EVALUATION OF HEAVY METALS FROM COCOA GROWING SOILS OF TRINIDAD & TOBAGO

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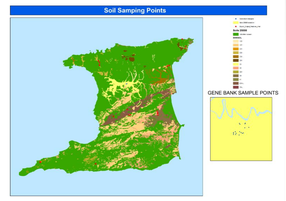
Presenter



Abstract: Extractability of cadmium and other heavy metals was studied on selected Cocoa growing soils representing 11 major soil classes of Trinidad and Tobago. For this study, a total number of 33 soil samples were collected from the island-wide representative cocoa-growing farms and another 12 representative soil samples from a 6.21 ha farm of "Home for International Cocoa Gene Bank" at University of West Indies [UWI]. These samples were used to study the extractability of Cd, Cr, Ni and Pb using 7 common chemical extractants described in literature. Results of this study revealed that Mehlich III and DTPA extracted more heavy metals compared to that of other extractants. Water extracted generally less heavy metals compared to all other extractants. Extractable Ni and Pb contents are comparatively higher than that of extractable Cd & Cr contents monitored in this study. Results also indicated that some of the soils had a very high level of water-extractable heavy metal contents, and, as such, they can act as a source and could potentially pollute the groundwater which is likely to be used as drinking water source. It can as well also result in elevated soil solution level concentrations and ultimately impacting human health. Further studies are planned to identify various chemical associations of these heavy metals in soils through 'sequential' extraction processes to understand the dynamics of these heavy metals and their impact on plant availability relationships by performing additional statistical studies such as Regression Correlation.

Introduction:

Heavy Metals: What are they? Why do we call them as heavy metals?

- Arsenic, beryllium, **cadmium**, **chromium**, **lead**, manganese, mercury, **nickel**, and selenium are some of the metals (called 'heavy' because of their high relative atomic mass) which persist in nature and can cause damage or death in animals, humans, and **plants** even at very low concentrations [1 or 2 (µg/g) in some cases].
- These metals are used in industrial processes and they are carried by air and water when discharged in the environment. Since heavy metals have a propensity to accumulate in selective body organs (such as brain, kidney and liver) their prescribed average safety levels in food or water are often misleadingly high.

Why are we interested in determining these Heavy Metals in Cocoa Growing Soils? – Due to Human Health Concerns.

- Most people who consume chocolate worry about the effect the sweet treat will have on their waistlines, but not the potential damage it could do to their kidneys.
- A naturally occurring heavy metal found in soil, **cadmium [Cd]** is present in a variety of foods including wheat and barely. While human bodies are designed to tolerate a certain amount of cadmium, too much of the heavy metal can cause a host of problems, from kidney failure, damage to neurons and also brittle bones.
- Cadmium levels in cocoa have raised the concern of the European Commission **[EC]**, which is seeking to regulate the amount of the cadmium in various foodstuffs by 2019 by imposing Maximum Allowable Levels [MAL].
- To help combat the problem, a number of European companies involved in the cocoa and chocolate industry have enlisted the Cocoa Research Centre at University of West Indies **[Home of International Cocoa Gene Bank]** to help find ways to reduce the amount of cadmium in foods such as chocolate other chocolate products.
- An initial evaluation study was performed in cocoa growing soils of Trinidad and Tobago by using selected chemical extractants to estimate extractable Cd and other heavy metals in soils which could be used to develop the best indicator to predict Cd content in Cocoa leaf and in Cocoa beans.

Objective: Compare various chemical extractants to estimate extractable heavy metal [Cd, Cr, Ni, & Pb] contents in representative Cocoa growing soils from Cocoa farms of Trinidad and Tobago.

Hypotheses:

- Various extractants differ in their potential to extract various heavy metals (including Cd) from cocoa growing soils of Trinidad.
- Various factors including pH of various chemical extractants have influence on extractability of selected heavy metals (including Cd) from cocoa growing soils of Trinidad.

Materials and Methods:

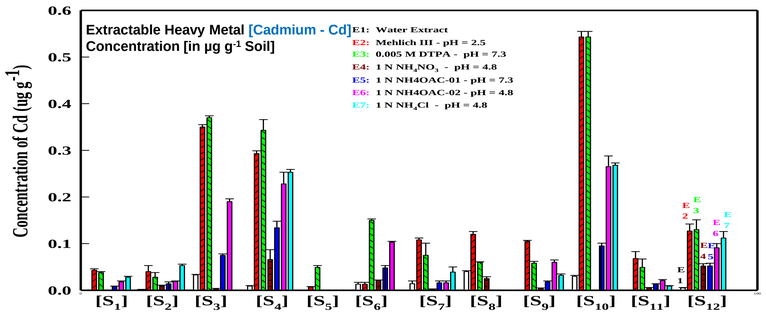
Materials: [Soils representing 11 major classes of cocoa growing soils] - Total 45 soil samples

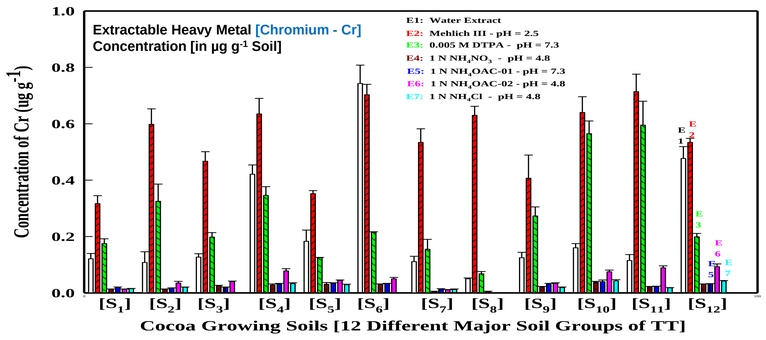
- 33 representative (island-wide) Cocoa Growing soil samples were collected from cocoa farms in Trinidad and Tobago. Each sample is a mixture of soil samples taken from 4 corners within the tree trunk and dripline.
- Another 12 representative soil samples were collected similarly from the "**Home of International Cocoa Gene Bank Farm**" in Trinidad and Tobago.

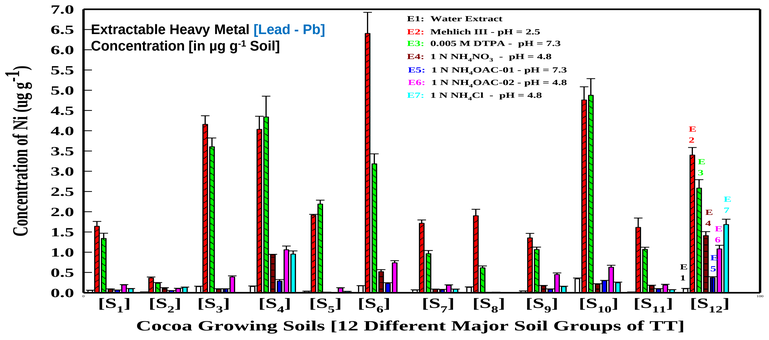
Methods:

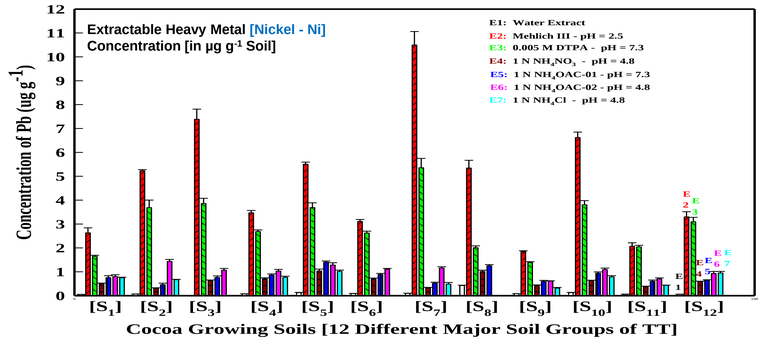
- pH and Electrical conductivity measurements were made on [**1:2.5** Soil : Water]
- Elemental analysis on various chemical extracts was done using Inductively Coupled Plasma Optical Emission Spectrometry [ICP-OES] RL 3100.

Results Of Extractable Heavy Metals









pH measurement [1:2.5 Soil : Water]

Soils	Range	Mean
Island wide Farmers Farms	**3.51 to 6.90**	**4.65**
International Gene Bank Farm	**3.98 to 4.74**	**4.20**

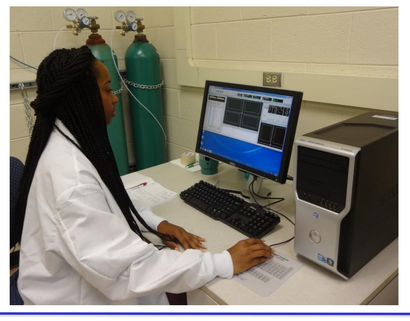
EC measurement [1:2.5 Soil: Water] (µScm^{-1})

Soils	Range	Mean
Island wide Farmers Farms	**51 to 888**	**200**
International Gene Bank Farm	**32 to 58**	**44**

BRIEF DESCRIPTION OF EXTRACTION PROCESS FOR ICP ANALYSIS

Extractants used	Soil:Extractant [Ratio]	Solution pH	Citation for Methods used
1. Water	1:10	4.4 – 5.8	
2. Mehlich III	1:10	2.5	Mehlich, [1984]
3. 0.005 *M* DTPA	1:10	7.3	Lindsay & Norvell [1972],
4. 1 *N* Ammonium Nitrate	1:5	4.8	Symeonides & McRae, [1977]
5. 1 *N* Ammonium Acetate	1:5	7.3	John et al., 1972b
6. 1 *N* Ammonium Acetate	1:5	4.8	Andersson & Nilsson, [974]
7. 1 *N* Ammonium Chloride	1:5	4.8	Krishnamurthy et al., [1995]

Setting up ICP- OES for Heavy Metal Analysis



Striking Observations of Heavy Metal contents in Water Extract of Cocoa Growing Soils of Trinidad and Tobago

Extractants		Origin of Soils (Island wide Farms		Origin of Soils (International Cocoa Gene Bank)		Allowable in Drinking water (in µg mL^{-1})
Metal	Water-Soil solution pH	Range [in µg g^{-1} Soil]	Mean [in µg g^{-1} Soil]	Range [in µg g^{-1} Soil]	Mean [in µg g^{-1} Soil]	
Cd	**4.4 – 5.8**	**0.000 – 0.040**	**0.006**	**0.000 – 0.080**	**0.008**	**0.005 [8 - 16]**
Cr	**4.4 – 5.8**	**0.007 – 0.640**	**0.222**	**0.283 – 0.873**	**0.538**	**0.100 [6 - 9]**
Ni	**4.4 – 5.8**	**0.007 – 0.640**	**0.076**	**0.033 – 0.180**	**0.106**	**0.100 [2 - 6]**
Pb	**4.4 – 5.8**	**0.000 - 0.427**	**0.076**	**0.003 – 0.197**	**0.048**	**0.015 [13 – 28]**

Some of these soils can act as source of heavy metal contents present in drinking water in these areas and exceeding allowable drinking water [ADW] level (monitoring of groundwater as per guidelines of US-EPA – 2017) could serve as potential threat to human health in addition to accumulation of these heavy metals. It is of special interest to study Cd in cocoa beans that could reach human body through chocolate and chocolate products through cocoa powder.

General Observations & Conclusions:

- Different extractants have their own merits and demerits on their extractability.
- Extractability of different heavy metals (Cd, Cr, Ni, Pb) varied and are affected by various factors.
- Mehlich III and DTPA extracted more heavy metals compared to others.
- Water extracted generally less heavy metals compared to all others.
- Extractable Ni and Pb contents are comparatively higher than that of extractable Cd & Cr contents evaluated in this study.

Future Studies:

1. Plan to perform additional **Statistical** (Regression and Correlation) **Analysis** on this information to choose a suitable chemical extractant which could depict close relationship with cadmium [Cd] content in Cocoa leaves and mainly in cocoa beans.
2. Plan to perform sequential extraction studies on selected soil samples to identify the form in which these heavy metals are residing in soils.

References: European Commission 2006. Commission Regulation (EC) No 188/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs.
US EPA 2017 (https://www.epa.gov/ground-water-and-drinking-water/table-regulated-drinking-water-contaminants).

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