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Estimation of Potential Pollution of Cigarette Butts Littered in Nightlife Areas in Bogota D.C upon its River

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ABSTRACT

Littered cigarette butts are very common waste on streets and sidewalks in nightlife areas in most cities. The chemicals and metals leached from butts are toxic to water ecosystems. In Bogota D.C. 94.9 million cigarette butts are thrown per year in pubs and dance club areas, which are drawn away by rain. The results of cigarette butts leaching tests are presented in this paper. The variables chosen were typical indicators of water quality such as pH, conductivity, turbidity, color, COD, cadmium, and arsenic. The results showed that in one hour, a hundred cigarette butts can add about 5917 mg/L of COD, 285 ppb cadmium and 10 ppb arsenic in one liter of water; they also can increase the turbidity and color values in 30 NTU and more than 3163 PCU, respectively. The leaching of these 94.9 million of cigarette butts littered annually upon roads and sidewalks in nightlife areas in Bogota, can add to its River about 51.6 tons/year of cadmium, 1.81 tons/year of arsenic and 1.07 million tons/year of chemical oxygen demand. In the case of reaching the wastewater facilities, these pollutants will affect sewage treatment, cause alteration over biological processes and a significant increase in operational costs.

Keywords: *tests, dance clubs, pubs, streets, sidewalks, urban rivers.*

INTRODUCTION

There are about 1300 million smokers around the world (1). The number of smokers in Colombia rises up to 9 million (2). Nearly half of those are young college students, whose cigarette consum-ption reaches about 46% (1, 3). Each smoker older than 15 years old reaches about 500 cigarettes per year in average consumption (2, 4).Different studies report that the cigarette combustion leaves traces of more than 4000 chemicals, at least 50 are carcinogenic, including hydrogen cyanide, nitrates, ammonium, acetalde-hyde, formaldehyde, benzene, phenols, pyridines and carbon monoxide (5-8). Cadmium (Cd), plumb (Pb), arsenic (As) and nickel (Ni) are also found; these elements are bio accumulative and along with nicotine and tar, they cause serious damage to water sources (9, 10). Also, the filter thrown away with the cigarette butt is not biodegradable (11) and the chemical pollutants, along with another remain toxic substances, are easily transferred by leaching to soil and water, causing damage to the environment and ecosystems (8, 12-16).

Slaughter and collaborators (12) found, under laboratory conditions, that the leaching of one cigarette butt in a liter of water can cause the death of 50% of fish exposed. This argument leads to thinking of cigarette butts as dangerous waste (17). In addition, these cigarette butts are able to obstruct sewerage remarkably when combined with other solid waste (18). Cigarette butts are the most common littering around the globe. In Australia, for example, between 24 and 32 billion of cigarette butts are thrown away, from which a 10% ends up in water ecosystems. Around the world, this figure exceeds 5.6 trillion (17, 19-21); such value would represent an annual global mass of 845,000 tons of cigarette butts (22). In Bogota D.C. 94.9 million of cigarette butts (16 tons) are littered upon roads and sidewalks in nightlife areas (23). These cigarette butts are drawn away by rainwater through sewerage systems and their pollutant leaching is transported, with meteoric water that flows into rivers and wetlands that, in turn, flow into the Bogota River.

In Colombia, in 2008, the Ministry of Social Protection issued Resolution 1956 which states: *"Smoking in enclosed areas of places of work and public places is forbidden"*. The purpose of this standard, as well as other worldwide anti-tobacco laws is to help the health of the population, to protect people from exposure to tobacco smoke, reduce health problems and avoid affecting the non-smoker population, reducing lung problems (24). However, this law had for Lozano-Rivas & Franco (9), a negative incidence from an environmental point of view, since the number of cigarette butts thrown increased, being the problem even more critical in areas of pubs, bars, dance clubs, and other sorts of nightlife establishments. The same issue caused by anti-tobacco laws, had already been exposed in other countries (11, 25).

Materials and Methods

This research was developed by students of the Research Incubator in Water Management and Technologies from the Environmental Sciences Faculty of Piloto de Colombia University. This group is affiliated to the Environmental and Sustainability Research Group (GUIAS, for its acronym in Spanish) from the same university. The pollution potential from the leaching of cigarette butts (referred to as CB, herein) thrown upon roads and sidewalks surrounding nightlife areas in Bogota D.C. upon its main river (Bogota River) was evaluated through a quasi-experimental design, performed in the Chemical and Environmental Analysis Laboratory.

Compilation of Cigarette Butts

The cigarette butts (CB) used in this research were picked up daily from two exclusive disposal containers in surroundings of the Piloto de Colombia University in Bogota D.C. Afterward, under a laminar flow cabin, the dry CB with traces of tobacco was chosen.

Analysis and Instrumentation

The main parameters considered were pH, conductivity (mS/cm), turbidity (NTU), color (PCU), chemical oxygen demand (COD) (mg/L), cadmium (Cd) (ppb) and arsenic (As) (ppb). The measuring instruments are given in Table1.

Table1. *Research variables and measuring instruments*

Variable and unit	Measuring instrument	Accuracy
pH	Thermo scientific Orion 2 Star	± 0.002
Temperature (°C)	Thermo scientific Orion 2 Star	± 0.1 °C
Conductivity (mS/cm)	Seven Easy meter Toledo	± 0.5%
Turbidity (NTU)	HF Scientific Micro TPW	± 2% (0-500 NTU); ± 3% (500-1100 NTU)
Color (PCU)	Hanna HI83099	± 5%
COD (mg/L)	Hanna HI83099	± 4%
Cadmium	Merck Spectro quant® 101745	Not reported
Arsenic	Merck MQuant® test strips 117927	Not reported

Leaching of Cigarette Butts

We use six (6) acrylic square-section jars (Jar-Tester) to emulate the washing of CB thrown upon roads during a rainfall event and the leaching of its contaminants. Each jar was filled with 1 L of distilled water and 2, 5, 10, 20, 50 and 100 CB were put into them. Every cup was taken to a flocculator (*Jar-Tester, E&Q, F6 model*) and they were blended at a constant speed of 76 RPM, which is equivalent to a gradient of 52 (1/s) equivalent to a linear velocity of 0.10 m/s, which is analog to the average speed of draining in the ditches in a rainfall event of a medium intensity. Every trial was carried out three times. Once began the mechanical mixing, samples from every jar were collected in the following terms: after 20, 40, 60, 90 and 120 minutes.

In addition, a leaching procedure for cadmium (Cd) and arsenic (As) analysis was performed. Each jar contained 100 CB was filled with 1 liter of distilled water. The concentration of heavy metals was determined in intervals of 2, 5, 10, 30, 60 and 120 minutes. The procedures were carried out three times.

Data Analysis

The results obtained were analyzed via the *ANOVA* tests and multiple linear correlation analysis (pH, conductivity, turbidity, color, and COD) $(p<0.05)$. Cadmium and arsenic were tested by simple regressions $(p<0.05)$. The software used was that of *Stat Graphics CENTURION18* $(\alpha=0.05)$.

Results and Discussion

Potential Pollution of Cigarette Butts in Nightlife Areas in bogota D.C.

The results show that the pH does not show any significant variation, neither with the number of CB, nor with the leaching time ($R^2=0.133; F=2.07;$

p>0.05) (Table 2). All tests were conducted in a temperature between 13.6 and 13.9 °C.

Table2. *pH results from leaching different amounts of CB at different time lapses.*

	pH (units)					
Time lapse (min)	**2 CB**	**5 CB**	**10 CB**	**20 CB**	**50 CB**	**100 CB**
20	7.98	8.01	7.25	7.93	7.58	7.54
40	8.52	7.52	7.36	7.69	7.79	7.75
60	8.69	7.63	7.78	7.90	7.79	7.69
90	8.27	7.72	7.74	7.77	7.88	7.91
120	8.33	8.10	7.72	7.93	7.78	7.91

An increase in the conductivity values is evidenced, which is proportional to the number of CB that are present in water. In contrast, the variation presented through the time (between 20 and 120 minutes) for the same number of CB leached in water is very slight (Fig 1).

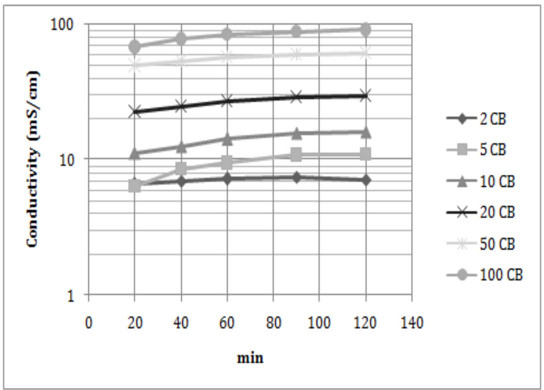

Fig1. *Results for conductivity from leaching CB*

The multiple linear correlation analysis shows that the conductivity value, in 1 L water sample, can be explained by equation 1, with an $R^2=0.962$ ($F=342.76; p<0.01$). Conductivity is expressed in mS/cm, 'CB' is the number of cigarette butts and't' is the leaching time in minutes.

[Eq. 1] $Conductivity = 2.53 + (0.78 * CB) + (0.083 * t)$

For turbidity, the highest increases were presented by the leaching processes of 50 and 100 CB in a sample of 1 liter of water, with similar values (Fig 2). This lack of difference could be caused by the saturation of suspended solids after fifty CB. It was found that these amounts of CB has the capacity to increase the turbidity of 1 liter of water sample in more than 30 NTU in an hour, and in more than 120 NTU in two hours. The multiple linear correlation analysis for turbidity shows that this variable can be explained by equation 2, with an $R^2=0.569$ ($F=17.79; p<0.01$). Turbidity is expressed in NTU, 'CB' is the number of cigarette butts and 't' is the leaching time in minutes.

[Eq. 2] $NTU = -32.87 + (0.73 * CB) + (0.46 * t)$

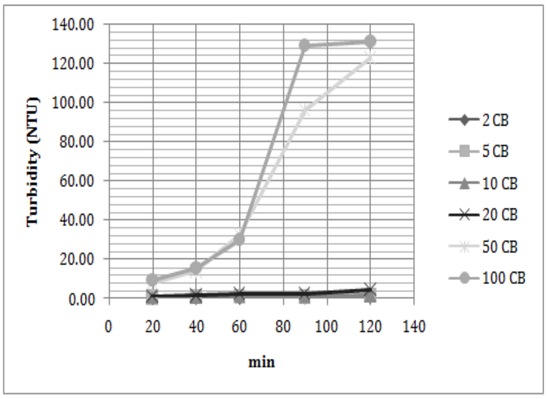

Fig2. *Results for turbidity from the leaching of CB*

The color behaves similar to the turbidity, its increase is more notorious in the leaching samples of 50 and 100 CB. In 1 liter of water, 50 CB have the ability to increase the color in about 2000 PCU in an hour and in more than 4000 PCU after two hours (Fig 3).

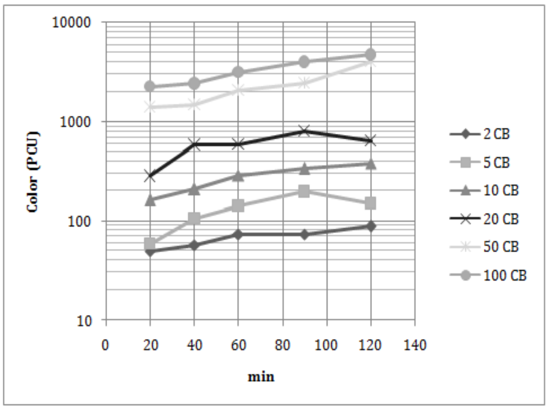

Fig3. *Results for color, from the leaching of CB*

The multiple linear correlation analysis shows that the value of color in water, in a sample of 1 liter, can be explained by equation 3, with an R^2 *of 0.871* ($F=90.80; p<0.01$). In the equation, color is expressed in PCU, 'CB' is the number of CB and 't' is the leaching time in minutes.

[Equation 3] $PCU = -627.26 + (35.04 * CB) + (9.70 * t)$

For the chemical oxygen demand (COD) a rise directly proportional to the number of CB in the water is shown. Two CB in a liter of water add more than 100 mg/L COD in a lapse as short as

20 minutes. In 1 hour, 50 CB add more than 3000 mg/L COD to the water and 100 CB can increase until around 6000 mg/L the COD from the water (Fig 4).

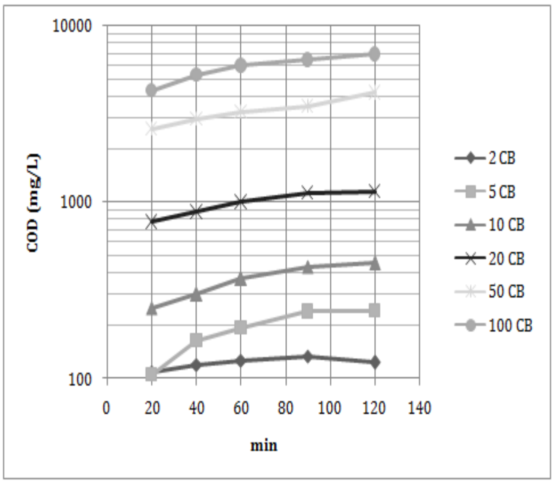

Fig4. *Results for COD from leaching CB*

The multiple linear correlation analysis shows that the COD values in a sample of 1 liter of water can be explained by Equation 4 with an R^2 *of 0.968* (*F=402.06; p<0.01*). In the equation COD is expressed in mg/L, 'CB' is the number of CB and't' is the leaching time in minutes.

[Eq. 4] $COD = -594.07 + (59.76 * CB) + (7.78 * t)$

The tests for 100 CB, an increase in cadmium values concentration was found in parts per billion (ppb). This was directly proportional to the leaching time, which respond in the first 120 minutes to a regression function with an R^2 *of 0.987* (*F=588.98; p<0.001*) (Fig 5). In the equation, Cd is expressed in ppb and 't' is the leaching time in minutes.

[Eq. 5] $Cd = \sqrt{-15{,}188.8 + 12{,}279.7 * \sqrt{t}}$

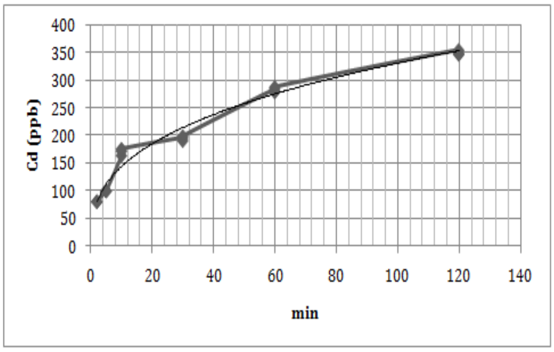

Fig5. *Results for cadmium from leaching 100 CB in 1 L of water*

Similarly to cadmium, an increase in arsenic traces (ppb) was found, which was directly proportional to the leaching time (Fig 6) and response during the first 120 minutes to a regression function with an R^2 *of 0.9878*(*F=642.00; p<0.001*). In the equation as is expressed in ppb and 't' is the leaching time in minutes.

[Eq. 6] $As = \sqrt{14.11 + 0.04 * t^2}$

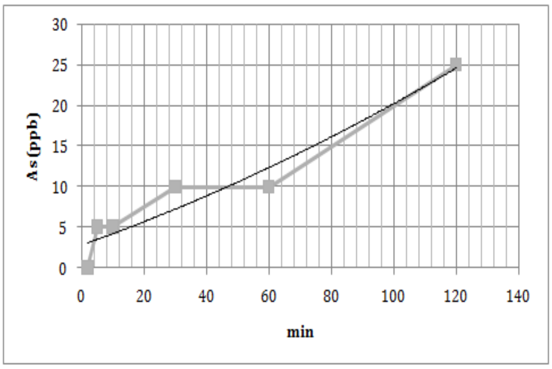

Fig6. *Results for arsenic from leaching 100 CB in 1 L of water*

The CB thrown on roads have the capacity to cause the effects shown in Table 3, for color (PCU) and COD, as well as Cd and As (in the case of 100 CB).

Table3. *Effects of leaching CB in 1 liter of water*

Amount of CB	Effects in 1 hour	Effects in 2 hours
2	123 mg/L of COD 74 PCU * **	126 mg/L of COD 88 PCU * **
50	3258 mg/L of COD 2083 PCU * **	4157 mg/L of COD 4017 PCU * **
100	5917 mg/L of COD 3163 PCU 285 ppb of Cd 10 ppb of As	6871 mg/L of COD 4677 PCU 351 ppb of Cd 25 ppb of As

**Cadmium not tested*

***Arsenic not tested*

The results obtained in this research evidence the significant adverse effect of CB in the environment and ecosystems, as well as reported by Slaughter and collaborators (12), Novotny, Lum, Smith, Wang, & Barnes (13), Sakas (14) y Micevska, Warne, Pablo, & Patra (8), among others. This supports the need to treat urban rainwater before discharging it into water ecosystems because its high amount of suspended solids (MES for its acronym in Spanish), COD and heavy metals, which have been reported by Torres Abello (26), Chocat (27), Levy & Lara (28), Ellis (29) y Degrémont (30), among others.

Calculation of the Contaminant Load added by CB in Nightlife Areas in Bogota D.C

Bogota city has an urban area of 307.36 km^2 (31) with an average's runoff coefficient of 0.64, precipitation of 920 mm/year and annual runoff volume of 180,973,568 m^3(32). This runoff volume travels through the urban area (for the 4 basins of the main rivers of the city: Tunjuelo, Fucha, Salitre and Torca) with an average concentration time of 149.9 minutes (33). In order to standardize the calculation and considering the multiple locations of the nightlife areas, this calculation is made taking as a reference a contact time, of the CB with the runoff waters, of 60 minutes.

In Bogota 94.9 million of annual CB are littered upon roads and sidewalks in nightlife areas, drawn into runoff water, taken to the sewerage systems and finally, to the urban streams and wetlands that discharge into the Bogota River. The potential pollutant load contributed, based on 100 CB in one hour as contact time, is estimated by multiplying the values of COD, Cd and As, by the annual runoff. Thus the potential contributions for COD would be up to 1.07 million tons/year, 51.6tons/year for Cd and 1.81 tons/year for As. Furthermore, these 94.9million CB could add, according to Equation 2 and 3, 69.3 million of turbidity units (NTU) and 3, 325 million of color units (PCU) to water throughout the year.

Conclusion

This is not a precise determination but an approximation to the potential contaminant of CB. Thereby, littering CB have a high potential to cause important environmental damage in water ecosystems, especially because of the heavy metals contained in them, whose figures reach up to 51.6 tons per year of Cd and 1.81tons per year of As, as well as 1.07 million tons per year of COD related to the leaching of the CB. It is undeniable that these contaminant loads will cause difficulties in the wastewater treatment plants, if they reach the sewerage network, which also represents an alteration of the biological processes and a substantial increase in the operational costs of these facilities.

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