USE OF VINASSE FOR SOIL RECLAMATION AND ITS IMPACT ON ELEMENTAL LOADS IN VERTISOL SOIL AND GROUNDWATER

By

MARCO ANTONIO GIRON TEJADA
Imecol S.A.
magiron@yahoo.com

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Abstract

A STUDY was carried out to evaluate the contamination of soils and groundwater through the use of vinasse in the reclamation of saline soils with trace elements such as Fe, Cu, Mn and Zn to sugarcane soils. The soils at the experimental site were located in the flat area of Valle del Cauca, Colombia and consisted of the Vertisols of the Galpón series characterised with a Loam Clay texture and problems of salinity and sodicity. Vinasse containing 10% total solids was applied at the rate of 1500 m^3/ha. The trace element contents in the soil increased compared to their initial values but did not reach levels that are considered as deleterious to the soils. Similarly, the concentration of trace elements in groundwater was not significantly increased and remained below the threshold values according to the Colombian Environmental Legislation. In conclusion, in this type of soil there were no contamination problems with heavy elements in soil and groundwater from the application of vinasse with 10% solids on the reclamation of saline soils.

Introduction

The Colombian government approved law 693 of 2001 and the 3510 CONPES (2008) for alcohol production and use of biofuels in motor vehicles with a mixture of 10% alcohol in gasoline and 5% in diesel to reduce the effects of pollution generated by fossil fuels. Therefore, fuel ethanol distilleries were installed to meet consumption needs. The area planted with sugarcane is 208 161 ha (Cenicaña, 2007) for the production of sugar, molasses, and alcohol fuel.

The average production of ethanol for use as a fuel is 1 100 000 litres per day (Conpes 3510, 2008) and vinasse containing 10% total solids is generated as a waste product at a rate of 12 to13 litres for every litre of ethanol that is produced. Vinasse can be produced at concentrations between 10% and 55% (Quintero, 2004) with varying amounts of organic matter and chemical oxygen demand (COD) (Rossi, 2007) which is considered as an environmental pollutant.

Numerous studies have shown that vinasse is a highly corrosive waste product with a high content of organic matter (OM), potassium (K) and calcium (Ca) (Alfaro and Alfaro, 1996; Garcia, 2007) and their contents of micro-elements such as Iron (Fe), Copper (Cu), Manganese (Mn) and Zinc (Zn) (Gnecco, 2007); in view of its high content of minerals, the vinasse has the potential to pollute soil and groundwater. However, the chemical composition of vinasse depends on the raw material used, the soil type and the process of preparing the alcohol (Rossi, 2007; Leal *et al.*, 2003). Furthermore, it has been reported by Garcia (2007) that vinasse can be used as an amendment in the reclamation of saline and sodic soils. Vinasse is enriched with other fertiliser nutrients for use in the fertilisation of sugarcane (Quintero, 2004). The rates of application for reclamation (Garcia, 2007) and fertilisation for sugarcane are variable, as reported by Alfaro and Alfaro (2008), Quintero

(2004), and Gomez (2007) and depend on soil type, sugarcane variety and the concentration of the vinasse.

The trial was conducted in Moraima farm in the municipality of El Cerrito, Valle del Cauca, Colombia under sugarcane and pasture on Vertisol soils with problems of salinity, sodium toxicity and Loam Clay texture. The vinasse with 10% total solids was applied at a rate of 1500 m^3/hectare. This study seeks to assess the use of vinasse on reclamation of soils that are saline or have sodium toxicity and to evaluate its effect on contamination of soil and groundwater with heavy elements such as Fe, Cu, Mn and Zn.

Materials and methods

The study area is located in the municipality of El Cerrito, Valle del Cauca Department, Colombia on the Moraima farm between latitude 3°43'20.97’ N and 76°23'22.46’ W near the Cauca River. It has an average temperature of 24°C, an average annual precipitation of 1200 mm and a mean annual average evaporation of 1700 mm. The project area consists of Vertisol soils of the series Galpón (GL). This soil is saline and has problems with sodium.

In the process of reclamation a network of internal drainage with corrugated plastic pipe of 4’ diameter, 1.5 m deep and gravel filter was designed and built. Later, pools were built with 30 x 30 m dimensions and 50 cm high using a tractor and implement used in rice crops. These pools were flooded to 10 to 15 cm of vinasse. The vinasse was from the company CALSA located in Palmira (Valle), and contains 10% total solids with chemical characteristics that are shown in Table 1. The vinasse was applied every 15 days, to reach infiltration of the vinasse. This process was repeated three times to reach 1500 m^3/ha.

The soil samples were collected at depths 0–20, 20–40 and 40–60 cm because the cane roots are located down to 60 cm according to the studies of Dominguez (1990). The water samples were collected in the external part of the installed internal drainage. These analyses of soil and water were sent to the Chemical Laboratory at Field Providencia sugar mill. The samples of soil and water were collected after application of the vinasse 15 days later when the infiltration of the vinasse finished.

The Colombian Environmental Legislation in ordinance 1594 of 1984 was used for evaluation of soil and groundwater pollution with the vinasse application.

Table 1—Composition of vinasse 10%.

ELEMENT	UNIT	AMOUNT
N	ppm	1278
P_20_5	ppm	20
K	ppm	3525
Ca	ppm	875
Mg	ppm	605
S	ppm	1118
Cu	ppm	5.18
Mn	ppm	8.53
Fe	ppm	16.9
Zn	ppm	2.72
B	ppm	2.75
M.O.	%	5.26
pH	–	5.57
CE	Ds/m	10.0
C:N	–	12.8

Results and discussion

Soils

Table 2 compares the analysis of soil before and after the final application of vinasse 10%. These values are discussed one to one according to the report of laboratory analysis of soil.

Application of vinasse resulted in an increase in soil pH that ranged from 8.4 in the 0–20 cm layer up to 9.0 in the 40–60 cm layer. The pH increase is due to the oxidation of organic components of the vinasse in the soil. These values are in accord with Montenegro (2008), Bautista *et al.* (2000), Rodriguez and Chaves (1999).

The electrical conductivity (EC) found was 0.47 dS/m in the 0–20 cm layer; this value decreased showing a strong washing in this layer of soil. Information above is according to the study of Garcia (2007), showing a quick wash with products with high salt content and high doses. However, with vinasse applications with low doses, the EC value tends to increase, according to Bautista *et al.* (2000), Rodriguez and Chaves (1999) and Rossi (2007). Therefore, care must be taken with the processes of salinisation of the soil when vinasse is applied with low doses.

The Organic Matter (OM) in soil was found to be 3.15% in the 0–20 cm layer an increase over the initial value, indicating the great contribution of vinasse to soil due to high concentrations of OM. Therefore, the soil acts as a filter for the OM not to reach the groundwater. This information is consistent with Montenegro (2008), Bautista *et al.* (2000), Rodriguez and Chaves (1999) and Rossi (2007).

Table 2—Soils analysis.

Place	Initial		Finish		
Deep - cm	0-30	30-60	0-20	20-40	40-60
DETERMINATION					
pH	8.00	8.40	8.40	8.50	9.00
EC - dS/m	2.70	2.56	0.47	0.31	0.28
OM - %	1.95	1.79	3.15	2.38	1.29
P - ppm	102.10	99.57	155.93	59.49	45.94
EXCHANGEABLE CATIONS (cmol/kg)					
Calcium (Ca++)	24.78	23.13	19.39	16.55	15.10
Magnesium (Mg	10.68	9.54	11.19	10.55	13.41
Potassium (K +)	0.76	1.12	2.34	1.60	1.38
Sodium (Na)	4.58	5.10	1.56	3.70	6.70
CEC	18.69	9.50	27.16	41.30	37.10
Ca/Mg	2.32	2.42	1.73	1.57	1.13
ESP	24.51	53.68	5.74	8.96	18.06
MICRO NUTRIENTS (PPM)					
Boro - B	0.67	0.94	0.30	0.21	0.15
Copper - Cu	3.32	2.72	3.85	3.10	3.32
Iron - Fe	3.35	1.98	17.73	21.85	15.83
Manganese - Mn	3.97	3.30	6.34	6.13	4.14
Zinc - Zn	0.36	0.40	1.39	1.26	1.28
TEXTURE					
Sand	17.12	25.12			
Silt (%)	41.28	37.28			
Clay	41.60	37.60			
Clasification	ArL	FAr			

Following the application of 1500 m^3/ha of vinasse, the increase in cation exchange capacity (CEC) in the top 0–20 cm to 27.16 cmol/kg and 37.10 cmol/kg in 40–60 cm layer indicates contributions of cations from the vinasse.

The observations made in this study were in accordance to those observed by Montenegro (2008), Bautista *et al*. (2000) and Rodriguez and Chaves (1999).

The exchangeable sodium percentage (ESP) changed from 5.74% in 0–20 cm layer to 18.06% in 40–60 cm layer; these percentages decreased considerably compared to the initial values of 24.51% in the 0–30 layer and 53.68% in the 30–60 cm layer.

This shows that the process of washing the soil with 1500 m^3/ha of vinasse in the reclamation of sodic soil is good and concurs with findings reported by García (2007) and Marulanda (1992).

Amount of micro-elements

The concentration of iron (Fe) found was 17.73 ppm in the 0–20 cm layer and 15.83 ppm in the 40–60 cm layer and increased with the application of 1500 m^3/ha of vinasse 10%. This increase in the soils is consistent with observations by Bautista *et al.* (2000), Montenegro (2008) and Quintero (2004). Meanwhile, the Environmental Legislation in Colombia has no records for this element in soils.

The concentration of copper (Cu) in the soil decreased to 1.85 ppm in the 0–20 cm layer while, in the 40–60 cm layer, this value increased slightly to 3.32 ppm. These values are considered low in the soil according to the Colombian Environmental Legislation that has the maximum value of 1200 ppm.

It is, therefore, considered that there is no soil contamination by copper. Increases of this element in the soil by application of the vinasse also were found by Bautista *et al.* (2000) and Rodriguez *et al*. (2003).

The concentration of manganese (Mn) found increased to 6.34 ppm in the 0–20 cm layer. The Colombian Environmental Legislation has not recorded this element as a problem in the soil. Information reported by Rodriguez and Chaves (1999), Montenegro (2008) and Bautista *et al.* (2000) is consistent with the increase in manganese with the applications of vinasse to soil.

The concentration of zinc (Zn) increased in the 0–20 cm layer to 1.39 ppm and to 1.28 ppm in the 40–60 cm layer. The value is low according to Colombian Environmental legislation.

Studies by Quintero (2004), Rodriguez and Chaves (1999), Bautista *et al.* (2000) and Montenegro (2008) found increases in zinc with the application of vinasse.

Groundwater

In Table 3 below are details of water analysis before and after the last application of 1500 m^3/ha of vinasse. These values are discussed according to water pollution and possible human consumption or agricultural use, according to Colombian Environmental Legislation.

The pH value increased from 7.5 to 7.8. These values show the increase in the washing of soluble cations with the application of vinasse. There are no restrictions with use for agriculture or livestock because the maximum value is pH 9.0.

The electrical conductivity (EC) increased over the initial data from 0.47 to 0.49 dS/m. The value established by law is less than 0.5 dS/m. We see how the water is increasing in salinity during soil reclamation with the application of vinasse.

The concentration of Sodium (Na) increased from 2.39 ppm to 5.51 ppm after application of vinasse 10%. This is in accordance with Garcia (2007).

Table 3—Water analysis.

Place:	Initial	Finish
N° Laboratory	237	238
DETERMINATION		
pH	7.5	7.8
EC - dS/m	0.47	0.49
SOLUBLE CATIONS (ppm)		
Calcium (Ca ++)	2.47	4.40
Magnesium (Mg ++)	2.67	4.14
Potassium (K +)	0.05	0.05
Sodium (Na)	2.39	5.51
Total cations	7.58	14.10
SAR	1.49	2.67
Total hardness	257.00	427.00
Nitrogen - mg/l	6.79	0.14
Nitrates - mg/l	0.06	0.04
Nitrites - mg/l	24.40	7.50
COD - kg/day	46.00	36.00
Totals solids (SST) mg/l	50.00	10.00
MICROELEMENTS (ppm)		
Boro	0.06	0.04
Copper (Cu)	0.02	0.02
Iron (Fe)	0.78	0.66
Manganese (Mn)	0.28	0.24
Zinc (Zn)	0.12	0.07

Amount of micro-elements

The concentration of Iron (Fe) initially was 0.78 ppm and, after the application of vinasse, the concentration was 0.66 ppm. This indicates that the groundwater did not increase its iron level after vinasse application at a dose of 1500 m^3/ha. The groundwater does not meet the conditions for human use by environmental regulations. The limitation is 0.30 ppm while, for agriculture and livestock, there are no limitations for use.

The Copper (Cu) concentration was 0.02 ppm, and remained with the same value, showing that there were no inputs of this element by the application of vinasse. The value contaminant is 1.0 ppm for human consumption, 0.5 ppm for use in agriculture and 0.2 ppm for livestock; consequently this water can be used in any activity.

The Manganese (Mn) concentration found in the groundwater after the application of vinasse is 0.24 ppm, a slight decrease. According to the classification, this item should be below 0.10 ppm for human consumption and 0.20 ppm for agricultural use. The use of this water for human consumption is restricted to agricultural use and livestock and can be used with caution.

The Zinc (Zn) concentration decreased to 0.07 ppm, indicating that this element was not provided by application of vinasse to groundwater. Its limit value should be 5 ppm for human consumption; agricultural use is 2 ppm and 25 ppm for livestock.

Conclusions

The saline and sodic soils were reclaimed with the application of 1500 m^3/ha vinasse with 10% total solids.

The concentration of heavy elements such as Cu, Zn, Mn and Fe increased in the soil with the soil reclamation with application of 1500 m^3/ha vinasse with 10% total solids but did not reach pollution problems.

The concentration of heavy metals such as Cu, Zn, Mn and Fe did not increase in the groundwater during the soil reclamation with application of 1500 m^3/ha vinasse with 10% total solids.

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UTILISATION DE LA VINASSE POUR LES BESOINS DU SOL ET IMPACT SUR LA CHARGE EN ELEMEBTS D'UN VERTISOL ET DE LA NAPPE PHREATIQUE

Par

MARCO ANTONIO GIRON TEJADA
Imecol S.A.
magiron@yahoo.com

**MOTS-CLÉS: Vinasse, Canne À Sucre, Sol,
Eau Phréatique, Besoin du Sol.**

Résumé

UNE ÉTUDE a été réalisée pour évaluer la contamination des sols et de la nappe phréatique par des oligoéléments tels que le Fe, le Cu, le manganèse et le Zn, lors de l'utilisation de vinasse pour la mise en valeur de sols salins sous culture de canne à sucre. Les sols du site expérimental étaient localisés dans la zone plate de la Vallée del Cauca, en Colombie, comprenaient des Vertisols de la série de Galpón caractérisés par une texture argilo-limoneuse et des problèmes de salinité et de sodicity. De la vinasse contenant 10% de solides totaux fur épandue à raison de 1500 m3/ha.

Les teneurs en oligoéléments du sol ont augmenté mais n'ont pas atteint des niveaux considérés comme nuisibles pour les sols. De même, les concentrations en oligoéléments des eaux souterraines n'a pas été sensiblement augmenté et sont restée au-dessous des valeurs- seuil selon la législation environnementale colombienne. En conclusion, sur ces sols salins, il n'y a pas eu de problèmes de contamination du sol et des eaux souterraines par les éléments métalliques issus d'épandage de vinasse contenant 10% solides totaux

USO DE VINAZAS PARA LA RECUPERACIÓN DE SUELOS Y SU IMPACTO SOBRE LA CARGA DE ELEMENTOS MENORES EN SUELOS VERTISOLES Y EN AGUAS SUBTERRÁNEAS

Por

MARCO ANTONIO GIRON TEJADA
Imecol S.A.
magiron@yahoo.com

**PALABRAS CLAVE: Vinaza, Caña de Azúcar, Suelo,
Agua Subterránea, Recuperación del Suelo.**

Resumen

SE REALIZÓ un estudio para evaluar la contaminación de suelos y aguas subterráneas al usar vinaza en la recuperación de suelos salinos con oligoelementos como Fe, Cu, Mn y Zn en suelos de caña de azúcar. Los suelos del sitio experimental se encuentran en la zona plana del Valle del Cauca, Colombia y consistieron en Vertisoles de la serie Galpón caracterizados por textura franco arcillosa y problemas de salinidad y sodicidad. Se les aplicó vinaza con el 10% de sólidos totales a una tasa de 1500 m 3 / ha. El contenido de elementos menores en el suelo aumentó con respecto a sus valores iniciales, pero no alcanzó niveles considerados perjudiciales para los suelos. Del mismo modo, la concentración de oligoelementos en el agua subterránea no aumentó significativamente y se mantuvo por debajo del umbral de los valores de acuerdo a la legislación ambiental colombiana. En conclusión, en este tipo de suelo que no hubo problemas de contaminación en los suelos ni en las aguas subterráneas con elementos pesados por aplicación de vinaza con 10% de sólidos para la recuperación de suelos salinos.