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Short communication

First evidences of Amazonian wildlife feeding on petroleum-contaminated soils: A new exposure route to petrogenic compounds?

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ABSTRACT

Videos recorded with infrared camera traps placed in petroleum contaminated areas of the Peruvian Amazon have shown that four wildlife species, the most important for indigenous peoples' diet (lowland tapir, paca, red-brocket deer and collared peccary), consume oil-contaminated soils and water. Further research is needed to clarify whether Amazonian wildlife's geophagy can be a route of exposure to petrogenic contamination for populations living in the vicinity of oil extraction areas and relying on subsistence hunting.

1. Main Text

The oil extraction industry can be very hazardous for the environment (Epstein and Selber, 2002). The main by-product of oil extraction industry is produced water. Worldwide, every day 300 million barrels (i.e. 48 million m^3) of produced water are brought to the surface during oil and gas extraction operations (Long et al., 2013). Produced water can contain a number of potentially toxic agents, including radioactive isotopes, dispersed hydrocarbons (i.e. phenolic and polyaromatic molecules among others), and heavy metals (i.e. cadmium, chromium, lead and barium among others) (Fakhru'l-Razi et al., 2009). The safe disposal of produced water is starting to create concern among environmental health researchers (Konkel, 2016). The use of sub-standard technologies for their disposal in low and middle income countries -LMICs- may add a further twist to this concern for public health (Jernelöv, 2010).

Oil and gas reserves overlap with 30% of the world's rainforests; and the Amazon is the tropical rainforest with the highest percentage (39.4%) of such overlap (own calculations based on Butt et al., 2013). Hydrocarbon extraction activities in the Amazon region started in the 1930's (Orta Martínez et al., 2007) and, in 2008, they spread over 688,000 km^2 of the western Amazon, in Bolivia, Brazil, Colombia, Ecuador and Peru (Finer et al., 2008). Despite the intense decades-long oil extraction activity in tropical rainforests and the toxicological effects of some oil-related pollutants, there is a dearth of scientific data on the potential impacts that oil extraction may have on this environment and on the health of people living in the vicinities of oil extraction sites (O'Callaghan-Gordo et al., 2016).

In the Northern Peruvian Amazon, oil concessions 1AB/192[1] and 8[2] were leased in the late 1960s. These concessions are the most productive ones in Peru, with 39% of total national accumulated oil production (Orta Martínez et al., 2007). The area within these oil concessions is inhabited by more than 45,000 Achuar, Quechua, Kichwa, Kukama-Kukamilla and Urarina indigenous people. Between 1987 and 2013, several official documents issued by different Peruvian state agencies reported that concentrations of hydrocarbons, hexavalent chromium, lead, mercury, barium and chlorides in soils, river waters and sediments from these areas were above the Peruvian maximum permissible limits

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[1] First held by Occidental Petroleum Corporation -Oxy-, then transferred to Pluspetrol Corporation S.A. in 2001, and to Pacific Stratus Energy/Frontera Energy Corporation in 2015.
[2] Initially operated by PetroPeru, then transferred to Pluspetrol Corporation S.A. in 1996.

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and that concentrations of cadmium and lead in fish were above acceptable limits for human consumption (Orta Martínez et al., 2007). In 2005, the Ministry of Health, found that 98.6% and 66.2% of Achuar children of 2–17 years of age exceeded the acceptable limits for cadmium and lead in blood, as well as 99.2% and 79.2% of adults (Orta Martínez et al., 2007). In 2013 and in 2014, the Peruvian government declared the environmental and health emergency, respectively, in the area (Ministerial Resolutions No 064–2013, 094–2013, 263–2013 and 370–2013, from the Ministry of the Environment and, Supreme Decree No 006–2014 from the Ministry of Health).

Despite the evidence that the population living in the area is exposed to high levels of contamination, no studies have been conducted to identify the exposure routes to these contaminants. Consumption of wild animals from the area has been suggested as a potential source of exposure by the local indigenous populations, which have repeatedly reported that many wildlife species ingest soil and water in places affected by the dumping of produced waters and oil. Intentional geophagy (i.e. deliberate ingestion of soil) in nutrient-poor ecosystems such as the Amazon, is a widespread behavior frequently observed in herbivores and omnivorous wildlife (Dudley et al., 2012). Geophagy is an important route for contaminant exposure in industrial areas, posing a risk to animal's health (Beyer and Fries, 2002). Thus, the soil-animal pathway to humans is important in many risk assessments (Beyer and Fries, 2002). The aim of the current study was to investigate whether wildlife species, through geophagy, are ingesting petroleum pollutants at the 1AB/192 oil block with camera trapping field observations.

2. Intentional ingestion of petroleum-contaminated soils

We selected two study sites within the 1AB/192 oil block (Department of Loreto, Province of Loreto) where, according to the local population, game species gathered to ingest soil. These sites were considered locally as hunting hotspots. Infrared camera traps (Bushnell 8MP Trophy Cam HD) were placed in both sites in May 2013. In site 1 (18 M 336588 9701714), a camera trap was placed overlooking a swamp located just below the overflow pipe of an uncovered sump tank. Sump tanks are designed to contain oil and produced water overflowing from a well due to unexpected increases in pressure. However, in the study area oil and produced water are rarely recovered from these tanks, and uncovered tanks often overflow with the regular heavy tropical rainfalls (Orta Martínez et al., 2007). In site 2 (18 M 350590 9679070), a camera trap was located next to an abandoned oil well. This well was drilled in 1970 and sealed in 1982. However, when the study was conducted, an unidentified fluid leaked from the well.

Soil from both sites were analyzed to assess the presence of petrogenic pollutants, using petroleum biomarkers (i.e. steranes and hopanes) as proxy indicators (Rosell-Melé et al., 2010). We took three soil samples in each site between 0 and 20 cm depth and a 10 × 10 cm section (after removing overlaying leaf litter) separated by several meters. We homogenized and pooled the three soil samples before the analysis. Approximately five grams of dry soil were extracted with 10 mL of trace analysis grade n-hexane–acetone (1:1, v/v) (Merck, Darmstadt, Germany) in the ultrasonic bath for 15 min. The extraction process was repeated three times. The identification of biomarkers was

Table 1
Compound identities and *m/z* of the ion used to identify the hopanes and steranes in the soil sample, displayed in Fig. 1.

Abbreviation	Name	*m/z*
27Ts (Ts)	18α(H)-22,29,30-trisnorhopane	191
27Tm	17α(H)-22,29,30-trisnorhopane	191
29ab	17α(H),21β(H)-30-norhopane	191
29ba	17β(H),21α(H)-30-normoretane (normoretane)	191
30ab	17α(H),21β(H)-30-hopane	191
31abS	22S-17α(H),21β(H)-30-homohopane	191
31abR	22R-17α(H),21β(H) = 30-homohopane	191
32abS	22S-17α(H),21β(H) = 30-bishomohopane	191
32abR	22R-17α(H),21β(H) = 30-bishomohopane	191
33abS	22S-17α(H),21β(H)-30-trishomohopane	191
33abR	22R-17α(H),21β(H)-30-trishomohopane	191
34abS	22S-17α(H),21β(H)-30-tetrakishomohopane	191
34abR	22R-17α(H),21β(H)-30-tetrakishomohopane	191
27dbS	13β(H),17α(H),20S-cholestane (diasterane)	217
27dbR	13β(H),17α(H),20R-cholestane (diasterane)	217
DIA27S	13α(H),17β(H)-20S-cholestane (diasterane)	217
27aaS	5 α(H),14 α(H),17α(H)-20S-cholestane	217
27bbR	5α(H),14β(H),17β(H),20R-cholestane	217
27bbS	5α(H),14β(H),17β(H),20S-cholestane	218
27aaR	5α(H),14α(H),17α(H),20R-cholestane	218
28bbR	24-Methyl-5α(H),14β(H),17β(H),20R-cholestane	218
28bbS	24-Methyl-5α(H),14β(H),17β(H),20S-cholestane	218
29aaS	24-Ethyl-5α(H),14α(H),17α(H),20S-cholestane	217
29bbR	24-Ethyl-5α(H),14β(H),17β(H),20R-cholestane	218
29bbS	24-Ethyl-5α(H),14β(H),17β(H),20S-cholestane	218
29aaR	24-Ethyl-5α(H),14α(H),17α(H),20R-cholestane	217

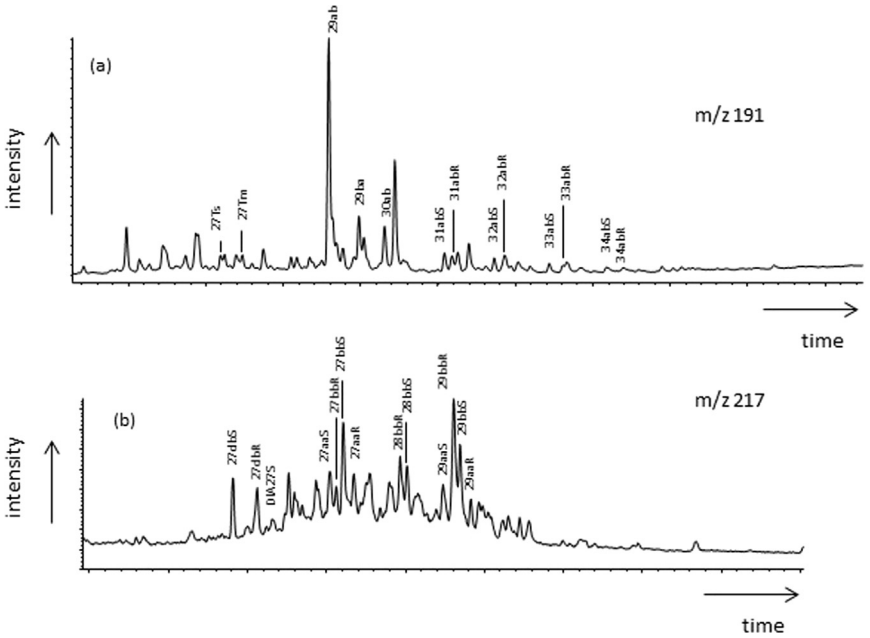

Fig. 1. Mass fragmentograms obtained by gas chromatography-mass spectrometry to investigate the presence of hopanes (a) and steranes (b) in the soil organic extract. Peak identities are provided in Table 1.

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