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Full Length Research Paper

Impact of extractive industry on an agricultural soil in San Luis Potosí, México

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This case study arose from the opening of an ordinary civil trial, brought by a farmer against a company in the extractive industry sector. The judge required an investigation of: 1) whether the plot of the producer contained waste materials; 2) if there were chemical residues present; 3) the nature of such residues; 4) whether the plot was suitable for agriculture; 5) what were the factors which made the soil unsuitable; and 6) the degree of erosion. 65% (1.63 ha) of the property was affected by industrial spills, mainly due to the high proportion of gravel at the surface (90%), calcium carbonate equivalent (62%), reduction of organic matter (1.85 to 1.25%) and excessive erosion (19.44 t ha^{-1}). The rest of the plot (0.87 ha) was not affected by these parameters. Both sites were not affected as regards heavy metals and metalloids pollution, abnormal pH and electrical conductivity.

Key words: Heavy metals, calcium carbonate, gravel.

INTRODUCTION

The main activity of the mining industry is the exploitation and processing of rock materials, clay, sand and other natural resources. The state of San Luis Potosi, Mexico, has been characterized since its foundation as a major producer of materials both metallic and nonmetallic, which in 2010 reached a combined production value of around $ 957.8 million. Due to the economic importance of this industry and the production potential of the organization, expectations of further growth are very high (Secretary of Economy, 2011).

However, several studies have shown that some extraction projects can significantly impact the environment. This damage can be of two types: 1) the impact of the depletion of nonrenewable resources for future generations; and 2) the impact of mining on the quality of the environment through air, soil, water, or noise pollution, destruction or disturbance of natural habitats, and visual impact on the landscape (Stacishin et al., 2008).The latter problem has been documented by several studies in Mexico and Latin America (Rea, 2001; García et al., 2007; McDonalds, 2009).

This case study arises from the opening of an ordinary civil trial, brought by a farmer against a company in the extractive industry sector (mainly a producer of limestone), which produces 25 000 t day^{-1} (Secretary of Economy, 2011). The producer, said to have been affected by the deposition of mineral materials in the plot (2.5 ha) from the year 2002, now finds himself unable to produce consumption commodities such as maize and beans.

In 2009, the judge of civil branch office requested to investigate the following:

1) Whether the plot contained waste materials,
2) If such materials were chemical wastes,
3) The nature of any material and chemical contaminants,
4) Whether the plot was suitable for agriculture,
5) What factors, if any, made the plot unsuitable for agriculture?
6) The degree of soil erosion.

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These points are the objectives of this study.

MATERIALS AND METHODS

The study plot has an area of 2.5 ha and is located in the municipality of Villa Hidalgo, San Luis Potosi, Mexico. The geographical coordinates are 100° 41' west longitude and 22° 27' north latitude, with a height of 1670 m above sea level. The climate of the area is dry semi-warm, with an average annual temperature of 18.6°C, ranging between a maximum of 40°C and a minimum of 8°C, and having 336 mm of rainfall per year. The soils are predominantly litosol eutric, with calcium xerosol associated with the medium (INFDM, 2005).

The study site was first cultivated in the second half of the decade of 1950, and has been maintained in a system of subsistence production (of maize, beans and squashes). It is a small property system, using antiquated technology (human and animal power) and using rainfall for crop water supply. Production yields were average for that climate zone.

The area was divided in two parts. Site 1, which borders the mining industry and receives input of materials, contains gravel (construction) significantly above the ground surface, has few tree and shrub plant species, and presents a slope of 3% against the industry. This site represents 65% of the total area of the plot.

Site 2 differs from Site 1 in having herbaceous vegetation present, no significant gravel surface, and a slope of <1. This site represents approximately 35% of the total area of the plot.

Site 1 was visually evaluated for surface mineral material. The gravel percentage was later defined at ten different points, selected in a systematic way (method provided by INEGI, 2005a), each of 1 m^2. An equal number of soil samples of the 0 to 20 cm layer were collected at these points. Sampling started in the area adjoining the extractive industry and the downstream slope.

Site 2 contains no gravel in the surface, and so, only the soil was sampled in the stratum of 0 to 20 cm, in the same manner afore described.

Ten samples of soil of an adjoining property that has not received material from the extractive industry were also taken, with the intention of comparing the results with the study plot (reference soil). In both sites, the methodologies used for soil sampling were in accordance with the Official Mexican Standard NOM-021-RECNAT-2000 (DOF, 2002).

The calcium carbonate equivalent is considered as a possible contaminant because the chemical composition of the gravel produced is of a calcareous type (limestone). These were quantified by acid neutralization according to the Mexican Official Standard NOM-021-RECNAT-2000, AS-29 method (DOF, 2002).

Heavy metals and metalloids were considered as possible contaminants due to the inorganic nature of the rock from which materials are extracted by the extractive industry. We determined As, Ba, Be, Cd, Cr, Hg, Ni, Ag, Pb, Se and Tl, which are considered in the Mexican Official Standard NOM-147-SEMARNAT/SSA1-2004 (DOF, 2007).

Quantification was performed at a single point (0 to 20 cm layer), the closest to the mining industry (Site 1). It was to be investigated if levels of metals and metalloids and soluble total exceeded the official limit before proceeding to analyze the other cited sampling points. Otherwise, there could not be considered to have been a carry-over of mining materials and other sources of these elements in the rest of the property. The bedrock was also analyzed for the same reason.

The determination of the heavy metals was by means of emission spectrometry with inductively coupled plasma, which is quoted in the same standard. We also determined the pH, soluble salts and organic matter (methods AS-02, AS-18 and AS-07, respectively of the NOM-021-RECNAT-2000). Both are considered basic physicochemical properties of soil for agricultural production, which could be affected by spills resulting from the extractive industry. Soil erosion was estimated using the universal equation of soil loss as follows:

$$A = RKLSCP$$

Where A = soil loss (ton ha^{-1} $year^{-1}$), R = rainfall erosivity (megajoules mm ha^{-1} h^{-1} $year^{-1}$), K = soil erodibility (ton h^{-1} MJ^{-1} mm), L = slope length factor (dimensionless), S = factor for degree of slope (dimensionless), C = vegetation cover factor for (dimensionless) and P = factor for management practices (dimensionless) (Wischmeier and Smith, 1978; FAO, 1980).

RESULTS AND DISCUSSION

Gravel

Site 1 showed an excessive gravel construction on its surface (mineral material between 0.5 and 5 cm in size), and the average percentage of gravel was 90% (Table 1). Agrologically, this soil is classified as Class VIII: a soil with little natural vegetation as limited by excessive stoniness according to INEGI (2005b). In the reference floor, there was no gravel on the surface, showing the pollution from the mining industry. In the case of Site 2, little of such material was seen on the surface.

Calcium carbonate equivalent

Site 1 showed an average level of calcium carbonate equivalent to 62%, ranging from 44 to 88% (Table 1). These values are interpreted as high, according the Mexican Official Standard NOM-021-RECNAT-2000. The average value for Site 1 significantly exceeded the value found for the reference soil, which was 12%, indicating an impact of the extractive industry. The carbonates of site 2 were at an average of 13.1%, a value similar to the soil reference, which shows that this site has not been affected by spills of materials by the industry.

Metals and metalloids

None of the 11 items evaluated in the single sample from Site 1 exceeded the maximum permissible limits in both their total and soluble form, as established by the Mexican Official Standard NOM-147-SEMARNAT/ SSA1-2004. In most cases, it remained well below the reference value (Table 2). These results can be explained by the low content of heavy metals that are naturally present in the bedrock (As<0.5, Ba<28, Be<0.05, Cd<0.5, Cr<7, Hg<0.2, Ni<12, Ag<0.1, Pb<1, Se<0.3 and Tl<0.06 mg kg^{-1} respectively). The content of some metals content were similar to those cited by Mas and Azcue (1993) and Alloway (1995).

The low content of heavy metals in limestone is as

Table 1. Physio-chemical properties of affected plot and reference soil (N=10).

Variable	Soil reference	Soil Site 1	Soil Site 2
Superficial gravel (%)	ND	90 ± 10	ND
$CaCO_3$ (%)	12±2.10	62±25.32	13.1±2.11
pH	8.35±0.20	8.4±0.25	8.35±0.26
Electric conductivity (dS m^{-1})	0.22±0.05	0.23±0.09	0.22±0.02
Organic matter (%)	1.85±0.32	1.25±0.30	1.9±0.70

ND = No detected.

Table 2. Heavy metals and metalloids concentrations in 0 to 20 cm soil stratum of site 1 (unique sample).

Metal	Total concentration (mg kg^{-1})		Soluble concentration (mg L^{-1})	
	Result	Reference*	Result	Reference*
As	< 1	22	< 0.001	0.5
Ba	88	5400	0.17	10000
Be	0.5	150	0.001	0.122
Cd	0.72	37	0.002	0.100
Cr	14	280	-	-
Hg	< 1	23	< 0.001	0.02
Ni	26	1600	0.052	1.10
Ag	0.42	390	0.006	0.5
Pb	13	400	0.0138	0.5
Se	< 1	390	< 0.001	0.1
Tl	< 1	5.2	< 0.001	0.02

*Official Mexican Standard, NOM-147-SEMARNAT /SSA1-2004 (DOF, 2007), N=10.

cited by García and Dorronsoro (2012) who mentioned that sedimentary rocks, as limestone, present reduced heavy metals content compared with igneous rocks. Therefore, the risk of heavy metal contamination in this case is reduced, due to the low concentration in the soil and bedrock and high levels of calcium carbonate. According to Galán and Romero (2008), $CaCO_3$ maintain elevated pH, precipitating the metals. The Cd and other metals tend to be absorbed by the carbonates.

Erosion

The level of soil erosion at Site 1 was estimated at 19.44 t ha^{-1}; this value is higher than the permissible limits of erosion set by the Soil Conservation Society of the United States (Loredo et al., 2007). This value is attributed to the low vegetation of the area and the average slope. The erosion of soil from Site 2 was estimated at 4.28 ton ha^{-1}, which is lower than the permissible limits.

pH and electrical conductivity

The mean values for pH and electrical conductivity at Sites 1 and 2 were very similar to the reference soil, showing that these physicochemical properties of the study sites have not been affected by industrial spills (Table 1).

Organic matter

Organic matter levels were affected by the extractive industry in Site 1, where the average value found as 1.25% can be compared to the average value for the reference soil at 1.85%. These are classified as low and medium respectively according to the NOM 021-RECNAT-2000. Site 2 was unaffected, having a value of 1.90%, which is very similar to the reference soil (Table 1).

The soil of Site 1 is affected by the spill of the extractive industry in the properties of gravel surface, equivalent calcium carbonate and organic matter. Owing to the first two impacts, the Site is unsuitable for the practice of agriculture.

The gravel prevents soil tillage using either mechanical or animal power (plowing, raking, etc.), and modification will prevent substantial and irreversible equipment damage caused by friction with the mineral material.

The high content of carbonates in the soil prevents adequate absorption of essential plant elements such as

Fe, P, Mn, Zn and K (Marschner, 1986). Therefore, the physiological processes of plants will be affected so that their growth and development is reduced drastically (Azcon-Bieto and Talon, 2000). Due to the high levels of carbonates found, remediation is not economically feasible; the agricultural technique used for this is acidification, which is only possible in soils with less than 20% of $CaCO_3$, according to Rivera et al. (2006).

It is important to reduce erosion immediately through the reduction of mining and quarrying spills, as well as through works and control practices such as sheet erosion terraces (living wall, individual, etc.), trenches (trench, ditch board, etc.), and vegetative practices (Joachim, 2003; CONAFOR, 2007). These measures will help, over time, to conserve soil from Site 2, which has not yet been affected by spills of mining. It is also recommended to keep this Site vegetated with grasses or any cover crops incorporating organic products as a source of nutrients and soil amendment.

Conclusion

The soil owned by the farmer applicant is affected by extractive industry spills by 65% (1.63 ha, Site 1), mainly due to the high surface gravel levels (90%), calcium carbonate equivalent (62%) and reduction in organic matter levels (1.85 to 1.25%). The calculated actual erosion (19.44 ton ha^{-1}) exceeds the maximum limits permissible under the Soil Conservation Society of the United States. Therefore, it is essential to stop the spillage of materials from the extractive industries, and immediately begin restoration work on this Site (using terraces, ditches, vegetative practices, etc.). This will simultaneously aid the conservation of Site 2 in the same plot, which has not yet been affected. Both sites showed to be unaffected with respect to heavy metals, metalloids, pH and electrical conductivity.

REFERENCES

Alloway BJ (1995). Heavy metals in soil. 2nd edn. Blackie Academic and Professional, New York.

Azcon-Bieto J, Talón M (2000). Plant phisiology fundaments. McGraw Hill. Barcelona, p. 522.CONAFOR (2007). Comisión Nacional Forestal Protección, restauración y conservación de suelos forestales. Manuel de obras y prácticas. Editado por la Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). Tercera edición. México, p. 298.

CONAFOR (2007). National forest protection commission,restoration and conservation of forest soils. Manual works and practices. Published by the ministry of environment and natural resources (SEMARNAT). third Edition. México, p. 298.

DOF (2002). Official Journal of the Federation. Mexican Official Standard NOM-021-RECNAT-2000, That establishes the specifications to fertility, salinity and soil classification. Studies, sampling and analysis. Mexico.

DOF (2007). Diario Oficial de la Federación. Norma Oficial Mexicana NOM-147-SEMARNAT/SSA1-2004, That establishes criteria for determine the concentrations of soil remediation contaminated by arsenic, barium, beryllium, cadmium, chromium VI, mercury, nickel, silver, lead, selenium, thallium and / or vanadium. México.

FAO (1980). Provisional methodology for assessing the soils degradation. Roma, p. 86.Galán HE, Romero A (2008). Contaminación de suelos por metales pesados. Date of consultation 24 march 2012. Macla, 10: 48-60.

García CL, Menchaca L, Rodríguez M, Sánchez G, Ramírez E, López U (2007). Evaluación de las tendencias de los contaminantes atmosféricos en la zona industrial del municipio de Santa Catarina, Nuevo León. Memorias del IX Congreso Regional de QFB. Monterrey, N. L. México.

Galán HE, Romero A (2008). Soil contamination by heavy metals. Date of consultation 24 march 2012. Macla, 10: 48-60.

García I, Dorronsoro C (2012). Contaminación por metales pesados. Date of consultation 20 march 2012. http://edafologia.ugr.es/conta/tema15/introd.htm.

INEGI (2005a). National institute of statistics, geography and Informatics. cartography interpretation guide:edaphology. México, p. 28. http://edafologia.ugr.es/conta/tema15/introd.htm.

INEGI (2005b). National institute of statistics, geography and informatics. Cartography interpretation guide:potential soil use. México. p. 43.

INFDM (2005). National institute for federalism and municipaly development, municipalities. Encyclopedia of the México municipalities, San

Luis Potosí state, Villa Hidalgo. On lines: http://www.elocal.

gob.mx/work/templates/enciclo/sanluispotosi/municipios/24051a

.htm.Joachim G (2003). Extractive industries in arid and semi-arid zones: Environmental planning and management. IUCN, Gland, Switzerland and Cambridge, United Kingdom. 8: 112.

Loredo OC, Beltrán S, Moreno F, Casiano M (2007). Water erosion risk and manegement projection and soil conservation in 32 microbasins to San Luis Potosí. Technical hanbook INIFAP-CIRNE-experimental field San Luis. San Luis Potosí, S. L. P. México, 3: 209.

Marschner H (1986). Mineral nutrition of higher plants. Academic Press, London.

M Mas A, Azcúe J (1993). Metals in biological systems. Universitary promotion and publishings, S.A. LCT-74. Barcelona.

McDonalds G (2009). Impacts of the extractive industries in latin america. Analysis and action track. CIDSE. Date of consultation 24

Julio2010.http://www.cidse.org/uploadedFiles/Regions/Latin_America/EPLA%20analysis%20final%20SPA.pdf.

Rea BRA (2001). The environmental socioeconomic problematic in the extractive industry in Nayarit. (Regional Economy). Publication:

Regional Economic Carte. Nayarit, México.Rivera OP, Etchevers BJ, Hidalgo MC, Castro MB, de la Garza RF, Rodríguez AJ, Martínez GA (2006). Acid-iron fertigation of citrus established in clacareous soils. Terra Latinoamericana, 26: 119-125.

Secretary of Economy (2011). Mining panorama to San Luis Potosi. http://www.sgm.gob.mx/pdfs/SAN_LUIS_POTOSI.pdf. Date of consultation 22 March 2012.

Stacishin QJ, App B, Morin R, Rice W (2008). Partnering with extractive industries for the conservation of biodiversity in Africa: a guide for USAID engagement. United States of Agency International Development, November 2008. Biodiversity Assessment and Technical Support Program (BATS). EPIQ IQC: EPP-I-00-03-00014-00, Task Order 02.

Wischmeier WH, Smith DD (1978). Predicting rainfall erosion losses- a quide to conservation planning-USDA; Agriculture Handbook 537. Sci. and educ. Admin. USDA, Washington, D. D. p. 59.