SOILS, SEC 4 · ECOTOXICOLOGY · RESEARCH ARTICLE

Remediation of a diesel-contaminated soil from a pipeline accidental spill: enhanced biodegradation and soil washing processes using natural gums and surfactants

Antonio Hernández-Espriú · Emilio Sánchez-León · Pedro Martínez-Santos · Luis G. Torres

Abstract

Purpose This paper addresses the application of bioproducts produced by plants (locust bean, guar, and mesquite seed gums) to enhance remediation processes of different nature: soil washing and biodegradation methodologies.

Materials and methods These natural gums were tested at laboratory scale to remove total petroleum hydrocarbons-diesel fraction (TPH-diesel) from oil-contaminated volcanic soils sampled from a polluted site in an agricultural area of western Mexico. TPH-diesel removal by natural gums was compared to common synthetic surfactants.

Results and discussion There is a strong evidence of contamination caused by the presence of TPH-diesel at a concentration of 32,100 mg/kg, which is above the legal limit of 1,200 mg/kg for agricultural soils in Mexico. Regarding the surfactant soil washing experiments, ionic surfactants showed removal rates above the control test of about 78.51 % (Maranil LAB), 71.27 % (Texapon 40), 60.13 % (SDS), and 48.19 % (Surfacpol G). In contrast, some non-ionic surfactants showed removal rates below soil-washing background rate (40 %). On the other hand, natural gums showed interesting and promising results. Guar gum and locust bean gum showed efficiencies of 54.38 % and 53.46 %, respectively. Biodegradation experiments confirmed the effectiveness of natural gums as biodegradation enhancers in diesel-contaminated soils. Specifically, guar gum showed an excellent performance. An 82 % TPH-diesel removal rate was achieved for a very low gum concentration (2 ppm). In this particular context, reported surfactant concentrations to assist biodegradation are, in general, higher.

Conclusions This work demonstrated the applicability of natural gums as soil remediation enhancers in diesel-contaminated systems. Particularly, guar gum might represent a cost-effective alternative for biodegradation enhancement processes.

Keywords Enhanced remediation · Guar gum · Natural gums · Soil remediation · Surfactants

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1 Introduction

There are many ways in which diesel can reach the vadose zone, thus contaminating soils and aquifers. Particularly in oil-based economies, leakage from pipelines due to installation failure or even to burglary activities can represent an important environmental threat. Other circumstances which produce diesel-contaminated soil are accidental spills from vehicles or leaks in storage tanks. Take for instance the case of Mexico. This country presents a strong oil industry, comprehending all stages of the manufacturing process: exploration, production, transformation, storage, and distribution of crude oil and its fractions. Over 30 % of the pipeline systems, which transport crude oil and subproducts all around the country, have been operating for over 30 years

La Formación Chivillas en Tehuacán, Puebla, México: definición, análisis de facies y procedencia

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Resumen

Se propone formalmente a la Formación Chivillas, unidad litoestratigráfica clave para descifrar el registro sedimentario de la Cuenca Cuicateca. Su localidad tipo se encuentra en la Barranca Las Salinas al noreste de Tehuacán, donde las rocas están prácticamente sin deformar. La Formación Chivillas consiste en derrames basálticos frecuentemente con estructura en almohadilla y depósitos siliciclásticos producto de corrientes turbidíticas y flujos de escombros que forman una sucesión volcanosedimentaria muy gruesa cortada por diques de composición similar a los derrames. Se estima un espesor total de más de 4875 m. La Formación Chivillas se asigna al Barremiano con base en la edad máxima de depósito por circones detríticos, edad que es congruente con el contenido fósil previamente reportado.

En la formación se identificaron 16 facies en cinco clases: conglomerática, arenosa, fina, calcárea e ígnea, las cuales se agruparon en ocho asociaciones de facies: A) Turbiditas de grano medio; B) Turbiditas de grano grueso; C) Turbiditas de grano fino; D) Areniscas sin estructura interna; E) Debritas soportadas por clastos; F) Debritas soportadas por matriz; G) Pliegues disarmónicos sinsedimentarios y H) Derrames y lavas almohadilladas. Con las asociaciones de facies reconocidas se interpreta un ambiente de depósito de abanico submarino.

Las rocas volcánicas de la Formación Chivillas tienen una composición máfica a intermedia alcalina con afinidad geoquímica tipo MORB u OIB, con valores isotópicos de plomo común similares a los valores de manto enriquecido, la firma isotópica Pb/Pb de los derrames de la Formación Chivillas sugiere una fuente asociada a la corteza inferior.

Las areniscas estudiadas están conformadas principalmente de cuarzo monocristalino, cuarzo policristalino milonítico, cuarzo policristalino en mosaico, microclina pertítica, y algunas plagioclasas; también son muy abundantes los líticos de limolita y caliza, y en menor cantidad líticos volcánicos y metamórficos, y otros similares a granito o gneis granulítico; texturalmente, los clastos son angulosos a subredondeados. Los clastos en los conglomerados son de caliza, arenisca (con estratificación cruzada) y gneis. Estas litologías son características de los complejos Milonítico Sierra de Juárez y Oaxaqueño, y su cubierta sedimentaria. Se observaron escasos líticos volcánicos en las areniscas, y algunos niveles con piroclastos de caída. Las areniscas tienen su procedencia en bloques continentales, específicamente en un cratón interior o de un basamento levantado, por lo que podemos suponer que proceden de la erosión de Oaxaquia. La presencia de circones de edad Pan-Africano-Brasiliano indica una procedencia de Gondwana probablemente transportados por sistemas fluviales complejos en una etapa evolucionada del proceso de *rifting* del Golfo de México.

Palabras clave: turbiditas, Golfo de México, Barremiano, *rift*, abanico submarino, circones detríticos.

Sedimentología, reconstrucción paleoambiental y significado tectónico de las sucesiones clásticas del Jurásico Medio en el área de Texcalapa, Puebla - Huajuapan de León, Oaxaca: Revisión de las formaciones Ayuquila y Tecomazúchil

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RESUMEN

Se propone subdividir la sucesión clástica pre-Oxfordiano de la cuenca Ayuquila en dos unidades litoestratigráficas, con base en el reconocimiento de una discordancia angular mayor en el análisis de facies, así como en fechamientos de circones magmáticos y detríticos. Se documenta que la sucesión se acumuló mediante sistemas fluviales trenzados con drenaje principal hacia el sur, bajo un clima inicialmente semiárido durante el Bajociano-Bathoniano y que se tornó más húmedo en el Calloviano, tal vez como respuesta del desplazamiento de la región meridional de México a una posición más ecuatorial. Se propone formalmente a la Formación Ayuquila para denominar a la sucesión por debajo de la discordancia. Esta sucesión, portadora de la flora fósil reportada en la región, consiste en conglomerados monomícticos de clastos metamórficos o de arenisca, intercalados con grauvaca lítica y feldespática. La acumulación de la Formación Ayuquila ocurrió en el Bajociano-Bathoniano y estuvo matizada con el desarrollo de facies lacustres. Se propone como localidad tipo de la Formación Ayuquila a la sucesión expuesta al norte de Chilixtlahuaca, Oaxaca. Se propone conservar la denominación de Formación Tecomazúchil para la sucesión del Calloviano, rica en cuarzo, expuesta en el arroyo Tecomazúchil, arriba de la discordancia mencionada. La Formación Tecomazúchil consiste en una sucesión de sublitarenitas y subarcosas con lentes de conglomerado de cuarzo, la cual decrece de abajo hacia arriba, tanto en el espesor de los estratos como en la granulometría de sus componentes.

Los circones magmáticos en los intrusivos emplazados en la Formación Ayuquila tienen edades de 164.3 ± 3.6 y 156.9 ± 3.5 Ma. Los circones detríticos en las formaciones Ayuquila y Tecomazúchil tienen un rango entre 1464 y 174 Ma, edades compatibles con una procedencia de los terrenos metamórficos y magmáticos del sur de México. Se reconoce que los circones detríticos con edades del Pérmico-Triásico pueden tener como fuente a la formación La Mora. El circón más joven en la Formación Tecomazúchil tiene una edad de 174 Ma y su fuente más probable son los intrusivos San Miguel, emplazados en el Litodema Chazumba metamorfoseado (Migmatita Magdalena), lo cual constriñe la exhumación del Complejo Ayú a tiempos previos al Oxfordiano. La dislocación producida por la falla Petlalcingo-Huajuapan condicionó la formación de la cuenca Ayuquila, de tal forma la falla tiene una edad Jurásico Medio. De acuerdo con la edad reportada para la migmatización del Complejo Ayú, el depósito de la sucesión clástica pre-

Corals from the Early Cretaceous (Barremian - Early Albian) of Puebla (Mexico) - Introduction and Family Stylinidae

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ABSTRACT

The present contribution is the first instalment of a systematic revision of the Early Cretaceous (Barremian to Early Albian) corals of Puebla, Mexico. The coral fauna preserved in the Tehuacán region represents one of the most species rich associations of its kind from the Early Cretaceous of the New World. This article provides a brief overview of the research history, geology, lithostratigraphy and biostratigraphy, and reports the presence of corals of the family Stylinidae (suborder Stylinina). The family is represented by the genera Acanthocoenia (one species), Enallhelia (two species), Stylangia (one species) and Stylina (six species).

Key words: corals, taxonomy, Cretaceous, Puebla, Mexico.

RESUMEN

El presente estudio es el primero en una serie de revisiones sistemáticas de los corales del Cretácico Inferior (Barremiano - Albiano Temprano) de Puebla, México. La fauna coralina preservada en la región de Tehuacán representa una de las asociaciones más diversas de su tipo para el Cretácico Temprano del Nuevo Mundo. Este artículo proporciona una breve revisión histórica de las investigaciones, geología, litoestratigrafía y estratigrafía local, y reporta la presencia de corales de la familia Stylinidae (suborden Stylina). La familia se encuentra representada por los géneros Acanthocoenia (una especie), Enallhelia (dos especies), Stylangia (una especie) y Stylina (seis especies).

Palabras clave: corales, taxonomía, Cretácico, Puebla, México.

Modelling discharge through artesian springs based on a high-resolution piezometric network

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Abstract:

Artesian springs are localized aquifer outlets that originate when pressurized ground water is allowed to rise to the surface. Computing artesian discharge directly is often subject to practical difficulties such as restricted accessibility, abundant vegetation or slow flow rates. These circumstances call for indirect approaches to quantify flow. This paper presents a method to estimate ground water discharge through an upwelling spring by means of a three-layer steady-state groundwater flow model. Model inputs include on-site measurements of vertical sediment permeability, sediment temperatures and hydraulic gradients. About 70 spring bed piezometers were used to carry out permeability tests within the spring sediments, as well as to quantify the hydraulic head at different depths below the discharge point. Sediment temperatures were measured at different depths and correlated to permeabilities in order to demonstrate the potential of temperature as a substitute for cumbersome slug tests. Results show that the spatial distribution of discharge through the spring bottom is highly heterogeneous, as sediment permeability varies by several orders of magnitude within centimetres. Sensitivity analyses imply that geostatistical interpolation is irrelevant to the results if field datasets come from a sufficiently high resolution of piezometric records. Copyright © 2013 John Wiley & Sons, Ltd.

KEY WORDS   artesian springs; piezometer; stream-aquifer interaction; groundwater; Modflow; sediment temperature

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INTRODUCTION

Springs are best described as localized aquifer outlets. As such, springs provide reliable sources of water for human beings, while also underpinning life in aquatic ecosystems. All hydrogeological environments are suitable for spring occurrence, but springs in carbonate aquifers have traditionally received greater attention in the literature. This is largely because karst systems are almost always spring rich, which is in turn one of the main reasons why communities in these areas frequently rely on spring water for urban supply (Barfield *et al.*, 2004; Khaldi *et al.*, 2011).

The location of a given spring is ultimately controlled by a combination of topographic, geological and hydrogeological factors. Many classifications are found in the literature, but it is generally accepted that most springs are formed due to the presence of land depressions, geological contacts or faults (Fetter, 1994; Younger, 2007). Thus, springs take place at topographic lows if the water table is shallow enough to intersect the land surface. This is for instance the mechanism behind many karst sinkholes. Similarly, fault outlets occur when groundwater is allowed to rise along a geological joint. This type of spring is particularly becoming to confined or semiconfined

aquifer systems. Finally, contrasting permeabilities between adjoining geological units also constitute a common cause for groundwater discharge, often resulting in several springs along the contact.

Under natural conditions spring flows depend on aquifer recharge. Hence, discharge can be used as an indicator of short or long-term changes in rainfall (Chen *et al.*, 2004; Fiorillo, 2009). The time required for water to flow from the recharge area of an aquifer to the springs depends on the size of the groundwater system, as well as on the thickness of the vadose and saturated zones. Conduits size also plays an important part whenever channel flow is significant. If the aquifer is reasonably small and flow is quick, spring hydrographs tend to reflect the effect of storm events. In this case, however, springs are frequently ephemeral. Conversely, if the aquifer system is large and flow is slow, recharge water may take decades to reach the outlet. Hence, springs will be permanent and flows considerably more stable (Távara and Sanz, 2010).

Artesian discharges often take place in ground depressions, where water tends to accumulate until the overflow stage is reached. Since the aquifer outlet is usually submerged, discharge cannot be observed directly. It can however be quantified by measuring the volume of water that exits the depression during a small time interval. This approach assumes that steady-state conditions hold. In other words, it is based on the premise that the amount of water coming out of the rock is identical to the overflow and that storage within the depression remains constant. The second

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Nitrate mass balance in agricultural areas of intensive fertilizer application: the North Maresme aquifer system case study (Spain)

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Abstract

Nitrate pollution is a worldwide problem in groundwater, as it may limit water supply and increase health risk when high concentrations are present. The North Maresme coastal alluvial groundwater-dependent agrosystem, one of the most heavily nitrate polluted aquifers in Spain, is located 70 km northeast from Barcelona. Field monitoring campaigns performed in this aquifer yielded nitrate concentrations up to ten times the permitted limit for drinking water suggested by the World Health Organization (50 mg/l), with a maximum concentration of 567 mg/l and a mean of 137.5 mg/l. Nitrate contamination was quantified by means of a mass balance, taking into account the main hydrogeological and anthropogenic processes that control the behavior of this ion in the aquifer, such as recharge, groundwater extraction, irrigation and fertilizer application to crops. Nitrate balance is an integrative approach for assessing nitrate loading based on linking different sources of nitrates to a groundwater balance. This methodology considers nitrate as a conservative ion because the geological-geochemical medium behaves under oxidant conditions. Results show that the studied aquifer system receives, yields and retains approximately 935, 844 and 91 tons of NO_3^-/year, respectively. This methodology can be applied to other nitrate-contaminated aquifers with similar conditions to improve management of fertilizers practices in areas of intensive agriculture.

Keywords: nitrate mass balance, nitrate contamination, groundwater balance, fertilizers, Maresme.

Resumen

La contaminación por nitratos en agua subterránea es un problema mundial, porque limita el abastecimiento del recurso e incrementa el riesgo a la salud humana cuando se presentan altas concentraciones disueltas. El sistema agrohidrológico activo del aluvial costero del Maresme Norte, uno de los acuíferos más severamente impactados por nitratos en España, se localiza a 70 km al noreste de Barcelona. Campañas de monitoreo han permitido establecer que este acuífero presenta concentraciones del ión nitrato hasta 10 veces superiores al límite máximo permisible sugerido por la Organización Mundial de la Salud (50 mg/l), con una concentración máxima de 567 mg/l y una concentración media del orden 137.5 mg/l. La contaminación de nitratos se cuantificó por medio de un balance de masas, considerando los procesos primarios hidrogeológicos y antropogénicos que controlan el comportamiento de este ión en el acuífero, tales como la recarga, extracción del agua subterránea, irrigación e incorporación de fertilizantes agroquímicos a cultivos. El balance de nitratos representa un enfoque integrador de estudio donde se han vinculado las diferentes fuentes de

El método de Polarización Inducida aplicado en la contaminación de suelos por hidrocarburos

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Resumen

Las pruebas obtenidas por algunos autores dedicados a los métodos eléctricos han mostrado que al realizar un levantamiento convencional de resistividad, no ha sido posible diferenciar zonas que presentan comportamientos electroquímicos semejantes, tanto de origen orgánico como inorgánico. Es por ello que en años recientes, el método de Polarización Inducida (PI) se ha aplicado a problemas de contaminación en suelos con resultados alentadores. Esta técnica ha sido puesta a prueba, trabajando en el dominio del tiempo, mediante un perfil de tomografía eléctrica con datos de resistividad y cargabilidad, el cual fue realizado en un sitio contaminado por hidrocarburos en una zona ubicada al norte de la Ciudad de México, en donde la estratigrafía y la distribución del contaminante eran complejas.

Los hidrocarburos se encontraban en fase libre y fase disuelta, en proceso de remediación, mismo que proporcionó las condiciones para la toma de muestras de suelo y agua que fueron enviadas a un laboratorio para su análisis químico, con lo que se obtuvieron concentraciones de benceno en cuatro pozos cercanos a la línea del perfil eléctrico.

Los resultados obtenidos muestran que se puede delimitar las zonas de mayor concentración de contaminantes, mediante la correlación de la información eléctrica, y capacitiva, y de manera cualitativa, con la información de los parámetros Cole-Cole, se demuestra el potencial del método de polarización inducida en problemas de contaminación

Palabras clave: tomografía de resistividad eléctrica, polarización, cargabilidad, hidrocarburos, contaminación.

Abstract

The evidence obtained by some authors devoted to electrical methods has shown that when a conventional resistivity survey is performed, it is not possible to differentiate areas with similar electrochemical behavior of both the organic and inorganic origin. Therefore, in recent years the method of Induced Polarization (IP) has been applied to soil contamination problems, showing encouraging results. This technique was tested, working in the time domain through an electrical tomography profile of resistivity and chargeability data, which was conducted at a site contaminated by hydrocarbons located in the north of Mexico City, where stratigraphy and distribution of the contaminant were complex.

The hydrocarbons were found in a free and dissolved phase, which provided the conditions for taking soil and water samples. These samples were sent to a laboratory for chemical analysis, which depicted benzene concentration in four wells.

The obtained results show that it is possible to define areas of large concentration of pollutants, by correlating electrical information, capacitive and qualitatively, with the information from the Cole-Cole parameters, demonstrating the potential of induced polarization method in pollution problems.

Keywords: electrical resistivity tomography, polarization, chargeability, hydrocarbons, pollution..

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Morphology and Texture of Polymetallic Nodules and their Association with Sediments of the Mexican Pacific

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This research deals with a regional comparative analysis of nodule morphology and texture with pelagic sediment distribution. Samples were collected on board of R/V El Puma during oceanographic cruise MIMAR VI. The study area is located in the northeastern portion of the Clarion Fracture Zone in the Economic Exclusive Zone of Mexico. The more abundant nodules sizes are smaller than 2 cm and discoid form with smooth and rough surfaces were dominant. Small sizes occur in the southern study area, while nodules larger than 4 cm are found in the northern portion. Sediments are enriched in Si, Al, Na, K, and Ti; in contrast the nodules are richer in Mn, Fe, Mg, Ca, Ni, Co, and Cu. Most of the Si and Al seem to be terrigenous probably due to the influence of winds carrying small particles from Vizcaino and Sonora deserts. Nodules are hydrogenic in the northern study area and diagenetics towards the south.

Keywords geochemistry, manganese nodules, Mexico, morphology, Pacific Ocean, pelagic sediments

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Geochronology and magmatic evolution of the Huautla volcanic field: last stages of the extinct Sierra Madre del Sur igneous province of southern Mexico

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The Huautla volcanic field (HVF), in the Sierra Madre del Sur (SMS), is part of an extensive record of Palaeogene magmatism reflecting subduction of the Farallon plate along the western edge of North America. Igneous activity resulting from Farallon subduction is also exposed to the north, in the Sierra Madre Occidental (SMO) and Mesa Central (MC) provinces. We present the results of a stratigraphic and K–Ar, Ar–Ar, and U–Pb geochronological study of the Huautla volcanic successions, in order to refine our knowledge on the petrologic and temporal evolution of the northern SMS and gain insights on magmatic–tectonic contrasts between the SMS and the SMO–MC provinces. The HVF is made up of lava flows and pyroclastic successions that overlie marine Cretaceous sequences and post-orogenic continental deposits of Palaeogene age. In the study area, the main Oligocene succession is pre-dated by the 36.7 million years its caldera west of the Sierra de Huautla. The HVF succession ranges in age from ~33.6 to 28.1 Ma and comprises a lower group of andesitic–dacitic lava flows, an intermediate sequence of ignimbrites and dacitic lavas, and an upper group of andesitic units. The silicic succession comprises a crystal-poor ignimbrite unit (i.e. the Maravillas ignimbrite; 31.4 ± 0.6, 32.0 ± 0.4 Ma; ~260 km³), overlain by a thick succession of dacitic lavas (i.e. the Agua Fría dacite; 30.5 ± 1.9, 31.0 ± 1.1 Ma). Integration of the new stratigraphic and geochronological data with prior information from other explosive centres of the north-central SMS allows us to constrain the temporal evolution of a silicic flare-up episode, indicating that it occurred between 37–32 Ma; it consisted of three major ignimbrite pulses at ~36.5, ~34.5, and ~33–32 Ma and probably resulted from a progressive, mantle flux-driven thermomechanical maturation of the continental crust, as suggested in the HVF by the transition from andesitic to voluminous siliceous volcanism. The information now available for the north-central sector of the SMS also allows recognition of differences between the temporal and spatial evolution of magmatism in this region, and of that documented in the southern SMO and MC provinces, suggesting that such contrasts are probably related to local differences in configuration of the subduction system. At ~28 Ma, the MC and southern SMO provinces experienced a trenchward migration of volcanism, associated with slab rollback; on the other hand, the broad, more stable distribution of Oligocene magmatism in the central and north oceanic plate was subducting at a low angle.

Keywords: southern Mexico; Sierra Madre del Sur; Huautla volcanic field; silicic flare-up; Sierra Madre Occidental; Farallon plate underflow

Introduction

The Sierra Madre del Sur (SMS) province of southern Mexico is made up of a Late Cretaceous–Miocene record of plutonic and volcanic rocks that extend south of the active Trans-Mexican Volcanic Belt (TMVB) (Figure 1; Schaaf *et al.* 1995; Morán-Zenteno *et al.* 1999; Morán-Zenteno *et al.* 2007a). The extinction of arc magmatism along this province occurred diachronically from the Palaeocene to the Miocene and was associated with continental margin truncation, northward trench migration, and a change in the subduction geometry (Schaaf *et al.* 1995; Morán-Zenteno *et al.* 1996; Keppie and Morán-Zenteno 2005; Keppie *et al.* 2009).

The SMS arc is represented by a chain of silicic plutons that extend almost continuously along the coast, and by an inland discontinuous volcanic belt that includes intermediate and silicic volcanic fields (Morán-Zenteno *et al.* 1999; Morán-Zenteno *et al.* 2007a). One of the most conspicuous volcanic features in the inland area is the record of a late Eocene–early Oligocene ignimbrite flare-up, represented by a group of explosive siliceous centres that extend for about 300 km along the north-central part of the SMS (Figure 1; Morán-Zenteno *et al.* 2007a). To the east of the silicic centres, the magmatic products have more mafic and intermediate compositions, and were mainly erupted through central volcanic edifices (Martiny *et al.*, 2000).

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Influencia de jales mineros sobre el río Maconí, Queretaro, y evaluación del proceso de atenuación natural por dispersión

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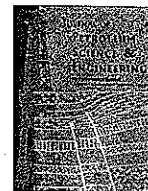[2]Licenciatura en Ingeniería de Minas y Metalurgia, Facultad de Ingeniería, UNAM, Circuito escolar, Ciudad Universitaria, México, D.F. 04510.

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Resumen

La mina La Negra se ubica en el estado de Querétaro (México), y durante su operación los jales producidos se han almacenado en cinco depósitos construidos en cauces que descargan al río Maconí, el cual a su vez, desemboca sobre el río Moctezuma a 5 km aguas abajo. El presente estudio tuvo como objetivo evaluar la dispersión física de los jales a partir de los depósitos y su influencia sobre el río Maconí, así como identificar la existencia de un fenómeno físico de atenuación natural por arrastre hídrico. Se tomaron muestras de los jales almacenados para determinar la concentración total de arsénico (As), plomo (Pb), cadmio (Cd), cobre (Cu) y zinc (Zn), así como la concentración en la fracción soluble en agua de estos elementos. Se tomaron muestras de sedimentos sobre los cauces donde se ubican los depósitos de jales y sobre el río Maconí; también se tomaron sedimentos en cauces ubicados fuera del área de influencia de los jales para considerarlos como referencia. A estas muestras se les hizo un análisis granulométrico, se les midió el pH y se les determinó la concentración total de As, Pb, Cd, Cu y Zn; asimismo se practicaron extracciones con agua y bicarbonato de sodio para determinar la concentración de estos elementos en fracción soluble e intercambiable, respectivamente. Muestras seleccionadas se estudiaron mediante microscopía óptica y difracción de rayos X. Las concentraciones totales que se encontraron en los jales son: As (1643 a 13459 mg/kg), Cd (5 a 64 mg/kg), Pb (469 a 4583 mg/kg), Cu (439 a 745 mg/kg) y Zn (1937 a 4316 mg/kg). La concentración de la fracción soluble en agua de As, Pb y Cd está por debajo de los límites de la normatividad ambiental mexicana (NOM-141), por lo que los jales no son peligrosos por la movilidad de estos elementos. Se observó que ha ocurrido la dispersión de los jales, ya que se identificó la acumulación de estos cerca de los depósitos; en el depósito 3 la influencia de los jales llega hasta 437 m, mientras que en el depósito 5 es hasta los 956 m. Sobre el río las concentraciones totales en los sedimentos fueron en promedio de 461 mg/kg para As, 140 mg/kg para Pb, 66 mg/kg para Cu, 290 mg/kg para Zn y menor al límite de detección para Cd; esto valores son del mismo orden que los determinados en las muestras de referencia: As (434 mg/kg), Pb (122 mg/kg), Cu (77 mg/kg), Zn (288 mg/kg) y Cd menor al límite de detección. Estos resultados muestran que hay un aporte natural de arsénico y metales pesados provenientes de los afloramientos de los yacimientos en la zona (dados los resultados en las muestras de referencia) y, por otro lado, hay un fenómeno natural de dispersión por arrastre hídrico sobre el río Maconí, ya que la concentración de los elementos analizados disminuye considerablemente respecto a las muestras cercanas a los depósitos. La concentración de As en la fracción soluble en agua está por arriba de 0.5 mg/L (valor indicado en la NOM-147 aplicable a suelos contaminados con metales) sólo en los sedimentos cercanos al depósito 3; sobre el cauce del depósito 5 y sobre el río Maconí las concentraciones solubles están por debajo de dicho valor. La fracción intercambiable en los sedimentos, extraída con bicarbonato de sodio, muestra que la concentración de As se incrementa respecto a la fracción soluble en agua.

Palabras clave: residuos mineros, dispersión de jales, atenuación natural, sedimentos de río, afectación ambiental.

ELSEVIER

Linear and non-linear analysis of flow instability in gas-lift wells

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ABSTRACT

Linear and non-linear analyses of flow instability in continuous gas-lift wells were performed in this study. The linear analysis is based on a modified gas-lift stability criterion that takes into account compressibility of the mixture below the injection point and is applicable to saturated reservoirs. The analysis of non-linear dynamics and stability of the well was performed using direct numerical integration in the time domain of the governing equations describing the gas-lift system. The transient gas-lift well model developed comprises of a model of transient three-phase gas–oil–water flow in the wellbore, a transient model of gas flow in the casing annulus, and a pseudo-steady flow model in the reservoir. The multiphase flow model used is based on the drift-flux theory. Stability boundaries predicted by both linear and non-linear analysis were compared with field data published in a previous study; both types of analysis reproduced the data. The effects of the main well design and flow parameters on the frequency and amplitude of the oscillations during heading in a typical gas-lift well were studied. It was found that flow instability results in the oil production loss, which depends on severity of heading. The largest reduction in oil production takes place in case of the most severe heading in the well (flow instability with the largest amplitude of production rate oscillations). An increase in the lift gas consumption is required to compensate for the production losses caused by heading. An increase in the depth of the injection point may result in heading and an increase in the operating costs caused by the increase in the lift gas consumption. An increase in the separator pressure has a destabilizing effect. At high separator pressures the well can experience two modes of instabilities: casing heading and density-wave oscillations.

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1. Introduction

Flow instability (heading) in continuous flow gas-lift wells has been the subject of many studies over the last three decades (Alhanati et al., 1993; Asheim, 1988; Blick et al., 1988; Fairuzov et al., 2004; Grupping et al., 1984a, 1984b; Hu, 2004; Hu and Golan, 2003; Poblano et al., 2002). Heading is the reason of many problems in the operation of oil production facilities (Alhanati et al., 1993) and finally leads to an increase in the operating costs. Two types of instabilities in gas-lift systems have been identified: casing heading and density-wave instability. The former is associated to variations of the injected gas flow rate caused by variations of the density of the multiphase fluid in the tubing downstream the injection point (Asheim, 1988). The flow in a gas-lift well can be also unstable even the downhole gas injection rate is constant due to density-wave oscillations (Hu, 2004; Hu and Golan, 2003). Self-excited pressure and flow rate oscillations in the tubing may either diverge (result in the complete loss of

liquid production and gas recirculation) or reach a self-sustained periodic mode (heading).

Two different approaches have been proposed in the literature to analyze gas-lift instability. The linear analysis has been used to develop flow stability criteria in terms of flow and well design parameters by different authors (Alhanati et al., 1993; Asheim 1988; Blick et al., 1988). In this type of analysis, the response of the system, which is initially at equilibrium, to an infinitesimal perturbation of tubing pressure at the injection point is predicted. To obtain practical analytical criteria, several strong simplifications in the description of the system are made. The stability criteria can be used to develop gas-lift stability maps (Fairuzov et al., 2004; Poblano et al., 2002), which significantly reduce the time required for the analysis. The disadvantage of the linear stability analysis is that it only predicts the onset of instability and cannot be used to model the operation of well in the unstable region.

The second approach to studying flow instability in gas lift-wells, the non-linear analysis, is usually based on numerical modeling of multiphase flow in the tubing. This technique has been used to develop active control systems to eliminate heading (Dalsmo et al., 2002; Eikrem et al., 2002, 2004; Hu and Golan, 2003; Jansen et al., 1999; Scibilia et al., 2008; Sinègre et al., 2005),

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Hindawi

Research Article

TESLA GPUs versus MPI with OpenMP for the Forward Modeling of Gravity and Gravity Gradient of Large Prisms Ensemble

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An implementation with the CUDA technology in a single and in several graphics processing units (GPUs) is presented for the calculation of the forward modeling of gravitational fields from a tridimensional volumetric ensemble composed by unitary prisms of constant density. We compared the performance results obtained with the GPUs against a previous version coded in OpenMP with MPI, and we analyzed the results on both platforms. Today, the use of GPUs represents a breakthrough in parallel computing, which has led to the development of several applications with various applications. Nevertheless, in some applications the decomposition of the tasks is not trivial, as can be appreciated in this paper. Unlike a trivial decomposition of the domain, we proposed to decompose the problem by sets of prisms and use different memory spaces per processing CUDA core, avoiding the performance decay as a result of the constant calls to kernels functions which would be needed in a parallelization by observations points. The design and implementation created are the main contributions of this work, because the parallelization scheme implemented is not trivial. The performance results obtained are comparable to those of a small processing cluster.

1. Introduction

In recent years the number of publications about parallel computing applications using the GPUs architecture has remarkably increased. These applications represent an economic and powerful way to access high-performance computing [1, 2]. However, since the architecture of the GPU is different to that of a conventional CPU, the programming paradigm should be changed. This had led to the development of a new research field within scientific computing which explores the performance of the GPU to general purpose applications, such as acoustic simulation [3], propagation of seismic waves [4], seismic migration [5], molecular engineering [6], fluid dynamics [7], even for astrophysical simulations [8] and many other implementations. In a few words, the objective of the general purpose computing in GPU (GPGPU) is to develop new applications for those who pretend to solve problems of numerical simulation requiring as less computing time as possible.

Even though the GPUs have become an accessible platform for general purpose programming, they still have some limitations and its programming entails some difficulties [2]. Compute unified device architecture (CUDA) is a set of tools that includes mainly a compiler for an extension of the C language, a set of libraries, and drivers for the specific programming of NVIDIA cards. Despite that these tools have eased the programming, it is still needed to know with precision the architecture of the card with its several memory levels to obtain the maximum performance. One of the greatest drawbacks that can occur in CUDA is the