

REMEDICATION OF THE IMPACTS CAUSED BY THE PETROLEUM SPILL IN THE LAGOON OF PAPALLACTA IN ECUADOR—SOUTH AMERICA

EXECUTION TIME: NOVEMBER 2003-MAY 2004

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SUMMARY

An affected area of approximate 7.2 ha (hectares) was cleaned and remediated after an oil spill of about 22,000 barrels at the Lagoon of Papallacta. The spill was due to the breakage of the trans-Ecuadorian pipeline. Shores, sediment, water of rivers and the Lagoon of Papallacta were decontaminated. The hydrocarbons in the water were extracted by skimming, adsorption, absorption and filtration processes. The contaminated sediments of the bottom of the lagoon were extracted by suction, dehydrated and transported to landfarming stations for their bioremediation using endemic microorganisms. The initial analyses of total hydrocarbon concentration in the shores of the rivers and the lagoon oscillated between 40,245 and 85,879 milligrams/Liter (mg/L), 4,500 mg/Kg in sediments of the bottom of lagoon and 89 mg/L in the water of the lagoon. The works of remediation were subdivided by logistic convenience in five sections. The cleaning and remediation included the bed of the rivers, rocks, shores of the Lagoon of Papallacta, vegetal material and contaminated water. The remediation reduced the petroleum hydrocarbon levels in grounds to less than 1,000 mg/Kg, in sediments of the lagoon below 500 mg/Kg and in the water of the lagoon below 0.5 mg/L. The values of aromatic polycyclic hydrocarbons in the lagoon water and sediments reached values of less than 1 mg/L. All these values are established as the permissible limits for sensible ecosystems and water for human consumption. The recovery of the ecosystem was confirmed by the presence of benthic invertebrates in the lagoon, which at the beginning of the cleaning activities were absent. Among the organisms recorded were bivalva, gastropods, nematodes, and insect larvae.

The remediation in the lagoon area was done without chemical or biological agents.

DISCUSSION

The Lagoon of Papallacta is located in the Napo province, at about 70 km to the Northeast of the city of Quito, on a glacier valley between the parallels 00°22' 30.7"-00°22' 56.2" of South latitude and between the meridians 78°09' 17.4"-78°10' 01.7" of western length, at an average altitude of 3,354m over sea level. It is part of the Ecological Reserve Cayambe-Coca and is alternating potable water source for Quito, capital of Ecuador. The lagoon mainly receives water from Sucus and Tambo rivers, whose waters are

formed by the natural currents of the mountains that surround it. The surface of the lagoon has an approximate average area of 35 ha, with a surface of around 31 ha during the dry season and a surface of 44 ha during the rainy season. On April 8th 2003, a breakage occurred in the Trans-Ecuadorian Pipe Line Oil System (SOTE) at km 197 +181 (9959600 N and E812830) at 4 km of the Lagoon of Papallacta. This zone has pronounced slopes, with herbaceous and shrub vegetation characteristic of the Andean páramo. The flow of 22,000 petroleum barrels contaminated the rivers Sucus, Cachilarca and Tambo and the Lagoon of Papallacta. Petroecuador, the state company, recovered most of the petroleum.

The contamination of the water of the lagoon went through several processes. At the beginning of the spill two phases formed, the one of water and the one of petroleum, with a small fraction of hydrocarbons dissolved in the water. Later, there was a continuous petroleum flow from the site of the spill through the rivers Sucus and Tambo, to the lagoon. At the beginning of the spill a continuous petroleum layer of approximately 0.1 cm up to 70 cm thick formed in an area of about 6.5 ha of the lagoon (Figure 1). The petroleum was then semi-oxidized by effect of the environmental conditions and then it precipitated to the bottom of the lagoon.

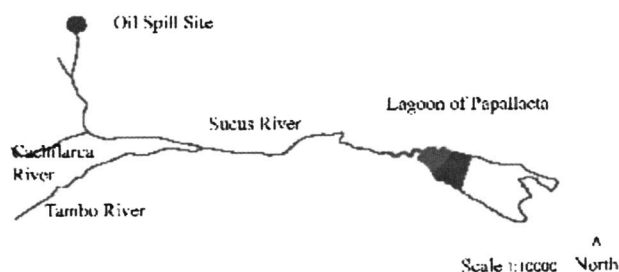


FIGURE 1. PAPALLACTA LAGOON MAP SHOWS THE AFFLUENT RIVERS AND THE AFFECTED ZONES BY THE OIL SPILL. THE SHADED ZONE WAS THE MOST AFFECTED AND THE SOLID ZONE THE LESS AFFECTED.

Ecuavital S.A. was designated by the Ecuadorian state petroleum company PETROECUADOR to clean and remediate the

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spill. Ecuavital began its activities on November 6th 2003, and concluded on May 4th 2004. It should be pointed out that there was an attempt of encapsulating the oil by other company.

The initial analyses of total hydrocarbon concentration in all the sections and the lagoon shores oscillated between 40,245 and 85,879 mg/Kg, 4,500 mg/Kg in sediments of the bottom of lagoon and 89 mg/L in the water.

METHODOLOGY

Soil

The following zones were decontaminated:

1. The surrounding zone close to the pipe line rupture (km 197 + 181)
2. The channels, shores and beds of the rivers Sucus, Tambo and Cachilarca that end at the Lagoon of Papallacta,
3. The three shores of the Lagoon of Papallacta and the contaminated sediments of the lagoon bed.

The contaminated material was extracted manually and mechanically, gathered together, stabilized, isolated and transported away from the lagoon to the units of biological treatment in a non-sensible zone. The transport units were covered with geomembrane S-500 to avoid spillage during the transport.

Vegetation

The vegetation impregnated with more than 60% with petroleum was extracted and incinerated in a zone located about 60 km of Papallacta. The process was certified by the company in charge and inspected by PETROECUADOR to satisfy the established norms. The vegetation impregnated with less than 60% was pulverized and introduced in the biological treatment units for bacterial degradation. In the platforms of landfarming endemic bacteria, nutrients and vegetal polymers were added.

Shores and Beds of Rivers

The contaminated rocky material from the Sucus, Cachilarca and Tambo rivers that could not be removed were cleaned with hot water (140°C) with pressure pumps (200 psi). The beds of the rivers were cleaned with pressure water pumps (150 psi) to desorb the hydrocarbons to the surface where they were recovered. In cases of acute petroleum impregnated stony material, it was washed with terpene compounds in a closed system (Protected Industrial Process).

Treatment of the Water of Rivers

For the decontamination of waters of the rivers Sucus, Cachilarca and Tambo, two simultaneous processes were used: 1) Containment (recovery) and 2) Filtration. Static barriers with nuclei of natural oleophilic material were installed approximately each 200 m and behind these, plastic barriers of 45 cm high. This methodology allowed to increasing the dwell time of the polluting agent in the oleophilic nucleus to trap and to recover the petroleum, which avoided that the mechanically removed petroleum could elute in the river and then continue towards the lagoon. In addition, another filtration barrier system with oleophilic units of vegetal material (cellulose) was installed to trap the hydrocarbons that could escape the barriers.

In order to guarantee the cleaning process, immediately after the barriers modules of filtration by adsorption were in place, with capacity to trap in their surface minimal amounts (100ppm) of hydrocarbons (litmus film on the water), assuring a good quality treatment of the water of the rivers Sucus, Cachilarca and Tambo.

Water Treatment of the Lagoon

Units of superficial adsorption by contact were designed to trap the hydrocarbons on the surface of the water. In addition filters type "T" were used, which have porous material to start off the removal of hydrocarbons. These filters were connected to two screw skimmers (Thermite) and to two skimmers Mínimax with two pumps of diaphragm with a flow of 30m³/hour. Additionally, filters type I, similar to filters "T" were used. These were placed longitudinally in the shore of the lagoon. These two filters were connected to Skimmers Minimax with diaphragm pumps, with a volume of 32m³/hour.

Analyses of Samples

The samples were collected and analyzed by an independent laboratory designated by PETROECUADOR. Total petroleum hydrocarbon analyses (TPH) in soil were done using the methodology EPA 8440, and analyses for water were done using the methodology EPA 418.1. The polycyclic aromatic hydrocarbons (PAH's) were analyzed with the methodology EPA 550.1 for water and by HPLC fluorescence for soils.

Biological Monitoring

From the beginning of the cleaning activities, monthly samplings of sediment of the lagoon were taken to monitor the recovery of benthic fauna.

RESULTS

Total petroleum hydrocarbon analyses (TPH) of the water of the rivers and of adjacent soil showed a decrease as the cleaning and remediation advanced. After the removal of sediments and the de-adsorption of hydrocarbons, the measurements of total petroleum hydrocarbons (TPH) in the water of rivers were reduced from 934 and 1,532 mg/L (30 of November and 4 December) down to 0.01 and 0.02 mg/L in two sampling sites (Figure 2). A third site of sampling, it registered values under 10.4 mg/L. The amount of hydrocarbons (TPH) in the soil was reduced from 34,321 to 89 mg/Kg (Figure 3). These results indicate a reduction under the permissible limits after six months of initiated the cleaning with samples taken in several sites (Figure 4). The allowed values complied with the Environmental Regulation for Hydrocarbon Operations in Ecuador (RAOHE) and to the Unified Text of Secondary Environmental Legislation (TULAS).

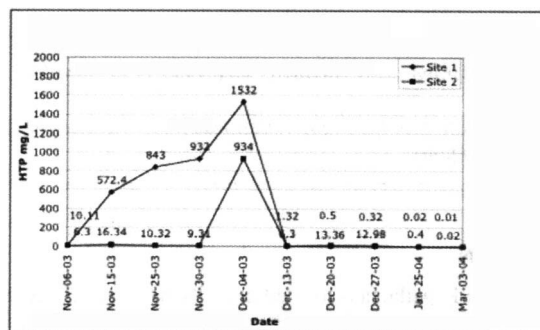


FIGURE 2. Total Petroleum Hydrocarbons (TPH) in water from two sampling sites from affluent rivers of the Papallacta lagoon. There is an increase of the values (Nov., Dec.) due to the processes of removal of precipitated hydrocarbon. The amount of hydrocarbons after the cleaning complied with the norm. The values of the first row correspond to sampling Site 1.

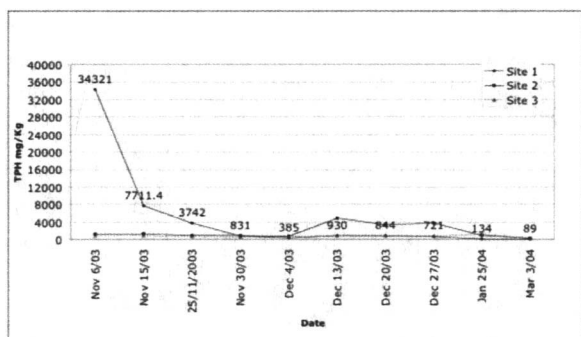


FIGURE 3. Total Petroleum Hydrocarbons (TPH) in adjacent soil of affluent rivers of the Papallacta lagoon from three sampling sites. The values of sites 2 and 3 are very low and at the end all of them complied with the norm.

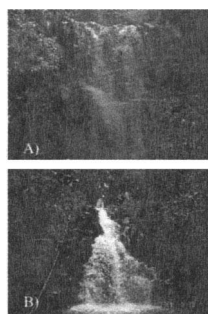


FIGURE 4. Contaminated cascade of Sucus river (A) and after remediation (B).

The values of TPH registered initially in the water of the Lagoon of Papallacta (6,451 mg/L) and in the sediment (6,445 mg/Kg) were reduced at the beginning of the cleaning, nevertheless exists an increase that is greater in sediments, which is due to removal of oil in the sediment when doing its de-adsorption (Figure 5). When concluding the cleaning, the values of the TPH were lower than the established values by the norms, <1000 mg/Kg in soil and <0.5 mg/L in water (Figure 6).

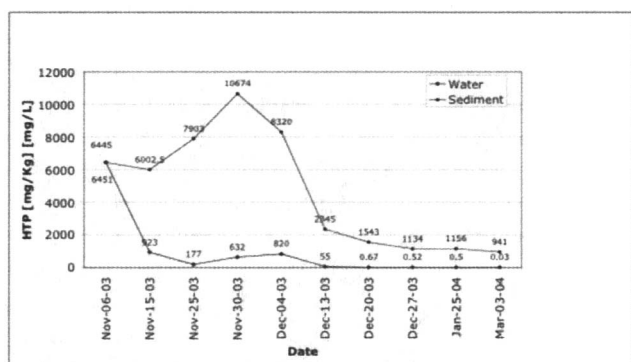


FIGURE 5. Total Petroleum Hydrocarbons (TPH) in water and sediment of Papallacta lagoon. There is an increase of the values (Nov., Dec.) due to removal of precipitated hydrocarbon. The amount of hydrocarbons complied with the norm at the end of the remediation.



FIGURE 6. Contaminated Papallacta lagoon (A) and after the remediation (B).

When cleaning was finished, the amount of the PAHs registered in the water was of <0,1 microgram/Liter (mg/L) and <0,5 mg/Kg for sediments. These amounts are under the established norm which are 0,3 mg/L for the water and 0,1 milligram/Kilogram (mg/Kg) for soil (RAOHE and TULAS).

The amount of hydrocarbons in the biological treatment platforms at the beginning was of up to 17,778 mg/Kg in soil and contaminated sediments that originated at the rivers and the lagoon. After six months of application of the bioremediation processes, hydrocarbon maximum values of 890 mg/Kg were obtained, fulfilling the established norm that is of 2,500 mg/Kg.

The biological monitoring done in the lagoon showed a recovery of the communities of invertebrates that at the beginning of the cleaning were absent. Among the organisms registered after the fourth month of cleaning were nematode worms (Nematoda), snails (Gasteropoda), shells bivalve (Bivalva) and larvae of flies (Diptera).

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BIOGRAPHY

Iván Aveiga del Pino was born in Latacunga in 1966. I. Aveiga is Molecular Biologist, he has worked as investigator and professor at the Pontifical Catholic University of Ecuador and in the University San Francisco of Quito, Ecuador. At the moment Mr. Aveiga is member of two companies, Ecuavital and Biox, dedicated to the investigation, cleaning and remediation of contaminated water and soil with hydrocarbons. Mr. Aveiga has 8 years of experience in field and laboratory work and he holds the intellectual property under the figure of non-disclosed information of processes and products related to his work.

