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THE ASTERCEAE AS NATURAL COAGULANTS OF THE WATER FROM THE BOGOTÁ RIVER (UPPER BASIN)

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Abstract

At the present time, aluminum sulfate ($Al_2(SO_4)_{3(s)}$) is used as a traditional coagulant. In the developing countries, supplies of it are short, thus, there is a need for an alternative, taking into account the diversity of promising native plants they may be used as a source. One such source are the A*steraceae*, a family which has more than 23,500 species distributed among 1600 genera, which means that they are the family of Angiosperms with the greatest biological wealth and diversity. The effectiveness as coagulants of extracts with a medium-high polarity of species of the Asteraceae family in the waters from the upper basin of the Bogota river were evaluated. To do that, the optical density at 500 nm (DO50) of a suspension of turbid water from the Bogotá river (upper basin) was measured, with variable volumes of the extracts obtained from the Asteraceae family. The species from the waters of the Bogotá river which showed the greatest coagulant capacity, at 50 ppm, are: *Chromolaena perglabra* (57.1%), *Achyrocline vell. aff. bogotensis* (43.4), *Chromolaena odorata* (41.1%) and *Chromolaena bullata* (39.8%), with respect to the aluminum sulfate, (72.7%), zinc sulfate (43.3%) and ammonium chloride (45.5%). At 100 ppm the coagulant capacities were: *Chromolaena perglabra* (41.1%) and *Lourtegia stoechadifolia* (32.3%), with respect to the aluminum sulfate (83.6%), zinc sulfate (55.0%) and ammonium chloride (66.7%); and at 250 ppm *Lourtegia stoechadifolia* (26.2%), with respect to the aluminum sulfate (87.5%), zinc sulfate (64.9%) and ammonium chloride (83.3%). Those results show that the extracts of the species under study, when subjected to this electroscropic technique, have a smaller coagulant capacity at a higher concentration, in contrast with the case of aluminum sulfate, zinc sulfate and ammonium chloride. The *Chromolaena perglabra*, *Achyrocline vell. aff. bogotensis* and *Chromolaena odorata* species show the greatest coagulant capacity with respect to the zinc sulfate and are very close to that of aluminum sulfate and ammonium chloride.

Key words: Asteraceae, Natural Coagulants, Water treatment.

Introduction

Due to its poor management and the unchecked development of communities, water, which is fundamental for life and indispensable for development, is becoming more and more scarce, a recurring problem in some regions due to a shortage of rainfall, the over-exploitation of aquifers and the contamination of the environment. Access to potable water is a fundamental and indispensable right for human beings. Despite that, millions of people currently lack that right. This situation has forced large numbers of them to consume water directly taken from rivers and tributaries, without any kind of prior treatment, which represents a grave health risk and is associated with the emergence of a large part of transmissible diseases, like hepatitis A, giardiasis, dysentery, cholera and typhoid fever [1]. For that reason, an interest in developing the use of natural coagulants has grown in recent years, ones which may be produced or extracted from microorganisms, or the tissues of plants and animals. Among the natural coagulants of animal origin, chitosan is used, which is derived from the chitin found in the shells of mollusks, the exoskeletons of arthropods, the cell walls of fungi, and yeast, and is able to eliminate up to 99% of the turbidity of raw water if it is combined with a sand bed filter: it also reduces the content of heavy metal, phosphorus and fat in the water [2]. Most of the natural extracts are derived from the seeds, leaves, barks or saps, roots and fruits extracted from trees and plants [3]. Among those which are used there are the seeds of the Nirmali tree *Strychnos potatorum*, roasted grains of maize *Zea mays* [4], the *Strychnos potatorum* (5-7], *Moringa oleifera* (8-17], okra [18], cassava [19], rice [20], starch [21-22], *Cactus Latifaria* and *Prosopis julifora* [23], valonia tannins [24-26], tamarind [27], *Samanea saman* [28], seaweed [29], *Alubia blanca,* white bean [30], cactus [31], the *Opuntia cochinellifera* cactus [32] and sweet corn [33]. In many countries aluminum sulfate ($Al_2(SO_4)_{3(s)}$), commonly known as alumina, and ferric chloride ($FeCl_3$) are traditional coagulants. Organic polymers are also used to help coagulation [34]. Natural tannins have been used for years as coagulants [35]. A tannin-based commercial cationic polymer (TBP) is likewise used, in order to establish their basic chemical properties and behavior as a coagulant. The upper basin of the Bogotá river, which is bounded by the town of Villapinzón and the Tequendama Falls, has an area of 4,321 km^2 and a length of 185 kilometers. As it flows through the upper basin, the Bogotá river receives the organic residues of a city with about 8 million inhabitants and the waste waters from many industries. The source of the river is in the town of Villapinzón. It is one of the 14 major river basins in the Colombian department of Cundinamarca [36-37].

The basin as a whole diagonally stretches across the department and covers an area of 5996 km^2. The Bogotá river is a central feature of the life of a number of towns and the city of Bogotá: for that reason, it has turned into a resource which integrates the life of the region and plays a key role in its economic and social dynamics, and, in turn, its environment and provision of environmental services. Culture is the factor which mediates between these socio-economic aspects and the environment itself and culture is what determines its use.

Methods

Collection of the species

The following species were collected in the Andean high plains region of central Colombia, which covers parts of the departments of Cundinamarca and Boyacá: *Chromolaena odorata*, *Chromolaena leivensis*, *Chromolanea perglabra* and *Achyrocline saturaoides* in Tinjaca, Boyacá; *Diplostephium phylicoides*, *Diplostephium revolutum* and *Achyrocline alata* in Guasca, Cundinamarca; *Gnaphalium pellitum* and *Achyrocline vell. aff. bogotensis* in Guatavita, Cundinamarca; *Lourtehgia stoechadifolia* and *Senecio pampae* in Tenjo, Cundinamarca; *Chromoalena bullata*, in Sibate, Cundinamarca; ; and *Baccharis revoluta* in Villapinzón, Cundinamarca.

Obtention of extracts

The aerial parts of the collected species were dried at room temperature and triturated in a blade mill for their subsequent extraction with ethanol in a Soxhlet extractor (72 hours) and maceration (four months), to obtain complete extracts. The vegetal material was subjected to a second extraction with water: formic acid 99:1 per maceration. At the end of two months, it was concentrated at low pressure to obtain the polar extract to be evaluated.

Coagulant Activity:

We adapted the methodology developed by the Applied Environmental Biotechnology Group of the Biotechnology Department of the Kungliga Tekniska Högskolan University of Stockholm, Sweden , based on a version of the extended jar test on a laboratory scale. Briefly, the method consists of measuring the optical density at 500 nm (DO500) of a suspension of synthetic turbid water (kaolin and clay) and test samples from the Bogota river (upper basin), to which is added a variable volume of the coagulant extract under study in a plastic bucket. In that way, the volume of turbid water is reduced to that needed to undertake the analysis, as is the concentration of crude extract which is required, thus allowing for several simultaneous assays [38]. For the study, different concentrations of extracts of Asteraceae and salts were used (100, 200 and 500 ml), taken from standard solutions of 10,000 ppm and it was completed at a volume of 2 ml with water from the river Bogotá. The final concentrations of the dilution obtained were: 500, 1000 and 2500 ppm; likewise, for the tannins with a standard solution of 1000 ppm and with the same procedure, concentrations of 50, 100 and 250 ppm were obtained. This protocol is also used for solutions of kaolin and clay prepared at 500 ppm. The solutions were immediately homogenized and measured at an absorbance of 500 nm in a Thermo Scientific Gensys 20 UV-Visible spectrophotometer. The dilution of the bucket was allowed to sediment for 1 hours; immediately afterwards the absorbance was measured again at 500 nm. The reduction of the value of the absorbance compared to the initial one defines the primary coagulant capacity of the crude extract, as shown in equation 1.

Coagulant Activity %= [((Absorbance at time zero to) – (Absorbance to t60)) / Absorbance to] x 100 (Equation 1).

Results

The coagulant activity of extracts of the species (Asteraceae) collected in the abovementioned region of Cundinamarca and Boyacá was evaluated and compared with the coagulant activity of the salts and tannins, in water samples collected in the upper basin of the Bogotá River and solutions of kaolin and clay ; the data can be seen in table 1.

Analysis

With the data obtained from the clotting ability of the species, the salts at concentrations of 500, 1000 and 2500 ppm and tannins at 50, 100 and 250 ppm, and using different matrices such as water from the upper basin of the Bogotá River and solutions of kaolin and clay at 500 ppm, it was clearly determined that the extracts of different species interact in different concentrations and influence the response (table 1).

The *Chromolaena perglabra, Lourtegia stoechadifolia, Achyrocline vell. aff. bogotensis,* and *Chromolaena odorata* species showed the greatest coagulant ability compared with the aluminum, zinc and ammonium chloride sulfate. This 500 nm spectroscopic evidence protocol shows that for the species at a higher concentration, the clotting capacity diminishes due to coloration, while, for the salts, the higher the concentration, the greater the coagulant capacity. For the kaolin matrix at 500 ppm, it was seen that the aluminum sulfate showed the greatest coagulant capacity, followed by the zinc sulfate and the ammonium chloride. The species which showed the greatest coagulant capacity at 500 ppm were: *D. revolutum*, *D. phylicoides, G. pellitum* and *Achyrocline vell. aff. bogotensis*.

In the clay matrix at 500 ppm, it was seen that the aluminum sulfate showed the greatest coagulant capacity, followed by the zinc sulfate and ammonium chloride and at 500 ppm, *L. stoechadifolia, C. perglabra* and *C. revolutum* showed the greatest coagulant capacities. Tannins: *Quebracho, Mimosa and Castaño*, at a concentration of 50 ppm, showed a coagulant activity in the water from the Bogotá river equal to 30.2%, 35.0% and 31.7%, respectively. At a concentration of 100 ppm, the values of the coagulant capacity were 17.2%, 20.0% and 21.5%, respectively. Moreover, at 250 ppm the values for the capacity obtained were 9.6%, 6.2% and 6.1%, respectively. The above results showed us that the coagulating ability of tannins is inversely proportional to the concentration used, whereas for the salts the relation is directly proportional, while the coagulating ability of tannins is inversely proportional to the concentration used. Tannins: *Quebracho*, Mimosa and Castaño, at a concentration of 50 ppm, show a coagulant capacity, with a kaolin matrix at 500 ppm, of 27.8%, 25.0% and 29.9%, respectively.

At a concentration of 100 ppm, the coagulant capacity was 26.5%, 26.9% and 22.1%, respectively. The results obtained at 250 ppm were 12.3%, 18.4% and 18.8%, respectively. The above results, in the conditions used in the experiment, allow us to state that the coagulant capacity of the tannins is inversely proportional to the concentration which is used.

At 50 ppm, the *Quebracho*, *Mimosa* and *Castaño* tannin showed no coagulant activity in a clay matrix at 8.6%, 9.8% and 11.5%. At 250 ppm they were 6.0%, 7.9% and 8.4%. What this electroscopic technique showed us is that, measured at 500 nm, the stronger the concentration of tannins, the less the coagulant activity. The data published by Guzmán [39], in his article entitled “Natural coagulants vs. turbidity - Reduction of the turbidity of water using natural coagulants” refer to a study by Šćiban [4], who reports a coagulant activity in the turbidimetry of the *Castaño* at 0.5 ppm, with a rate of effective removal of 40-85%, and also to that of Beltrán [35], who reports a coagulant activity in the *quebracho* at 0.25 ppm, with a rate of effective removal of 80-95% and that of Vásquez [40], "The removal of the turbidity of water with natural coagulants obtained from the seeds of the *Eritrina americana*, *Quercus ilex*, *Acacia farnesiana*, *Viscum album* and *Senna candolleana*". He reports a coagulant activity in the turbidimetry of the *quebracho* at 50 ppm with an effective rate of coagulation of 56.5%. At 100 ppm it is 62.3% and at 250 ppm it is 73.5%. What this shows us is that the results are important but their comparison is not coherent because different methods are used: turbidimetry in one case and spectrophotometry in the other. It was shown that the interaction of the samples (species), in different concentrations and different matrixes (waters from the upper basin of the Bogota river, kaolin or clay) had effects on the coagulant response, compared to the salts and tannins. *C. perglabra* and *L. stoechadifolia* are the species which showed the best coagulant capacity, independently of the matrix.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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Table 1. Coagulant capacity of Asteraceae, salts and tannins from the river Bogotá (upper basin), kaolin and clay (500 ppm).

% Coagulant Capacity	Water			Kaolin			Clay		
	Extract : Water			Extract: Kaolin			Extract: Clay		
Species and Salts	**500 ppm**	**1000 ppm**	**2500 ppm**	**500 ppm**	**1000 ppm**	**2500 ppm**	**500 ppm**	**1000 ppm**	**2500 ppm**
	0.1:1.9	**0.2:1.8**	**0.5:1.5**	**0.1:1.9**	**0.2:1.8**	**0.5:1.5**	**0.1:1.9**	**0.2:1.8**	**0.5:1.5**
Achyrocline alata	28.0	21.1	10.6	30.7	21.1	17.5	11.4	7.7	6.5
Achyrocline satureioides	19.3	17.9	14.2	26.3	19.7	14.4	10.0	9.1	6.9
Achyrocline vell. aff. bogotensis	43.4	33.7	25.0	39.7	35.6	33.2	12.3	10.7	7.5
Baccharis revoluta	9.9	8.9	3.8	21.7	18.2	12.2	12.9	11.0	7.8
Chromolaena bullata	39.8	28.5	14.8	23.5	20.7	11.4	12.4	9.8	8.2
Chromolaena leivensis	23.7	9.0	1.7	25.9	19.2	13.5	13.3	11.0	7.6
Chromolaena leivensis (tallos)	26.4	17.3	11.8	26.0	21.6	17.0	8.4	6.2	4.7
Chromolaena odorata	41.4	24.4	11.8	31.2	20.1	17.9	14.8	13.3	10.3
Chromolaena perglabra	57.1	41.1	24.2	16.5	31.7	38.2	27.2	19.5	12.4
Diplostephium philicoides	23.9	15.8	10.0	38.7	33.0	11.6	13.1	11.9	7.9
Diplostephium phylicoides (tallos)	33.7	19.5	13.3	44.9	39.3	14.9	19.8	12.7	9.4
Diplostephium revolutum	23.3	12.2	7.4	39.5	19.4	8.7	18.5	12.7	9.9
Gnaphalium pellitum	16.5	5.7	2.8	38.1	32.0	18.3	22.7	15.9	7.0
Lourtegia stoechadifolia	36.4	32.3	26.2	30.8	27.8	14.0	19.4	14.4	10.3
Senecio pampae	6.1	3.1	2.4	23.4	17.5	10.0	12.0	9.2	8.6
Sulfato de Aluminio	72.7	83.6	87.5	86.7	88.1	89.0	91.5	93.4	96.6
Cloruro de Amonio	45.5	66.7	83.3	58.3	74.0	87.3	88.2	91.5	94.7
Sulfato de Cinc	43.3	55.0	64.9	57.1	68.5	79.5	66.3	73.7	84.7
Tannins	**50 ppm**	**100 ppm**	**250 ppm**	**50 ppm**	**100 ppm**	**250 ppm**	**50 ppm**	**100 ppm**	**250 ppm**
	0.1:1.9	**0.2:1.8**	**0.5:1.5**	**0.1:1.9**	**0.2:1.8**	**0.5:1.5**	**0.1:1.9**	**0.2:1.8**	**0.5:1.5**
Quebracho	30.2	17.2	9.6	27.8	26.5	12.3	8.6	7.2	6.0
Mimosa	35.0	20.0	6.2	25.0	26.9	18.4	9.8	8.2	7.9
Castaño	31.7	21.5	6.1	29.9	22.1	18.8	11.5	10.5	8.4