IAEA-TCR-03481

INTERNATIONAL ATOMIC ENERGY AGENCY

END OF MISSION REPORT

ON

"Groundwater pollution by hydrocarbons in the Central Valley Aquifer, Costa Rica"

2007-03-19 to 2007-03-23

by

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(IAEA-TCR-03481)

"Human Resource Development and Nuclear Technology Support"

Latin America Section 1

GROUNDWATER CONTAMINATION IN THE CENTRAL VALLEY, COSTA RICA

Project and Task Number C3-COS/0/004 03 01

US EPA, Region 4 for the International Atomic Energy Agency

April 2007

KEY RECOMMENDATIONS

1.) Remove the gasoline tanks and their contents

2.) Remove the free product from the soils

3.) Abandon well AB-1089 by cementing from bottom to top

4.) Re sample water supply wells and analyze for specific constituents with the minimum detection limit of the analysis being below the established health based number. Take action if test results are above health-based numbers.

5.) Establish a monitoring well network to protect the Colima Superior because it is the source of major water supplies for the Central Valley, Costa Rica (Puente de Mulas)

6.) Define the extent of the free product in the perched aquifer and remove free product

Introduction

In response to a request from the Municipality of Belén in Costa Rica, the International Atomic Energy Agency (IAEA) requested through EPA's Office of International Affairs (OIA) that Region 4 EPA provide assistance in characterizing the nature and extent of a ground water plume of petroleum hydrocarbons and provide recommendations regarding actions to address health-concerns related to contaminated drinking water wells. There was a concern on the part of the government of Costa Rica regarding the protection of vital water supplies and to determine steps necessary to remediate contamination at this site. In addition, if the groundwater plume is not contained, it may continue to spread and impact the water supply for over 300,000 people, approximately 10 percent of the population. The government has been evaluating the plume for more than two years. However, the plume is still uncontrolled and remains a threat to drinking water supply wells in the vicinity and to drinking water supplies in the region. This request has come from IAEA who has been assisting the Costa Rican government on water resource management issues. Two Region 4 scientists, Lee Thomas, Regional Expert in Hydrology and Jacq Marie Jack, Regional Expert in Oil Pollution Remediaiton, traveled to Costa Rica during the week of March 18, 2007 to visit the site, hear presentations regarding the site, and gather site-related information and data.

Summary

There has been contamination detected in water supply wells at the southern most part or Heredia Province, Costa Rica (See Figure 1). In September 2004, routine sampling of

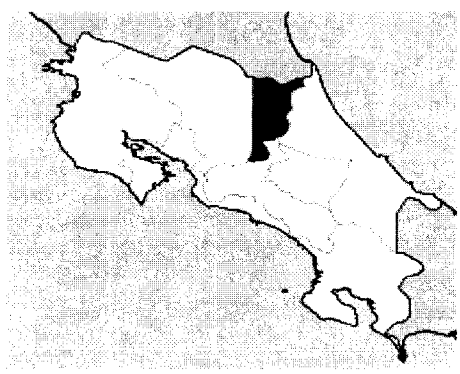

Figure 1 Heredia Province, Costa Rica

AB-1089, a dry season make up water supply well, resulted in detection of hydrocarbons. The well is located in the Ulloa District of the Heredia Canton, Heredia Province and is on property immediately adjacent to a gasoline station. Water supply well AB-1089 was resampled in October 2004 and again had a detection of hydrocarbons. Sampling has been conducted on nearby water supply wells in February/March 2005, July/August 2005, December 2005, July/August 2006, September/October 2006 and January 2007. Sampled wells were located in the Ulloa Distirct of Heredia Canton and the adjacent Asuncion and La Ribera Districts of Belen Canton. In a number of the nearby wells, hydrocarbons have been detected during one or more of the sampling events.

Piezometers and borings have been constructed at the site of the gasoline station which show that free product, a mixture of diesel, gasoline, and motor oil, is found beneath the station.

The site is immediately underlain by a series of formations and associated aquifers. These zones are formed from interbedded layers of volcanic lava flows and pyroclastic zones. The aquifer nearest to the surface is an unnamed perched aquifer. It is located in the upper portion of the Formation Colima Superior between approximately 18 meters and 30 meters in depth below land surface. The horizontal extent of this aquifer is unknown but it is probably small in size. Below the perched aquifer are two aquifers which are important regionally for water supplies, the Aquifer Colima Superior and the Aquifer Colima Inferior. The Aquifer Colima Superior is particularly notable because downgradient of the area of this study, it is the source for Puente de Mulas spring which supplies much of the water to the city of San Jose. Puente de Mulas is the second most important spring in the Central Valley and produces 450 liters/second from several infiltration galleries.

The effort toward plume delineation has been centered on free product which is located in the unnamed perched aquifer. There has been no effort to delineate the plume in the Aquifer Colima Superior. The plume delineation effort in the perched aquifer was a geophysical study based on resistivity anomalies. In November 2006, the report Estudio Geofísico Mediante Resistividad Eléctrica en el Área del Pozo AB1089, Ubicado en Barreal de Heredia, Provincia de Heredia was published. The use of resistivity anomalies for plume delimitation is limited to the free phase (pure) hydrocarbons. Unfortunately, the dissolved phase of the plume can not be delineated by resistivity anomalies because the technique is not adequately sensitive at the concentrations typical of the dissolved phase. Also, rock type or lithologic variations are likely to complicate the use of resistivity for plume delineation, since these lithologic variations may also result in resistivity anomalies. In this study it is not possible to distinguish between the resistivity anomalies produced by lithologic variations and those produced by free product. However, the November 2006 study did indicate that the free product portion of the plume extends significantly beyond the property where the gasoline tanks are located. The dissolved product portion of the plume may extend a much greater distance downgradient than the free product phase.

In addition to the geophysical report, there have been a number of reports and presentations about the site. There is a list of reports and investigations which the authors are aware of in the Reference section at the end of this report. The quality of work related to the site has been outstanding. A number of government agencies have been involved in various phases of the investigations at the site. In particular, Belén, in Heredia, has been very proactive in addressing issues related to the site.

Project Goals

Information and data from the site, from reports, and from presentations was evaluated and recommendations are presented with three goals.

1) Protect the Aquifer Colima Superior which is an important source of water for San Jose. Since Puente de Mulas is one of the most important sources of water, it is important to take actions to ensure that the plume does not have adverse impacts on Puente de Mulas. Puente de Mulas produces water at a rate of 450 liters/second. It is an important source of water for 320,000 people who live in the city of San Jose.

2) Reduce the threat of the plume of hydrocarbons. At the present time, only limited efforts have been made to control the plume of hydrocarbons from the site. It is important to take measures to control the plume to ensure that it does not become a threat to additional areas. The plume of free phase hydrocarbons represents the greatest threat and is present in shallow zones near the site. The free phase hydrocarbons can be found floating at the top water table and in soils which extend from near the surface to the water table. The areas where free phase hydrocarbons continue to exist represent a very potent source of contamination. Free phase hydrocarbons have the potential to create dissolved phase plumes many times greater in volume than the free product plume. The plume of dissolved hydrocarbons is sourced from the free phase plume and extends an unknown distance in the perched aquifer. It may already be present in the Aquifer Colima Superior.

3) Prevent impacts to the health of persons. At the present time hydrocarbons have been detected in a number of water supply wells which produce from the Aquifer Colima Superior in one or more sampling events. It is important to know the concentrations of specific chemicals which may be found in the water supply wells. However, since most of the analysis has been conducted only for total petroleum hydrocarbons rather than for specific chemicals, the concentrations of specific chemicals in the water supply wells are not presently known. Once the concentrations of specific chemicals are known, they can be compared to health-based limits. Where chemicals are found at concentrations above health-based limits, measures should be taken as soon as possible to ensure that any threats to health are addressed.

Background on Hydrocarbon Plumes

The recovery rate of free product from leaking underground storage tanks is usually less than 30% of the original volume leaked. The site with the largest documented free product recovery had the removal of only 60% of the spilled hydrocarbons over a 13-year period. The average recovery of free products floating on an aquifer is 26% of the original volume leaked. Despite an enormous effort to clean up plumes of free product from leaking gas stations, hydrocarbons persist in the subsurface. Free product remains because of the physical limitations to recovery and from inefficiencies in the hydraulic recovery system. In the United States of America, the costs for remediating sites with soil contamination are typically from $10,000 to $125,000. Costs for remediating sites with groundwater contamination are typically from $100,000 to over $1 million dollars in addition to the soil remediation costs.

Phased Recommendations

Recommendations are provided in phases. The first phase is the most critical and should be started as soon as practical. The remaining phases will require more time and for certain recommendations, additional data will be required to complete the tasks in these phases.

Phase I Addressing the Most Critical Issues

1.) Remove the Tanks and Their Contents

Remove the residual liquids from each tank and then remove each tank and the contents of the grease pit from the subsurface following the procedure described in the "Closure of Underground Petroleum Storage Tanks," Edition: 3rd (American Petroleum Institute / 01-Mar-1996 / 5 pages) (See appendix A, attached). Tank removal is necessary for two reasons. First, standard pumping leaves residual hydrocarbons in the tanks. These hydrocarbons could continue to discharge into the soil. Secondly, and more importantly, hydrocarbon can pool beneath the leaking tanks. The underground tanks block access to areas of free product and the most contaminated soil and groundwater. Access to these areas is critical to remediating the shallow aquifer and protecting the Colima Superior. After removing the tanks, suction up free product that pooled beneath the tanks. Pump the free product through the oil water separator and store onsite in a tank with above ground secondary encapsulation until the tank is full. Ship the free product to the refinery in Limon, as necessary.

2.) Remove the Free Product from the Soils

After removing the free product in the soil, remove all hydrocarbon stained soils and all soils that contain a hydrocarbon odor down to the bedrock. Make every effort to locate and excavate the vertical extent of the contaminated soils. As the hydrocarbons reach less permeable zones in the subsurface, the hydrocarbons will spread laterally. This is particularly prevalent at the soil rock interface. Before back filling the excavated area, test the remaining soil beneath and adjacent to the soil excavation pit for the following constituents found in Table 1. to determine if additional soil needs to be removed. Remove additional soil as indicated by test analysis. Once the soil samples indicate contamination does not exist above levels hazardous to health, fill the hole with clean soil.

Either truck the excavated soil off site for land farming (see phase 2) or establish an area on site to store the contaminated soil. For on site storage, construct secondary encapsulation around the area designated for onsite storage. Construct berms around the area intended for the temporary storage of the contaminated soil. Line the bermed area with impermeable cloth. Place the excavated contaminated soil on the impermeable cloth and cover the soil with plastic sheeting. Ship the contaminated soil to the land farm area (see phase 2) as necessary.

3.) Abandon Well AB-1089

Cementing AB-1089 well will reduce the risk of hydrocarbons being released from the perched aquifer into the drinking water aquifer of the Colima Superior. The space between the casing and well bore AB-1089 is a likely conduit for hydrocarbons from the perched aquifer to enter the Colima superior aquifer (see figure 2). Plug well AB-1089 by removing the casing and emplacing Portland cement pumped under pressure such that a continuous impervious and impermeable plug occupies the void created by AB-1089. In addition, plug any borings drilled during the investigation of the gas station that penetrated the Toba Calcinada, a zone of lower permeability which helps to protect the Aquifer Colima Superior, as these as act as potential pathways for contaminants to enter the Aquifer Colima Superior. Plug each borehole with one continuous plug of Portland cement emplaced under pressure with a trimmie tube emplaced at the bottom of the hole. Sealing the AB-1089 wells and the borings that penetrate the Toba Calcinada will help to prevent downward migration of hydrocarbons into the Colima Superior.

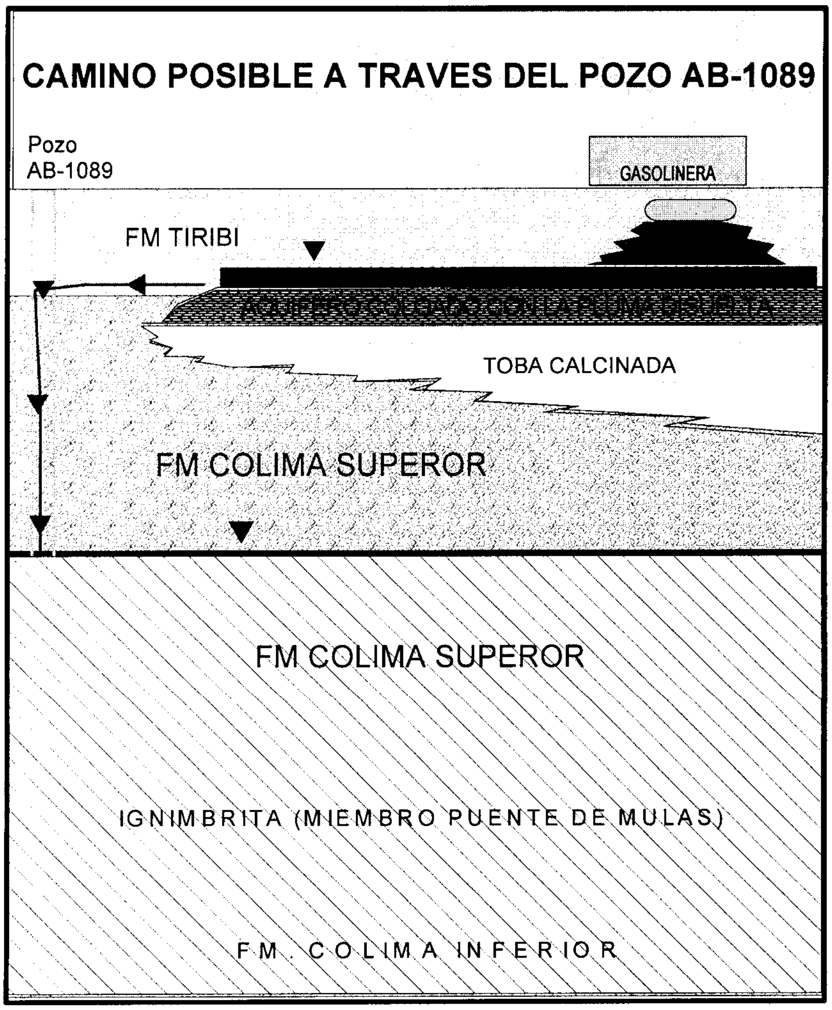

Figure 2 – Pathway Through AB-1089 Connecting Perched Aquifer and Colima Superior

Phase II Treat Excavated Soils and Resample Water Supply Wells

1.) Treat the Excavated Soils

Treat the excavated soils contaminated with hydrocarbons by land farming (also known as land treatment or land application.) Land farming is an aboveground remediation technology for soils that reduces concentrations of petroleum constituents through biodegradation. The enhanced microbial activity results in degradation of adsorbed petroleum product constituents through microbial respiration. Appendix B contains a description on how to conduct land farming.

2) Take Comprehensive Samples of Water Supply Wells

Take a comprehensive set of samples in the water supply wells close to the site that have had contamination in the past or that have the potential to be impacted from the site. Sampling of nearby water supply wells has been conducted on at least six occasions since hydrocarbons were discovered in AB-1089 in 2004. However, the sampling was not sufficient to address whether health concerns may exist.

Figure 3 depicts water supply wells which produce from the Aquifer Colima from CAD

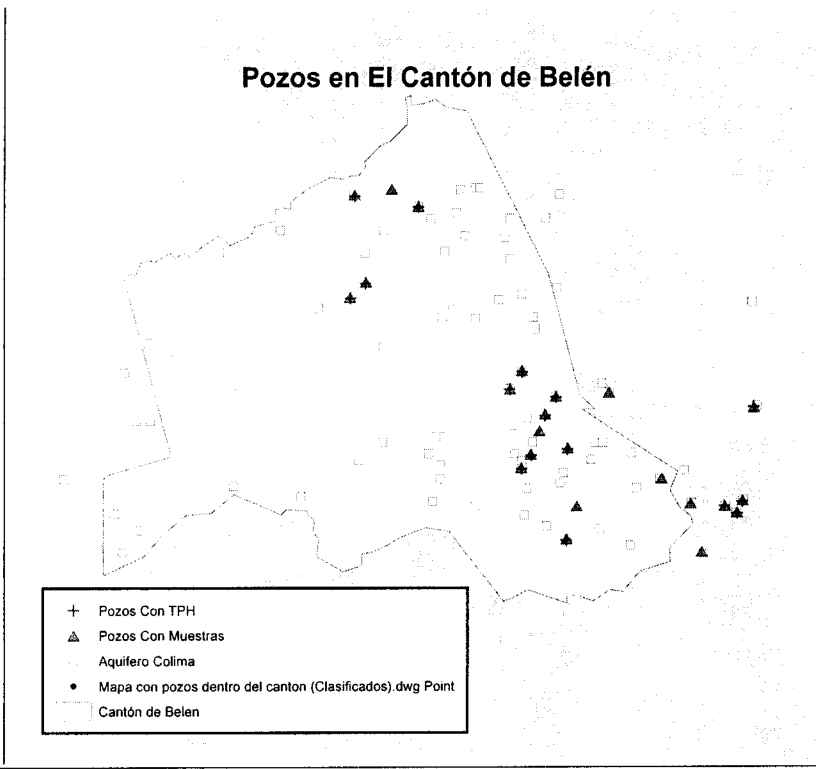

Figure 3 Aquifer Colima Water Supply Wells

files provided to us during the visit to Costa Rica. We have matched the wells identified in sampling reports, where possible, to wells in the CAD files. Most wells in the sampling reports could be matched based on a number. However, some wells which were in the sampling data could not be matched and are not included on the map. The Aquifer Colima wells appear as yellow squares. The wells which were sampled appear as green triangles. Where hydrocarbons were detected, a red cross was placed on the well. It is striking that there appear to be a large number of wells which have not been included in any of the sampling events. It is recommended that as many wells be included in the sampling as is possible, particularly near the site of the plume.

An upgradient well should also be included in the sampling of the Aquifer Colima. It is important to understand the quality of water moving from upgradient locations to ensure that appropriate actions are taken. There are wells nearby which could be used as an upgradient well such as AB-1206. The use of an upgradient well will help to determine if there are additional sources which may be upgradient which may be of concern.

3) Send the Samples to a Certified Laboratory
Send the samples to a certified or accredited laboratory inside or outside Costa Rica. It is important that the laboratories that conduct the sample analysis have the recognized ability to run analytical methods and obtain verifiable repeatable results. Also, it is important to have in place a method to track each sample from the time it is taken until analysis occurs. Sample tracking ensures that the sample vials do not become mixed up and also ensures that results can be traced back to a specific sample location.

4) Conduct Analysis for Specific Compounds
Conduct analysis for specific compounds of concern with analytical methods which are appropriate for health-based concentrations. Most of the sampling conducted to date has been for total petroleum hydrocarbons. Analyzing for total petroleum hydrocarbons will not yield data which can be compared to information about human health risks. Unfortunately, there are many different chemicals which make up total petroleum hydrocarbons. Temporal variations occur in the chemical composition of gasoline, diesel, and motor oil. Also, chemical changes in these products are expected to occur as they age. These variations make the meaningful evaluation of potential health impacts based solely on total petroleum hydrocarbons difficult if not impossible. In some instances in past sampling, detection limits for total petroleum hydrocarbons have been above health-based limits for specific compounds. A total petroleum hydrocarbon sample with a non detect analysis does not mean that the well is free of the potential health-damaging chemicals.

In place of total hydrocarbons, analysis is needed for specific compounds of greatest concern that are likely to be present. Benzene, ethylbenzene, toluene and xylene are commonly found in petroleum products such as gasoline and their presence in drinking water is even small quantities is cause for concern. In addition, Methyl-t-butyl-ether (MTBE) was a gasoline additive that is believed to cause health issues at low concentrations. It is very mobile in groundwater. If it was added to gasoline in Costa Rica at the time that leaks may have occurred, it should be added to the list of analyites. There are two lead scavengers also included in the list, 1,2-Dibromethene (AKA ethylene dibromide), 1,2-Dichloroethane. When lead was eliminated from gasoline (Costa Rica circa 1996) these constituents were added to gasoline in many countries. It is now known that they are highly toxic and mobile in groundwater. Benzo[a]pyrene is a hydrocarbon typically found in diesel and motor oil in small quanitites. The table below (Table 1)

	Costa Rica	World Health Organiza-tion	European Union	United States EPA	Carcinogen	Health Impacts
Benzene		0.01 mg/L	0.001 mg/L	0.005 mg/L	Yes	Acute Myeloid Leukemia
Ethyl-benzene	0.3 mg/L	0.3 mg/L		0.7 mg/L	No	Liver, Stomach & Kidney Damage
Toluene	0.7 mg/L	0.7 mg/L		1 mg/L	No	Liver, Stomach& Kidney Effects, Central Nervous System Injury
Xylene	0.5 mg/L	0.5 mg/L		10 mg/L	No	Acute Systemic Toxicity
MTBE			0.01 mg/L	0.04 mg/L	No	
1,2-Dibro-methene		0.0004 mg/L		0.00005 mg/L	No	Liver, Stomach, & Kidney Damage, Reproductive Problems
1,2-Dichloro-ethane	30 mg/L	0.03 mg/L		0.005 mg/L	Increased Risk	Central Nervous System Damage
Benzo[a] pyrene	0.0007 mg/L	0.0007 mg/L	0.000010 mg/L	0.0002 mg/L	Probable	Reproductive Difficulties

Table 1 Recommended List for Common Hydrocarbon Compounds for Analysis of Colima Superior Water Supply Wells and Associated Health Effects

provides a list of the recommended chemical for analysis from water supply wells along with health-based limits based on consumption of water from several sources.

Analytical methods should be selected with quantitation limits for each chemical which are lower than the health based limits for each chemical. Detection limit was 0.001 mg/L in July/August 2005 sampling and 0.005 mg/l in the December 2005 sampling. The quantitation limits were 0.004 mg/L and 0.008 mg/L for the same sampling events respectively. Many of the health base limits are below these levels. Also, the analytical methods should be selected for sampling which will specify quantities of liquid required for analysis, method of preservation of samples, and holding time for samples. Analytical methods will also specify the detection limit for each chemical which should be below the health-based limit for each chemical of concern.

Table 1 provides a comprehensive list of chemicals which should be included in the next round of analysis for each sample from the Colima Superior wells. After the next analysis has been conducted and the actual chemicals which are part of the plume are known, it may be possible to reduce the list. The number of chemicals on the list can be reduced if they are found to not be present.

Phase III Address Health Concerns and Establish a Monitoring Well Network to Protect the Colima Superior

1) Actions to Mitigate Threats to Health

If the data from the well samples indicate that there is a threat to health, take immediate actions to eliminate those impacts. Where the concentrations of specific chemicals are of concern, an alternative supply of water should be provided as soon as possible. Normally, it will be necessary to provide a temporary source such as bottled water while arrangements are made for a long term alternative source of water. In the US a single family home will typically use approximately 200 liters per person per day. However, this figure is highly variable. For volatile compounds such as those found at this site, bathing and cooking may be of concern since these activities cause exposure via the airborne pathway. The long term alternative source may either be municipal water through the local distribution network, filters, or a new well in an area not impacted by the plume.

2) Establish a Network of Observation Wells

Establish a network of observation wells in the aquifer Colima Superior between the area of contamination and important springs (i.e. Puente de Mulas). There are a number of public and private water supply wells which are located downgradient of the plume and the area of concern. Once the extent of the dissolved phase of contamination is known, a network of observation wells should be established for periodic sampling. Existing water supply wells would probably be adequate for use in this network. Sampling the network of observation wells can help give early warning that the water quality of important sources (i.e. Puente de Mulas) could be threatened. In order to provide a warning about movement of the plume in the direction of important water sources as early as possible, the network of observation wells should be placed parallel to the downgradient edge of the plume.

Begin to take samples from the network of observation wells as soon as the network is established. It is recommended that a schedule for periodic sampling be developed.

Develop contingency plans in case the downgradient wells indicate an increase in contamination or movement of the plume toward Puente de Mulas.

Phase IV Address Contamination in the Colima Superior and Perched Aquifer

1.) Define the Extent of the Free Product in the Perched Aquifer.
Install a grid of small diameter monitoring wells over the perched aquifer. Construct the monitoring wells by cementing surface casing through the soil zone. Do not drill into the Toba Calcinada as it forms a barrier that separates the contaminated aquifer from the Colima Superior. Sample the wells to determine the water level and to determine if free product is present. Based on the measurements from the monitoring wells, construct a water level map showing the elevation of the top of the perched aquifer. On the water level map, superimpose the outline of the free product. Install extraction pumps at the monitoring wells located within the outline of the free product.

2.) Remove the Free Product from the Perched Aquifer Using the Pulsed Pumping Method.
Pulsed pumping is the most effective way to remove free product. Incomplete or inefficient pumping will doom the free product recovery project. Place the well intakes in the free product zone. If the well intake is below the free product zone and into the aquifer, pumping will create draw down and will smear the hydrocarbons into the underlying aquifer, thereby spreading contamination and making plume control more difficult and costly.

Pump the free phase of the hydrocarbons as slowly as possible to maximize hydrocarbon extraction and minimize the drawdown (cone of depression) into the perched aquifer. Pump the wells until the wells produce water. Stop pumping until the hydrocarbons reappear in the well. When free product is once again in the well, commence pumping until the well produces only water. Repeat until the well no longer recovers free product.

Pump the produced (hydrocarbon/water) mixture to the oil water separator. Discharge the separated products to holding tanks. Record the volume of pure product retrieved. Do not record the total of the water/free product mixture produced. Enclose the separator, produced water tank and free product tank with above ground secondary encapsulation. Treat the produced water by passing it through an air-striping column. Test the quality of the produced water to ensure it is below the acceptable concentration limits before discharging to the Quebrada Guaria that flows to the Rio Bermudez.

3.) Document the Reduction of Dissolved Product in the Perched Aquifer
Collect samples from groundwater below the perched aquifer and test for the presence of chemicals shown in Table 1. Construct a map for each constituent, because each constituent dissolved in the shallow aquifer has different health levels and behaves differently in ground water. These maps will show the distribution, transport and

degradation rates of the dissolved phase of the contaminations in the perched aquifer. **It is not possible to conduct remediation of dissolved hydrocarbons in an aquifer beyond natural attenuation when free product is floating on the aquifer**

4.) Document the Reduction of Dissolved Product in the Colima Superior
Collect samples from the Colima Superior and test for chemicals shown in Table 1. Consider in constructing the plume maps that contamination could be from more than one source.

<u>Other Treatment Option</u>

If it is not possible to remove all contaminated soil, conduct in-situ treatment.
If the soil contamination is deeper than can be physically removed, consider alternatives. It is possible to treat unsaturated soils in situ with a soil vapor extraction system (see Appendix C) and/or natural attenuation. The first priority should be soil removal. **Attempting to remediate contaminated soil in situ is more expensive and less effective than removing the contaminated soil.**

<u>General Comment</u>

Future protection of aquifers possibly impacted by gasoline stations
Because of the risk that the 334 gasoline stations pose to the vulnerable aquifers in Costa Rica and the cost and time associated with remediating a site, it is more efficient and effective to install a network of sentinel wells and take soil borings at each gas station than to wait until contamination appears in a drinking water aquifer. To determine that gasoline stations do not pose a threat to vulnerable drinking water wells, install 4 small bore sentinel wells into the shallow aquifer at cardinal directions from each gasoline station (north, south, east and west.) Twice a year, once during the peak of the rainy season and once during the peak of the dry season, collect groundwater samples. At the same time, collect a sample of unsaturated soil near each sentinel well. Analyze the soil and ground water for the presence of hydrocarbons. If the test results indicate the presence of hydrocarbons, take immediate steps to protect the threatened groundwater aquifers.

<u>Conclusions and Recommendations</u>

There is an uncontrolled plume of hydrocarbons at the study area which has significantly impacted the perched aquifer and threatens water supply wells nearby in the Colima Superior aquifer. Recommendations are provided to contain the threat from the plume of hydrocarbons and remediate the impacted aquifers.

In the first phase, remove the tanks at the service station; remove the free product which remains at the site; excavate visibly contaminated soils; abandon with cement from bottom to top Pozo AB-1089 and any other boreholes which connect the highly contaminated perched aquifer to the Colima Superior; construct secondary containment for temporary storage at the site for contaminated soils and other products; send recovered free product to the refinerary at Puerto Limon.

In the second phase, treat contaminated soils by landfarming; samples should be taken in the wells downgradient of the site; send the samples to a certified or accredited laboratory; and conduct analysis for benzene, toluene, xylene, ethylbenzene, MTBE, 1,2-dibromethene, 1,2-dichloroethane, and benzo[a]pyrene.

The third phase should include measures to address any locations where contamination is found at concentrations above health-based limits; establish a network of observations wells to protect the Colima Superior and Puente de Mulas; begin periodic sampling of the network of observation wells as soon as practical.

In phase four, define the extent of the free product in the perched aquifer; remove the free product from the perched aquifer; periodically sample the water (not the free product) in the perched aquifer for the chemicals in Table 1 and construct maps to show the natural attenuation of the dissolved phase of each constituent; document the reduction of dissolved product in the Colima Superior. Additionally, if possible, address contaminated soils at the site too deep to be excavated. Prior to discharge of water from the site in the Quebrada de Guaria use an air stripper to remove additional impurities.

Hopefully, these recommendations will be useful in helping to mitigate any impacts that this site may have. If there are any questions concerning this report and/or visit, contact Lee Thomas at Thomas.Lee@epa.gov and Jacq Marie Jack at Jack.Jacqueline@epa.gov. They may also be contacted at US EPA Region 4, 61 Forsyth Street, Atlanta, GA 30303.

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Remediación Pozo AB-1089 de la ESPH, La Aurora de Heredia

Reporte de Diagnóstico Para la Organización Mundial de la Salud, Contaminación Del Pozo AB 1089, Contrato de Servicios CR/CNT/0500071.001, Asesor Técnico: Ing. L. Alejandro Gullén Guardia, MSCE, P.E., 28 Octobre 2005

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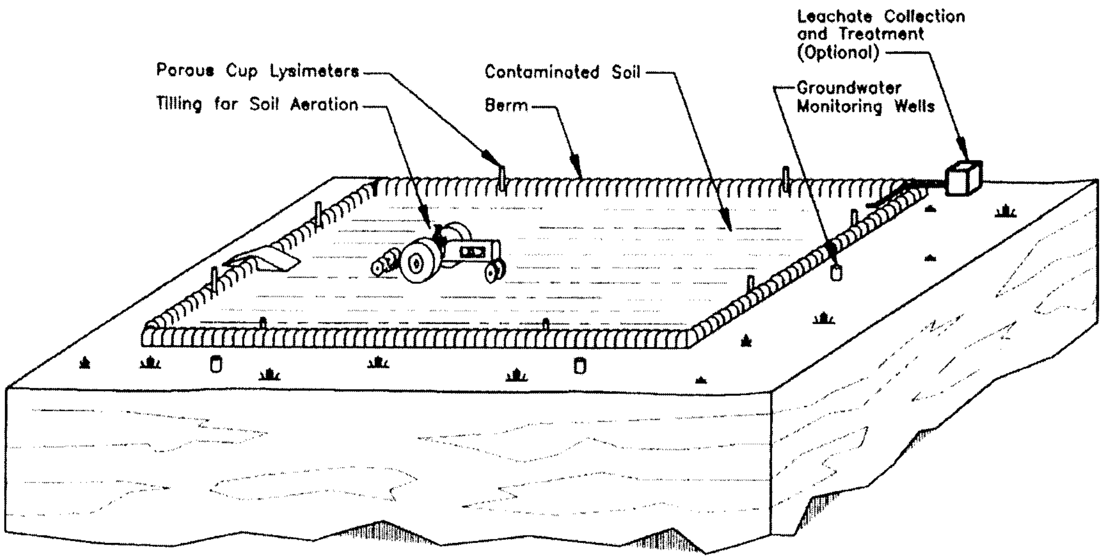
Appendix A

See attached pdf file "Closure of Underground Petroleum Storage Tanks"

Appendix B Land Farming

Typical Landfarming Operation



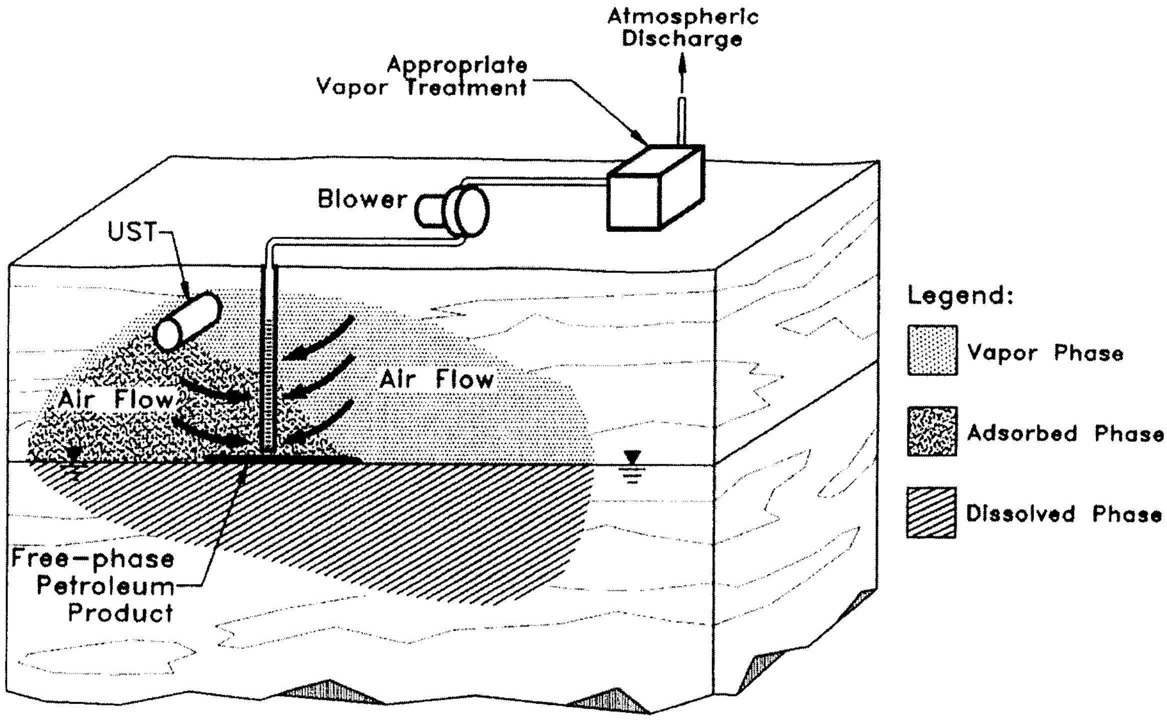
Land Farming (Also known as land treatment, land application)

Land farming is an aboveground remediation technology for soils that reduces concentrations of petroleum constituents through biodegradation. The enhanced microbial activity results in degradation of adsorbed petroleum product constituents through microbial respiration.

Spread excavated soils in thin layers (12-24 inches) on an impervious sheet draped over a beamed area (An impervious liner placed over the berms and inside the land farming area will prevent leachate from contaminating groundwater.) Aerate soils by periodic tilling. Soils may require irrigation during the dry season (moisture needed for degradation hydrocarbons). In addition, during the dry season, covering the soil with plastic to keep moisture and heat in will speed bioremediation. The addition of nutrients (fertilizer and/or animal manure) will speed the breakdown of the hydrocarbons.

Appendix C Soil Vapor Extraction

Typical SVE System



Soil vapor extraction (Also known as vacuum extraction, soil venting)
Soil vapor extraction is an in-situ remediation of unsaturated zone soil. ***This method is less efficient and more costly than soil extraction.***

Install a network of wells screened across area of contamination attached to vacuum pumps, which vacuum the soil of off gassing hydrocarbon vapors. This process exchanges the natural biodegradation of the hydrocarbons in the soil. Test the extracted vapors to ensure they do not exceed health-based numbers. The critical factors to successfully utilizing this recovery system are the permeability of the soil. The drier, more permeable and homogeneous the soil is, the greater the efficiency of the extraction operation. To determine efficiency of the operation, document the quantity of the extracted hydrocarbons and the extraction flow rate. Quarterly take soil borings and analyses the soil for the following constituents.

The advantage of using Soil Vapor Extraction is that it is easy to install, parts are readily available costs approximately $20-$50 to treat a ton to contaminated soil. The disadvantages of the Spoil Vapor Extraction system is that it will lee over 10% of the hydrocarbons in the unsaturated soil... The lower the permeability or the more stratified the soil the less effective is the system. This treatment only works in the unsaturated soil zone. Soil vapor extraction will not treat soils saturated with hydrocarbons, free product in the subsurface or dissolved hydrocarbons in an aquifer.

Appendix D - Work Programme March 18 to 24

Travelers: Lee Thomas, Jacq Marie Jack, EPA, Region 4

The purpose of this trip was to provide assistance to the government of Costa Rica in the assessment of a site with a gasoline station with leaking underground storage tanks. The problem was discovered in September 2004 during routine sampling of AB-1089, a dry season water supply make up well, located on property immediately adjacent to the service station. In addition to total petroleum hydrocarbons found in AB-1089, several water supply wells located downgradient have also had detections of petroleum hydrocarbons. The aquifer Colima Superior which is one of the sources of water for AB-1089 is also the source for Puente de Mulas, a prolific spring which supplies 10% of the water for Costa Rica.

$ On March 18, 2007 February 9-11, 2005, Lee Thomas and Jacq Marie Jack traveled to Costa Rica.

$ On March 19, 2007, in the morning there were presentations about the site from several organizations involved with the site including Secretaria Técnica del Ambiente (SETENA), Unversidad National de Costa Rica (UNA), and the Universidad de Costa Rica (UCR) regarding the situation at the site and studies that have been conducted. In the afternoon, the were visits to Puente de Mulas spring, several public water supply wells where hydrocarbons have been detected and the site of the gasoline station and adjacent AB-1089.

$ On March 20, 2007 reports were review and preliminary recommendations were begun to be drafted. In the afternoon, there was a visit to Elaine Sampson, US Embassy Press Attaché; Bernie Link, US Embassy Control Officer and other Embassy personnel to discuss the site and preliminary recommendations.

$ On the morning of March 21, 2007, there were presentations by representatives of Acuductos y Alcantarillados which is the agency responsible for the site. In the afternoon, there was a visit to UNA and a meeting with Hugo Rodriguez who conducted aquifer testing at AB-1089.

$ On the morning of March 22, 2007 work began on the presentation of preliminary recommendations. In the afternoon, there was a meeting at the office of the Commission de Energia Atomica de Costa Rica who are the local liaisons with the IAEA.

$ On the morning of March 23, 2007 there were presentations by Jacq Marie Jack and Lee Thomas at UNA on the toxicity of petroleum, typical site remediation activities for gasoline stations in the US with leaking tanks, and also the preliminary recommendations for the site. There were several reporters present and an adjacent room had to be opened for the overflow attendance. In the evening the same recommendations were made before the municipal council of Belen of Heredia.

$ On March 24, 2007 the travelers returned to the United States.