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Water contamination from oil extraction activities in Northern Peruvian Amazonian rivers☆

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ABSTRACT

Oil extraction activities in the Northern Peruvian Amazon have generated a long-standing socio-environmental conflict between oil companies, governmental authorities and indigenous communities, partly derived from the discharge of produced waters containing high amounts of heavy metals and hydrocarbons. To assess the impact of produced waters discharges we conducted a meta-analysis of 2951 river water and 652 produced water chemical analyses from governmental institutions and oil companies reports, collected in four Amazonian river basins (Marañon, Tigre, Corrientes and Pastaza) and their tributaries. Produced water discharges had much higher concentrations of chloride, barium, cadmium and lead than are typically found in fresh waters, resulting in the widespread contamination of the natural water courses. A significant number of water samples had levels of cadmium, barium, hexavalent chromium and lead that did not meet Peruvian and international water standards. Our study shows that spillage of produced water in Peruvian Amazon rivers placed at risk indigenous population and wildlife during several decades. Furthermore, the impact of such activities in the headwaters of the Amazon extended well beyond the boundaries of oil concessions and national borders, which should be taken into consideration when evaluating large scale anthropogenic impacts in the Amazon.

1. Introduction

Oil demand is increasing globally (British Petroleum, 2016), and its extraction places under pressure ecologically sensitive environments (Finer et al., 2008; Torrice, 2009), like the Peruvian Amazon (Finer and Orta-Martínez, 2010). Peru holds the fifth highest biodiversity index (Groombridge and Jenkins, 2002), and has vast extensions of pristine tropical rainforests that are the ancestral homeland of approximately 60 indigenous ethnic groups, including 14 to 15 living in voluntary isolation (Defensoría del Pueblo, 2006). In the Peruvian Amazon, oil has been extracted since 1932 (Finer and Orta-Martínez, 2010), and between 2003 and 2010 the area under petroleum exploration expanded from 7.1% to 41.2% of the territory (Finer and Orta-Martínez, 2010). In this region, oil blocks 1AB (now 192) and 8, both leased at the beginning of the 1970s, became the most productive oil concessions in Peru, and at their peak yielded 67% of Peru's total oil production (Orta-Martínez and Finer, 2010a). Oil exploration and extraction activities in these two oil blocks have generated a long-standing socio-environmental conflict between oil companies, governmental institutions and local indigenous communities (Orta-Martínez and Finer, 2010a). Evidence of severe pollution led eventually the Peruvian authorities to declare an Environmental and Health Emergency for the whole area (Ministerio del Ambiente, 2014, 2013a, 2013b, 2013c).

Worldwide, the spillage of oil by accident (Jernelöv, 2010; Reddy et al., 2002) or the dumping of formation or produced water (PW), the main waste product of oil extraction operations (Bakke et al., 2013), has been reported to pollute local waters. PW can amount to 70% by volume of an average well production (Fakhru'l-Razi et al., 2009), and it increases with the age of the wells to as much

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as 98% of all the fluids extracted (Weideman, 1996). PW is a complex mixture of dissolved and particulate inorganic and organic matter. It can be highly enriched in chloride ($5–20.1 \cdot 10^4$ mg/L), and includes dispersed oil, dissolved hydrocarbons, organic acids, phenols, and metals like cadmium ($5 \cdot 10^{-7}$ - 0.49 mg/L), chromium ($<1 \cdot 10^{-6}$- 0.39 mg/L), lead ($<1 \cdot 10^{-6}$- 18 mg/L) or barium ($<1 \cdot 10^{-3}$- 2.0 mg/L) (Neff, 2002), some of them reported to be carcinogenic or neurotoxic (Barceloux, 1999; Sanders et al., 2010; Satarug et al., 2003; Staudinger and Roth, 1998; World Health Organization, 2013, 2012a, 2012b, 2006a, 2006b). Solubility of the various chemicals in PW is enhanced by the elevated temperature of the fluid at 50 to 94 °C (Tibbets et al., 1992). The management of PW presents many challenges and can pose significant operational costs. In offshore wells, dumping of PW in open seas is allowed when the levels of chemicals in the discharged waters are below certain concentrations (Environmental Protection Agency, 2004a; Ospar Commision, 2001). In onshore areas, the first option is the reinjection of PW back into the oil wells (Environmental Protection Agency, 2004b). If PW is to be dumped on land or freshwater streams, a previous treatment is required to reduce pollution levels below legal standards (Fakhru'l-Razi et al., 2009).

However, PW reinjection in the North Peruvian Amazon was only implemented from 2009 onwards (Comisión de Pueblos Andinos Amazónicos y Afroperuanos Ambiente y Ecología, 2012). Although there have been nascent attempts to study the social and conservation impacts of oil exploration in the Western Amazon (Ecuadorian National Court of Justice, 2013; Kimerling, 2013; O'Callaghan-Gordo et al., 2016; Orta-Martínez and Finer, 2010b; Orta Martínez et al., 2007), to our knowledge there are few reports in the scientific literature that investigate the quantitative occurrence of widespread pollution in the Amazon, or any other tropical rainforest, associated to oil extraction activities. This could be significant, as in block 8 the average number of barrels of PW released into the environment per day in 2008 was 363,000, and in block 1AB/192 was 576,000 (Organismo Supervisor de la Inversión en Energía y Minería, 2009). Such a release of PW has been argued to be a significant source of the dissolved Na and Cl flux of the Amazon River (Moquet et al., 2014).

To gain insights on the regional impacts of the spillage of PW in watercourses, we conducted a meta-analysis of water analyses reports generated by Peruvian governmental institutions and oil companies between 1987 and 2013. The approach adopted allowed us to circumvent some of the significant challenges that poses the remoteness of the region in order to conduct a large scale independent scientific pollution survey.

2. Methodology

2.1. Study area

The study area included two adjacent oil concession blocks: 1AB/192 and 8 (Fig. 1). These oil blocks have been operated by different oil companies over the last 45 years: Occidental Petroleum Corporation, Pluspetrol Norte and Pacific Stratus Energy, in the case

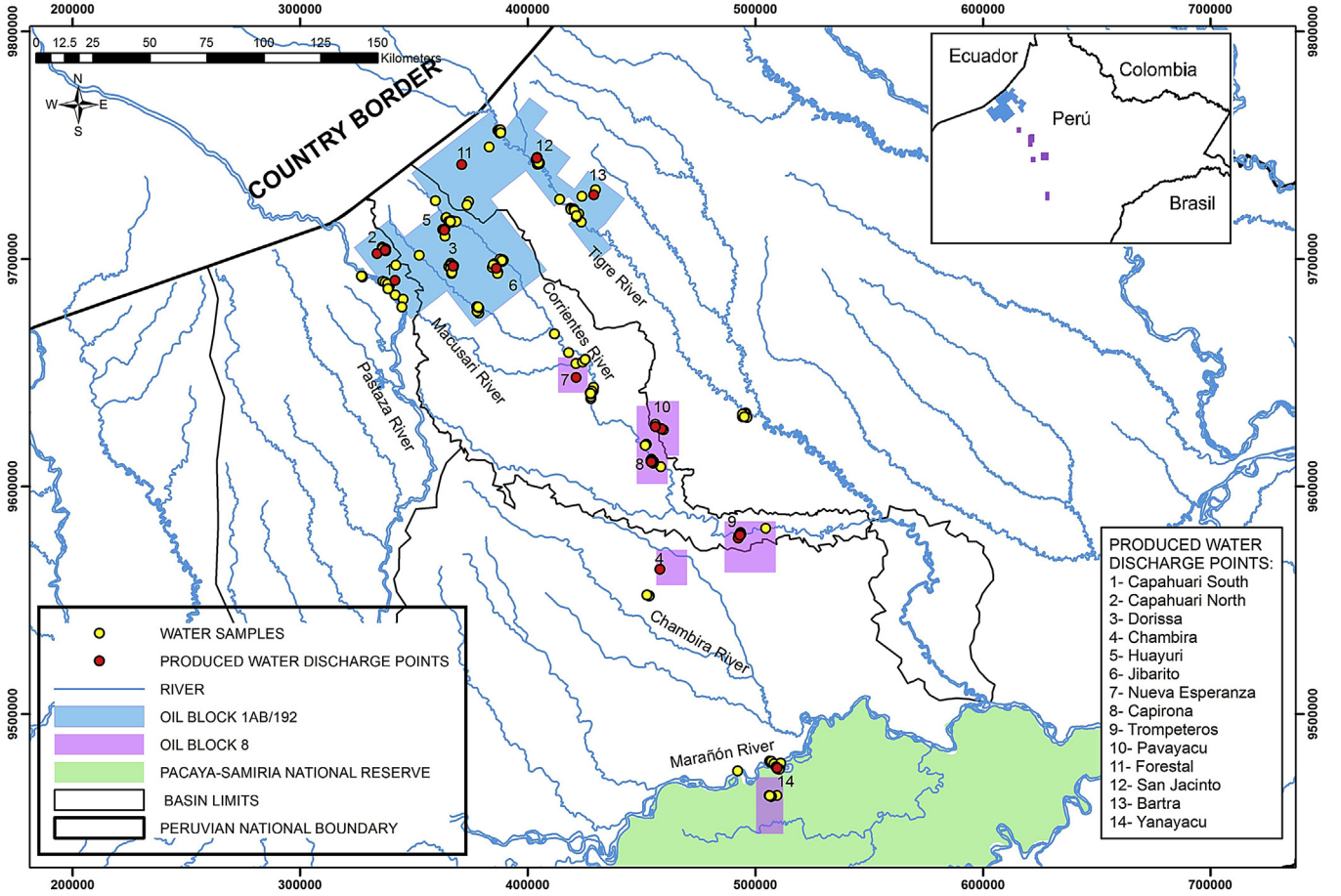

Fig. 1. Map of the study area depicting the main river courses, overall location of sampling points, and oil concession blocks 1AB/192 and 8 as configured in 2009, when produced water spills generally stopped. Oil concession block 1AB/192 partially overlaps the Corrientes, Pastaza and Tigre basins, while block 8 does so with the Corrientes and Marañon basins.