows high uranium specific activities up to 7.7 Bq/L [3] that goes far beyond the reference level of 0.001 Bq/L for drinking water [14]. The high uranium concentrations in the area are attributed to the erosion of the uraniferous deposits located in San Marcos [2], as well as the natural contamination from a spring located in the San Marcos dam [5].

The objective of this study is to analyze the behavior of the plant under high uranium concentrations and determine the possibility of being considered as a biomonitor for the uranium contamination in arid areas. The use of this plant can be a tool to identify contaminated areas not identified by other methods and it can also represent a very important connection between the presence of natural uraniferous deposits and the transmission along the food chain. It is known that the analytical data of these biological samples represent the result of an intricate relationship between the concentration levels and absorption of chemical processes and transport [3].

The *Baccharis salicifolia* (known as Jarilla) is an indigenous species of the study area and many other areas in North America. It has been selected because it is one of the most common vegetable species in the basin. It is also important to know that this plant grows in high contaminated areas without being affected in its growth by the contaminant.

An article has been published about the use of phytoremediation of the species Baccharis *sarothroides Gray*, which grows in mining residues in Arizona [15]. This article concluded that this desert shrub is a potential hyperaccumulator of the elements Cu, Pb, Cr, Zn, As, and Ni. Since the *Baccharis salicifolia* is a plant related to the *B sarothroides*, [15] has been used as background information assuming that both bushes are resistant to contaminants such as metals and metalloids, including uranium.

FIGURE 1. Location of the study area at Chihuahua State.

FIGURE 2. Sampling sites.

2. Materials and methods

2.1. Study area

The municipality of the City of Chihuahua (Fig. 1) has a surface of 9219.33 km^2, its altitude is 1440 m above sea level, its latitude is 28°38'07" and its longitude is 106°05'20".

The sampling of the plants was preformed in 8 sites located along the San Marcos River (Fig. 2), where high concentrations of uranium were expected [1].

2.2. Translocation and accumulation factors

These factors allow us to evaluate the capacity of the plant to absorb the environment contaminant [15]. The translocation factor is defined as the quotient between the concentration of the contaminant that is present in the stem and leaves related to the contents in the roots [15,16]

$$\text{Translocation Factor} = [\text{element}]_{\text{stem and leaves}}/[\text{element}]_{\text{root}} \rightarrow \text{Equation}(1).$$

The accumulation factor is defined as the quotient between the contaminant concentration in the plant that grew in contaminated soil and the plant that grew in healthy soil [15].

$$\text{Accumulation Factor} = [\text{element}]_{\text{contaminated plant}}/[\text{element}]_{\text{healthy plant}} \rightarrow \text{Equation}(2)$$

It is possible that a plant presents translocation characteristics, showing high or low accumulation factors [17].

2.3. Preparation and analysis of vegetable samples for uranium determination

Prior to analysis, the samples were carefully washed three times with deionized water to eliminate soil particles attached

TABLE I. Uranium Concentration in samples for different locations. Statistical error for activity determination was 12 %.

	LEAF	STEM	ROOT	SEDIMENT
SAMPLE	ACTIVITY Bq/kg	ACTIVITY Bq/kg	ACTIVITY Bq/kg	ACTIVITY Bq/kg
M1	95	19	35	326
M2	29	22	25	227
M3	18	20	79	522
M4	40	27	59	350
M5	24	30	27	287
M6	461	37	67	275
M7	25	24	44	253
M8	29	41	62	462

TABLE II. Accumulation and Translocation factors for *Baccharis salicifolia*.

SAMPLE	ACCUMULATION FACTOR (AF)	TRANSLOCATION FACTOR (TF)
M1	1.1	3.3
M2	0.6	3.3
M3	0.9	0.5
M4	1.0	1.2
M5	0.6	2.0
M6	4.3	8.0
M7	0.7	1.1
M8	1.0	1.1

to the plants' surface. After the washing, the samples were oven dried at 80°C during 12 hours. The plant samples were divided into roots, stems and leaves, and then they were sieved and homogenized.

The leaves, stems and roots were digested with HNO^3 using the method from the book L'Anunciatta [18,19].

2.4. Sediment sample preparation and analysis to determine the presence of uranium

Previous to the analysis, the sediments were carefully rinsed three times with deionized water. After rinsing the samples were oven dried at 80°C for 12 hours. They were sieve with a 2 mm mesh and they were homogenized. Two aliquots of 0.5 g each were separated for analysis, the sediments were digested with the salt fusion method validated and accredited by the CIMAV chemical analysis laboratory [20].

2.5. Alpha spectrometry with liquid scintillation detector

Alpha spectrometry was the method applied to determine the total activity of the uranium in the plant sections and the sediments. A Triathler (from HIDEX) liquid scintillation detector with alpha-beta separation was used. The sample analysis was performed using the internal standard method [21]. A uranium solution was used from High Purity Standards Inc (A=24.911 Bq/mL) as the internal standard for the relative analysis.

Di-(2-ethylhexyl) phosphoric acid (HDEHP) was added to the samples for the extraction of uranium. The liquid scintillator used was UltimaGold AB (PerkinElmer). The sample in the scintillation vial is bubbled with argon gas for the extraction of dissolved oxygen. Finally the disintegration rates of the sample and the sample + standard were measured by the Triathler detector.

3. Results

In Table I the results are shown for specific activities obtained for the plants and sediments at the different sampling sites. With the results in Table I, implementing Eqs. 1 and 2 the Accumulation and Translocation Factors were calculated and shown in Table II.

As it is shown in Table II, the Accumulation Factors AF exhibits an interval from 0.6 up to 4.3, which leads us to recognize that the adult plants of the *Baccharis salicifolia* species as a possible accumulator of uranium [16]. Representing the most interest is the Translocation Factor TF that is predominantly higher than 1 and up to 8. These values indicate the translocation of the uranium from the root to stem and leaves that may be due to an efficient transportation system in the plant [15,22]. It has been discussed that the same species could behave as an accumulator, indicator or even exclude a contaminant depending of the concentration intervals in the soil [17]. The plant seems to behave as a translocator at low concentrations, but may behave as uranium excluder when there is uranium at high concentrations, as shown in the values obtained in the sample M3, (Tables I and II). The plant has not shown any difference in growth quality between areas with high contents of uranium or in the absence of it.

4. Conclusions

The uranium concentration in *Baccharis Salicifolia* and the results of the Translocation and Accumulation factors suggest that at low concentrations the plant absorbs the contaminant from its environment, translocating it essentially to the stem and leaves. The plant behaves without showing any effects in growth quality at high concentrations of uranium, having the ability of high capacity to adapt in arid environments with high concentrations of uranium such is the case in San Marcos area.

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