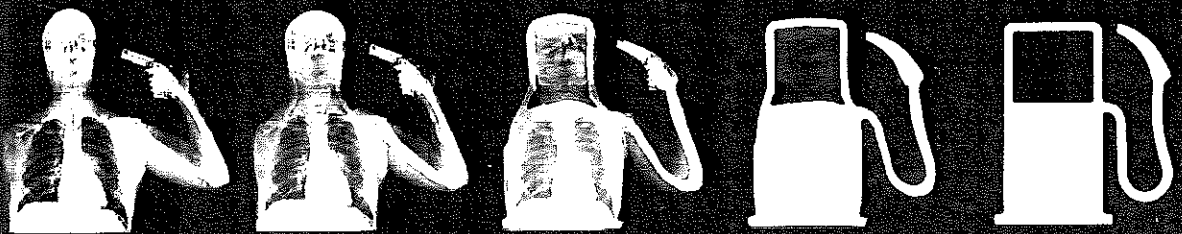


SUBTERRANEAN



ESTATES LIFE WORLDS OF OIL AND GAS

EDITED BY HANNAH APPEL, ARTHUR MASON & MICHAEL WATTS

Chapter 7

Crude Contamination

Law, Science, and Indeterminacy in Ecuador and Beyond

Suzana Sawyer, University of California, Davis

Between 2004 and 2007, dozens of judicial inspections of alleged contaminated sites unfolded in the Ecuadorian Amazon as part of a lawsuit filed in 2003 on behalf of thirty thousand local inhabitants against the Chevron Corporation for environmental contamination.¹ Presented in the Superior Court of Nueva Loja² (or Lago Agrio as the town is commonly known)—a bustling Amazonian oil frontier town—the lawsuit alleged that, between 1964 and 1990, Texaco (which merged with Chevron in 2001) spewed industrial wastes in its oil concession, contaminating the environment during

This chapter would not have been possible without the generosity of Steven Donziger and Doug Beltman. Steven Donziger, the plaintiffs' long-term legal adviser in the United States, graciously facilitated my access to the case file. Doug Beltman, an environmental scientist with Stratus Consultants, graciously shared his time and knowledge in answering my questions about the science of crude oil. I also would like to thank Kate Scow (professor, Department of Land, Air and Water Resources) and Peter G. Green (associate research engineer, Department of Civil and Environmental Engineering) at the University of California, Davis, for their scientific guidance. Douglas M. Mackay (adjunct professor, Department of Land, Air and Water Resources) would also surely have spoken with me had not Chevron lawyers instructed him not to do so. Similarly, I am grateful for my conversations with Sara McMillen (Chevron's chief scientist for the lawsuit). I also thank Sara Wylie for her critical read and Hannah Appel, Arthur Mason, and Michael Watts for their insightful comments.

1. Initially, both sides agreed to complete judicial inspections at 122 alleged contaminated sites. Given the length of time needed to complete an inspection and analyze the data emerging from it, and given that the results garnered from the inspections were by and large corroborative, the plaintiffs proposed, and the court agreed, that the number of inspections required of alleged contaminated sites be reduced to fifty-four.

2. In 2009 the court's name was changed to the Provincial Court of Justice of Sucumbios in Nueva Loja.

its thirty-odd years of operating in the northern Ecuadorian Amazon. Industrial wastes, plaintiffs claimed, devastated the local ecology and endangered the health of local inhabitants.

The judicial inspections comprised the legal teams from both sides accompanying the judge (variously followed by the press, interested observers, and local inhabitants) as he tramped through the secondary rainforest surrounding former Texaco oil wells, processing stations, and exposed or purportedly remediated waste pits. At each site the plaintiffs' and the defendant's team of technical experts extracted soil and water samples, examined them visually, and sent them off to laboratories to be analyzed for their chemical content. Two written reports—one from the plaintiffs and one from the defendant—with multiple appendices resulted from each site inspection. Ranging in the hundreds of pages, the reports each map an inspection site, the coordinates of each extracted sample's location, and its position relative to waterways, human habitation, and other Texaco infrastructure (wells, pipelines, pumping and processing stations), and they methodically detail the geomorphic and chemical composition of the samples taken.

In line with legal procedure in Ecuador's civil law tradition—an inquisitorial system of law—the judicial inspections constituted the “evidentiary phase” of the trial and, as such, they represented the crucial events for garnering or dispelling proof of contamination. The scientific reports emerging from them formed an integral part of the evidence on which the Superior Court judge ruled in February 2011. Among the issues at the heart of the legal proceedings was each party's capacity to materialize or dematerialize the presence of toxic elements, derivative of Texaco's operations, in the region's soil and water systems forty-odd years after crude production began. Although the presence of crude and its by-products in the environment was not in question, the *toxicity* of these substances was, and still is.

Virtually all the technical reports submitted to the Superior Court of Nueva Loja on the *plaintiffs'* behalf assert that “soils, dispersed at various points [at the site], are severely contaminated with the presence of petroleum residues and toxic heavy metals. . . . [and this] represents a real present and future risk to the [local] population” (FDA Informe Sacha-57 2005). By contrast, those that the *defendant* submitted reach opposite conclusions. Chevron's scientific analyses assert that alleged contaminated sites pose “no oil-related risk to public health or the environment” and that collected samples of water and soil “contained no hydrocarbons—BTEX, PAH, and metal concentrations—that pose risks to human health” (CVX Informe Sacha-57 2005, v).

With Chevron admitting that Texaco's operations dumped over sixteen billion gallons of formation waters (the high-salinity subterranean

liquids that surface along with crude during all oil production) directly into the environment, burned roughly 230 million cubic feet of natural gas, and dumped heavy oil from exploratory and producing wells into open waste pits, some might suggest that Chevron representatives must have distorted, manipulated, or concocted evidence for the corporation to receive such clean reports.³ Much is at stake. This lawsuit could, after all, lead to the largest cash outlay that a multinational corporation has made for environmental cleanup outside U.S. borders. On February 14, 2011—after more than seven years of litigation in Ecuador layered on top of a prior decade of pretrial hearings in the U.S. federal court system—Superior Court Judge Nicolas Zambrano Lozada found Chevron liable and fined the company \$8.646 billion in damages.⁴

3. This is information from Texaco's drilling logs as compiled by DINAPA, the Dirección Nacional de Protección Ambiental (Cabrera's Report 2008, appendix F, page 15, and appendix U3). TEXACO extracted 1,312,940,910 barrels of oil, dumped 379,246,100 barrels of wastewater into the environment, and burned 230,464,948 cubic feet of gas.

4. On January 3, 2012, the Sucumbios Court of Appeals upheld Zambrano's ruling. In November 2013, Ecuador's National Court of Justice—the country's highest court—upheld the appellate court's decision. On March 4, 2014, Judge Lewis Kaplan of the U.S. District Court for the Southern District of New York rendered a ruling in a counterlawsuit filed by Chevron in 2011 seeking to delegitimize the Ecuadorian judgment. Judge Kaplan's decision issued an injunction against attempts to enforce the Ecuadorian judgment in the United States because, in his judgment, the ruling in Ecuador was the product of bribery, fraud, and extortion. The defendants in Chevron's countersuit have (for the second time now) appealed Kaplan's ruling in the 2nd Circuit Court of Appeals. (In 2011, the appellate court struck down Kaplan's interim ruling on this case.)

A labyrinth of webs entangles Zambrano's 2011 judgment in Ecuador and Kaplan's 2014 judgment in the United States, rendering a postcolonial landscape in which the partiality of evidence, attribution, and translations (*writ large*) is lost and instantiated as truths within the hubris of U.S. law. Unpacking this requires a chapter of its own. Clearly improprieties transpired during the seven-year trial in Ecuador—improprieties by *both* sides, however. The first significant concern Judge Kaplan underscores in his 485-page 2014 opinion—that the plaintiffs' technical team ghostwrote the extensive report of a court-appointed and purportedly independent expert—did not figure in the 2011 Ecuadorian ruling; Judge Nicolas Zambrano explicitly chose not to consider the expert report in his judgment because of the emerging controversy over the report's providence. The second significant concern Judge Kaplan underscores—that Judge Zambrano did not in fact write the ruling and that it was authored instead in part (or whole) by the plaintiffs' legal team and a hired ex-judge—is based on compromised and circumstantial evidence.

The over \$32 million that Chevron spent (11 Civ. 00691 [LAK-JCF], Document 1855, page 40) to fuel the company's aggressive legal tactics and mount its 2011 counterlawsuit in the United States raises probing questions about law and U.S. litigation. In hiring armies of lawyers and filing seventeen legal claims in jurisdictions across the country scouring for evidence of potential wrongdoing by anyone connected to the plaintiffs and their lawyers, Chevron created a "truth"—one that Judge Kaplan similarly espouses. The effect of Kaplan's ruling is to turn the second largest oil corporation in the United States into a "victim" (11 Civ. 0691 [LAK], Document 1874, pp. 3, 309, 343, 352, 258, 364, 378, 380) and simultaneously to leave the compromised nature of Chevron's "truth"—especially once adopted by a district court judge—seemingly conclusive and incontestable. The making of that corporate-legal truth is ripe for examining.

In most cases, however, the test results and concentration levels detailed and submitted to the Ecuadorian court on behalf of Chevron are not radically dissimilar from the results obtained from the soil- and water-sample analyses that the *plaintiffs'* experts submitted to the court in their reports. This is not to dismiss differences; they do exist.⁵ But despite these differences, the laboratory results for samples taken from or near former waste pits by both the defendant and plaintiff broadly corroborate and coincide with one another. Indeed, one of the plaintiffs' key pieces of evidence that Chevron contaminated the environment is the fact that levels of total petroleum hydrocarbon (TPH)—as measured by both the plaintiffs *and* the defendant—exceed Ecuadorian standards (by tens to hundreds of times) in 97% of the sites examined during the judicial inspection. Clearly—so the lawyers for the plaintiffs argued—this is the present toxic materialization of past negligent practices. So how do diametrically opposed interpretations of contamination emerge?

In this chapter, I explore one dimension of the imbricated technical, chemical, and legal work that allowed toxins to matter, or not, in the lawsuit against Chevron. In particular, I read the scientific reports produced by the plaintiffs' and defendant's technical experts analyzing alleged contaminated sites *against* transformations in industry science and regulation in the United States. Doing so helps unravel the sociomaterial formation of toxicity, and how that specifically has played itself out in the lawsuit

Notably, as Judge Kaplan states, his "analysis, it should be understood, does not reflect any review by this Court of the substantive merits of the [Ecuadorian] Judgment" (11 Civ. 0691 [LAK], Document 1874, page 211). He writes: "The Court assumes there is pollution in the Orienté [*sic*]. . . . The issue here is not what happened in the Orienté [*sic*] more than twenty years ago. . . . It instead is whether a court decision was procured by corrupt means" (11 Civ. 0691 [LAK], Document 1874, page 4). Consequently, Kaplan's ruling does not speak to the substance of the Ecuadorian lawsuit, and thus does not address the concerns around contamination and toxicity that are at the core of the Ecuadorian litigation. This leaves indeterminate future interpretation and application of the Ecuadorian ruling, given that both the Ecuadorian court of appeals and equivalent-to-supreme court have upheld and extended its legal soundness. Similarly, Judge Kaplan's ruling does not block enforcement of the Ecuador judgment elsewhere in the world; his opinion, however, presents a formidable obstacle if upheld on appeal. As of July 2014, the defendants' appeal had submitted significant evidence seeking to vacate Kaplan's ruling. It is anticipated that the 2nd Circuit Court of Appeal will render a decision by 2016.

For analyses of the lawsuit during its first decade of pretrial hearings in the New York federal court during the 1990s, see Sawyer (2001, 2002); and for analyses of the 2003 opening hearings of the trial in Ecuador, see Sawyer (2006, 2007).

5. The sampling strategies and laboratory techniques used to derive results differed significantly between the parties. First, Chevron took five times as many samples as the plaintiffs and these samples were taken from obviously problematic areas (e.g., waste pits and their effluents) and obviously unproblematic areas (e.g. higher elevations away from oil operations), whereas the plaintiffs took samples only from locations they deemed problematic (e.g., waste pits, effluents, contaminated platforms, oil spills). Second, the parties each used a scientific assay that registered the existence of hydrocarbons differently.

against Chevron. As such, this chapter is not an ethnography of the judicial inspections in Ecuador. Rather, it interrogates the ways in which matters of concern were made (often prematurely and under the influence of interests) into matters of fact (cf. Latour 2005). First, this chapter is an archaeology of the North-South-traversing knowledge-producing practices that informed the reports that came out of the judicial inspections and were distinctively able to render crude oil as toxic or not. Second, it explores the legal logic that delivered a consequential judicial pronouncement notwithstanding the controversy that experts on hydrocarbons generated around toxicity. Strikingly, U.S. capital-informed regulatory science was not universally recognized and did not seamlessly translate into the Ecuadorian realm.

Contrary to common assumptions, toxicity is far from natural. Rather, the mattering of toxins—whether from seepage, spills, or combustion—is suspended in chains of association enrolling industry and atoms, legal contracts and chemical bonds, corporate profit and failing bodies, and scientific knowledge and regulatory standards. Part of a larger project on the lawsuit, this chapter explores one facet of how toxins came to matter through the interrelations among regulatory, scientific, and molecular processes. I argue that crucial to understanding determinations of toxicity is understanding how the complex connections among the production of scientific knowledge, the spatial/temporal complexity of hydrocarbon compounds, and the structure of legal reasoning allow for multiple determinations of crude oil that index distinct toxic and nontoxic realities.

The work on “historical ontology” (Hacking 2002) by a number of historians and anthropologists of science is particularly informative to my analysis. Historical ontology is an analytical framework that claims, as Michelle Murphy writes, that “what counts as ‘truth’ is the result of historically specific practices of truth-telling—laboratory techniques, instruments, methods of observing, etc.—and the objects that are apprehended through that truth-telling are also historical” (2006, 7–8). If, as key scholars suggest, reality is the product of historically situated and precisioned instruments, techniques, protocols, nonhuman capacities, and human subject positions (Latour and Woolgar 1986; Law 2004; Mol 2002; Murphy 2006; Shapin and Shaffer 1985), how is this consequential to understanding the ways in which crude oil is deemed toxic or not—both scientifically and legally?

Within the context of the litigation, the manner in which each party distinctively dissected or collapsed the chemical elements of petroleum differentially determined whether crude oil could be said to be toxic or not. The plaintiffs espoused a conviction that toxicity was absolute and incontrovertible, and that scientific analyses repeatedly registered levels of total hydrocarbons in excess of Ecuadorian standards established in 2001. By contrast, the defense sustained the conviction that crude toxicity was

not directly related to total hydrocarbon readings and that a corporate science of risk management—based on discrete subsets of hydrocarbon compounds and powerful enough to shift the regulatory process in the United States—best determined the extent to which crude contamination posed a risk to human and environmental health. Recognizing that Ecuadorian law is not retroactive (thus a 2001 law was not applicable) and that crude toxicity is controversial, Judge Zambrano's ruling departed from both convictions and trenchantly opened an Ecuadorian legal reasoning of measured action in the face of indeterminacy, which thereby astutely affirmed a distinction between a scientific and a legal fact.

Chemical Bonds and Corporate Risk Criteria

Crude oil is a complex brew composed of thousands of hydrocarbons—molecules or compounds composed of carbon and hydrogen atoms. Because of this complexity, various analytic techniques have emerged to make sense and give meaning to the concoction that makes up “rock oil.” Total petroleum hydrocarbon (TPH) is the umbrella term used to capture this chemical complexity and—as the US Agency for Toxic Substances and Disease Registry (ATSDR, a division of the U.S. Department of Health and Human Services) notes in its toxic profile of crude oil—is “the measurable amount of petroleum-based hydrocarbon in an environmental medium” (ATSDR 1999, 9). The amount of TPH found in a sample is “useful as a general indicator of petroleum contamination at that site” (ATSDR 1999, 2). Further chemical isolation and analysis proffers a sense of the constituents in a TPH measure.

The technical reports generated from the judicial inspections and submitted to the Nueva Loja Superior Court contain reams of data on the chemical composition of thousands of soil and water samples. They enumerate the various analytical results for 2,837 unique samples (2,371 from the defendant and 446 from the plaintiffs). These values include measures for TPH and various constituents—benzene, toluene, ethylbenzene, and xylene (BTEX), polycyclic aromatic hydrocarbons (PAHs), and a collection of heavy metals. This data was to provide the empirical scientific evidence for whether or not chemicals derived from Texaco's former petroleum operations were still present in the environment in sufficient quantity to cause harm. Yet far from being indicative, these data were a source of disagreement. Determining what exactly specific chemical values actually signify is embroiled in controversy as science differs on how to measure and assess the presence of hydrocarbons and their effects.

Take “total petroleum hydrocarbon.” A dominant understanding among scientists in the United States maintains that, although levels of

TPH are general indicators of petroleum contamination in soil, water, or air, the amount of TPH calculated tells little about how the particular petroleum hydrocarbons in a given sample may affect humans, animals, and the environment. First, TPH is a method-dependent reading. That is, different analytical methods and techniques for extracting hydrocarbons from a matrix will result in different TPH values (ATSDR 1999, 24; TPH-CWG 1998, 3). Second, North American scientific wisdom contends that a TPH measurement does not determine risk. Being a gross assessment, a TPH value does not proffer any meaningful information on the multiple chemical compounds within that measure. Nor does it offer insight into how chemical components have in the past or will in the future interact with each other or the medium in which they exist—both key concerns in understanding toxicity (ATSDR 1999; TPHCWG 1998).

In the first of its five volumes outlining a method for understanding the complexity of petroleum hydrocarbons, the U.S.-based Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) noted: “TPH concentration data cannot be used to quantitatively estimate human health risk. The same concentration of TPH may represent very different compositions and very different risks to human health and the environment. For example, two sites may have TPH measurement of 500 ppm but constituents at one site may include carcinogenic compounds while these compounds may be absent at the other site” (TPHCWG 1998, 5). With this paradox being of primary concern, the TPHCWG was formed “to develop scientifically defensible information for establishing soil cleanup levels protective of human health at hydrocarbon-contaminated sites” (TPHCWG 1997a, ix; Twerdok 1999).

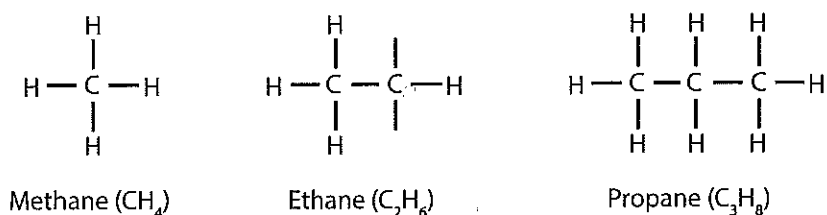
Within the United States, TPH is not regulated by the federal government, and never has been. Rather, beginning in the 1970s, individual U.S. states have engaged in monitoring TPH by establishing regulatory cleanup levels—that is, levels beyond which contamination is not permissible. These cleanup standards (measured in parts per million, ppm) have varied dramatically from state to state, ranging from 10 ppm to 10,000 ppm TPH, with regulation in the preponderance of states hovering around 100–200 ppm TPH (Michelsen and Boyce 1993, 3; Staats, Mattie, and Fisher 1997, 660). This variation was thought by many, especially industry, to be a problem. Established in 1993, the TPHCWG—a consortium of scientists from the oil and gas industry, the consulting community, the U.S. military, state regulatory agencies, and the University of Massachusetts—sought to address this great disparity in state regulatory directives for cleaning up sites contaminated with petroleum hydrocarbons. It reasoned that by standardizing the science used to set standards, regulatory disparities among states would diminish.

In pursuing this goal, the TPHCWG enacted a crucial transformation in how to assess contamination. This transformation shifted the focus from

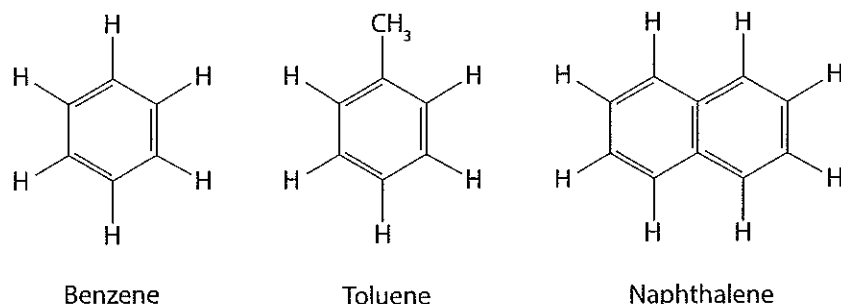
measuring the gross value of hydrocarbons in a matrix to assessing the risk to human health that constitutive groupings of hydrocarbon compounds (or subsets) might cause. In explaining the science behind assessing the toxicity of crude oil, Sara McMillen, Chevron's senior scientific adviser for the lawsuit, noted: "It used to be, in encountering petroleum in the environment, that we would ask, 'how much of the contamination do we need to clean-up.' Now we ask, 'how much do we need to clean-up to make the area safe for humans'" (*Crude* 2009). Unpacking this statement provides insight into the recent shift among U.S. states to regulate for specific compounds, instead of gross TPH levels as they previously had. And it offers insights into the capacity to materialize and dematerialize toxins in the Ecuadorian Amazon.

Such an unpacking requires a brief excursion through the chemistry of crude oil. Hydrocarbons are a class of organic chemical compounds composed largely of the elements carbon (C) and hydrogen (H). They account for roughly 95–99% of what makes up crude oil. The carbon atoms join together to form an architecture for the compound, and the hydrogen atoms variously attach themselves in a plurality of configurations. The exact chemistry of an individual hydrocarbon depends in large part on the *structure* and *type* of chemical bonds that form between and within constituent carbon and hydrogen atoms (ATSDR 1999; TPHCWG 1997; TPHCWG 1998, 54).

Schematically, hydrocarbons are broken into two groups on the basis of structure: *aliphatic* and *aromatic* (fig. 7.1). Aliphatic hydrocarbons are



Simple aliphatic hydrocarbon



Simple aromatic hydrocarbon

Figure 7.1. Chemical structure of aliphatic and aromatic hydrocarbons.

chains or branching chains of single bonds, or carbon-carbon double bond, or carbon-carbon triple bond. Aromatic hydrocarbons are ringed compounds—with benzene being the purest. This ringed structure of alternating carbon-carbon double and carbon-carbon single bonds is said to possess a “special stability” due to the movement (or what in chemistry is called “dislocation”) of valence electrons in the bonding of the six carbon atoms forming the ring. This special dislocation-dependent stability creates the uniqueness of an aromatic ring compound such that its ringed structure (not simply carbon-carbon links) solidifies the compound, making it stronger than would be mathematically anticipated. Chemically this means that aromatic rings are more stable and less reactive, yet similarly contain greater thermodynamic force. These structures and qualities give aromatics the capacity to transform into different compounds under the right conditions. Similarly, as I’ll discuss below, there is an association between this structure and toxic capacity.

In trying to assess the toxic effects of TPH, scientists classify constituent compounds into groupings—or fractions—that cluster hydrocarbons according to their structure (aliphatic versus aromatic), their equivalent carbon number, their boiling point, and their “fate”—meaning how they will react and move in the environment depending on their solubility, vapor pressure, and propensity to bind with geomorphic and organic particles. Together these properties serve to establish the proclivity of a hydrocarbon to be volatile, to leach, or to persist in a matrix (ATSDR 1999; McMillen, Magaw, and Carovillano 2001a; TPHCWG 1998). The assumption is that chemicals grouped by transport fraction have similar toxicological properties, although this is not always the case (ATSDR 1999, 13–14).

Minimal risk levels have been determined for some fractions with respect to inhalation and oral contact. But crude oil contains thousands of hydrocarbon compounds—some consisting of one hundred carbon atoms or more—and the majority of these compounds have never been analyzed. As of 2001, scientists had identified the physical and chemical properties of only 250 hydrocarbon compounds (ATSDR 1999, 9, D-1; TPHCWG 1999, 3; McMillen et al. 2001c, 58). Yet only twenty-five hydrocarbons have been sufficiently studied and characterized to determine their toxicity, and virtually all of those contain less than a couple dozen carbon atoms.

Of these twenty-five hydrocarbons, two classes of aromatic hydrocarbons—BTEX (benzene, toluene, ethylbenzene, and xylene) and seventeen PAHs (polycyclic aromatic hydrocarbons)—are of most concern. BTEX are crude oil’s lightest aromatic compounds—all based on one benzene ring—while PAHs, a class consisting of several hundred compounds (Sanders and Wise 2011), are hydrocarbons composed of two or more

fused benzene rings. BTEX and the seventeen light PAHs are known to be carcinogenic, mutagenic, or teratogenic, or all three; they intervene in the cellular development of life-forms. Beginning in the 1970s with the Clean Water Act, the U.S. EPA incrementally included these hydrocarbons among its "priority pollutants"—a set of chemicals that the agency regulates given their potential harm.

With respect to the judicial inspection, the technical reports that both the plaintiffs and defendant submitted to the Nueva Loja Superior Court between 2004 and 2007 present data detailing the analytical results from soil and water samples. Tables enumerate concentrations of TPH, BTEX, aliphatic and aromatic hydrocarbons (divided into incremental fractions according to the number of carbon molecules they contain), and the seventeen PAHs within a given soil core or water sample. Overall, TPH values from laboratory analysis by both the defendant and plaintiffs overlap—ranging from low to astronomical levels.⁶ But notably, the technical reports from both sides register no (or only a scant) presence of BTEX and light PAHs—the hydrocarbon compounds within crude oil understood universally to detrimentally affect life-forms.

It is on this basis that Chevron's chief counsel and experts were able to state that former Texaco operations pose no present oil-related risk to public health or the ecosystem. When crude oil is released into the environment, its composition changes quickly and irreversibly as a result of various physical and biological processes known collectively as degradation. BTEX (the four aromatic compounds composed of one benzene ring with between six to eight carbon atoms) is extremely volatile, and tends to dissipate from oil relatively quickly. As oil weathers, BTEX evaporates within days to weeks to months, depending on the conditions once exposed to the air; when underground, BTEX dissolves in groundwater and can even slightly evaporate. The same is true of light PAHs—that is, those with less than a dozen carbon atoms and a relatively low molecular weight. Consequently, Chevron is correct when it says that "all our test results demonstrate the virtual absence of BTEX, and the disappearance of light and mobile fractions of PAH" (CVX Informe Sacha-57 2005, vii). For those isolated cases in which Chevron's sampling did indicate the presence of one or two of these known toxic compounds (e.g., benzene) at well sites still under production, the corporation quite legitimately argued that given these compounds' volatility their appearance could not be the result of Texaco activities between 1964 and 1990.

6. The number of samples and analytical results taken by each party, however, differs significantly: Chevron took 2,371 samples, producing 50,939 test results, and the plaintiffs took 466 samples, producing 6,239 results. The highest TPH reading was 900,000 ppm (mg/kg) taken from oil well Shushufindi #4.

Perforce, crude oil's capacity for harm radically differs depending on the matrix of legibility—TPH levels versus BTEX and light PAHs—in which it is placed. Each matrix of legibility rests on, as it fuses together, a distinct constellation of molecular, technical, and social processes. Differently assembled atomic, laboratory, and policy actions invest hydrocarbon compounds with unique meaning—evincing and foreclosing qualities, capacities, and the possibilities of their effect. Much to Chevron's favor, in the late twentieth century United States, the spatial and temporal volatility of light hydrocarbon compounds conjoined with a scientific impulse to standardize and a corporate compulsion to obviate undue regulation; the effect was to institutionalize restrictive parameters for what defined crude oil toxicity. Disturbingly, this assemblage allowed toxins (narrowly defined—BTEX, light PAHs) to dematerialize and culpability for them to disappear precisely at the moment when the industry was advocating for an “accurate” (rather than “general”) science for making a contaminated “area safe for humans” (Chevron chief scientist, in *Crude* 2009).

Knowledge Production and Risk Management

In reworking a methodology for assessing hydrocarbon contamination, the TPHCWG was motivated by one “truth”: “there is no single TPH toxicity criterion for developing human health risk-based cleanup goals” (TPHCWG 1999, 2). As such, the “introduction” to each of its five volumes affirms that the range of TPH standards used across different U.S. states to assess the need for hydrocarbon cleanup are “not based on a scientific assessment of human health risk” (TPHCWG 1998, ix). Although these “sometimes arbitrary TPH standards” may “reduce human health risk,” this is “by an unknown amount” (1999, 2), and standards may be overly conservative and costly. After compiling and reviewing hydrocarbon chemical and toxicological data in five extensive volumes, the TPHCWG “developed an approach for calculating RBSL [risk-based screening level] that provides a quantifiable degree of health protection” (1999, 2).

TPHCWG risk-based cleanup goals emerged from a tiered risk-based decision-making framework: (1) determining the specific fraction composition of the particular hydrocarbon contaminant at a site; (2) executing mathematical calculations (ingestion/inhalation/dermal contact) that establish risk-based-screening levels for thirteen hydrocarbon fractions (in soil/groundwater/surface water) based on TPHCWG's assigned toxicity criteria; and (3) and assessing the hydrogeological conditions, history, possible exposure pathways, receptors of contamination, and present and future land use of the site.

Since the late 1990s, scientists working for oil companies, the American Petroleum Institute, and environmental consulting firms have

avidly promoted, disseminated, and extended the TPHCWG's work in peer-reviewed scientific journals and books. As noted in the preface to a much cited book coedited by Chevron's chief scientist for the Ecuadorian lawsuit (McMillen et al. 2001a), the work of the TPHCWG was formative in transforming how hydrocarbon-contaminated sites are understood in the United States: "The most desirable environmental goal" is "risk reduction . . . not achieving generic hydrocarbon concentration limits" (Loehr 20014). "Risk assessment" and "risk management" based on scientific knowledge is what will "achieve an environmentally protective endpoint, i.e., a concentration of a chemical in such soils below which there is no expected adverse effect to human health and the environment" (Loehr 2001, 2). This reasoning was powerful. Whereas all U.S. oil-producing states regulated gross TPH levels when the TPHCWG published its reports between 1997 and 1999, by the mid-2000s not one U.S. state regulated or determined cleanup on the basis of TPH levels. Rather, following and adapting TPHCWG guidelines, state regulatory agencies set new cleanup standards based on dividing hydrocarbons into the thirteen constituent fractions. In theory, breaking up hydrocarbons into these fractions provides a more accurate understanding of risk.

The publications of a cohort of industry-related scientists that build on the TPHCWG's work sound a recurrent take-home message: after a contamination event, those hydrocarbon compounds known to detrimentally affect human health and the environment—light aromatic compounds (BTEX and two-ring PAHs)—dissipate or biodegrade in the environment. Heavy PAHs (> three rings) remain in the environment but are immobile, inert, and safe to human health and the environment (Alexander 1995; Bobra, Shiu, and Mackay 1983; McMillen et al. 2001a; Heath, Koblis, and Sager 1993; O'Reilly and Thorsen 2010; Vorhees and Butler 1999; Twerdok 1999; Staats et al. 1997; Claff 1999). These studies reach this conclusion using scientific methodologies and reasoning: they complete a review of "the literature" and perform the requisite tests and equations (K coefficient for sorption, Henry's Law coefficient for volatility, vapor pressure, and water solubility) necessary to demonstrate that the petroleum hydrocarbons that remain after seepage, discharge, or a spill—the crude oil that contains heavy PAHs—do not pose a risk to human health and the environment.

Research conducted by Sara McMillen (the Chevron chief scientist) and colleagues (McMillen et al. 2001d) used the TPHCWG's thirteen equivalent-carbon fraction method to reconstruct a risk-based-TPH screening level for seventy different crude oils representative of the chemical composition of the types of crude produced around the world. Their analysis indicated that a composite TPH level of 41,300 ppm (derived from a range of 35,000 ppm to 67,300 ppm) at production and exploration sites was "protective of human health." Although significantly greater than all

state regulatory directives at the time, McMillen et al. determined that such a level was valid “because most of the equivalent carbon fractions found in crude oils are either not soluble or volatile enough to cause a concern” (2001d, 126). Analyzing data that Chevron’s technical experts collected during the Ecuadorian judicial inspections, Kirk O’Reilly (a former Chevron employee and then consulting scientist) and Waverly Thorsen examined whether weathering affects the solubility of large “recalcitrant” PAHs. They concluded that, given the “rapid weathering of the more soluble aromatics and the low effective solubility of larger PAHs,” soils impacted by Ecuadorian crude would “not . . . result in dissolved [PAH] concentrations that exceed health-based drinking water goals” (O’Reilly and Thorsen 2010, 402)

Alternative Chemical Stories

Within other spheres of science, however, a growing literature suggests the opposite of industry-related studies. For a number of decades, scientists have understood that the aging of crude reduces *acute* toxicity—as single-ringed (BTEX) and double-ringed (light PAHs) aromatic compounds evaporate and dissolve (Griffin & Calder 1977; MacKay and McAuliffe 1988). Similarly, scientists have understood that aromatics with a greater molecular weight (three to six rings) are more toxic, and increasingly so by an order of magnitude per carbon ring, than their lighter, more volatile counterparts (Black et al. 1983; Griffin and Calder 1977). Because of their low solubility and tendency to sequester in the micropores of soil particles, however, it was thought these aromatics compounds were not biologically available and thus posed little concern.

But research following the *Exxon Valdez* and other oil spills challenged this assumption. Spurred by declines in fisheries populations, a number of studies have documented the negative effect that long-term exposure to low concentrations of weathered crude have had on fish embryos and larvae (Rice et al. 2001; Marty et al. 1997; Peterson et al. 2003; Incardona et al. 2005 and 2012). Contrary to prior assumptions, these scientists discovered that many of the multiringed PAHs in weathered oil are bioavailable and that chronic exposure to weathered crude can result in long-term negative effects. In Alaska’s Prince William Sound, heavy aromatics passed through the porous membranes of fish embryos and lodged in lipophilic yolk reservoirs during cellular differentiation and development. Observed long-term toxic consequences—although often not expressed until long after exposure ended—included cranial and spinal malformations, cardiac dysfunction, decreased size, slowed development, inhibited swimming, increased mortality, reduced marine survival, and reproductive impairment on larvae and fish (Bue et al. 1996; Incardona et al. 2005).

Most likely these effects were the result of PAH clastogenesis; three-five ringed PAHs metabolized as clastogens—or agents that added, deleted, or rearranged sections of chromosomes—inducing chromosomal disruption (Incardona et al. 2005; Rice et al. 2001). Significantly, scientists' capacity to materialize the toxic effects of multiringed PAHs depended on experimental designs whose locus of analysis and laboratory techniques differed significantly from that of industry-associated science.

Overall, these studies on molecular and genetic toxicity suggest that weathering does not, *necessarily*, mean becoming more benign. Although the acute toxicity of crude may quickly dissipate through degradation, the chronic, long-term, sublethal effects of crude have been shown to increase with time and toxicity can intensify, rather than diminish—especially for tricyclic PAHs (Amat et al. 2006; Heintz, Short, and Rice 1999; Incardona et al. 2005 and 2012). The mechanisms by which this occurs have yet to be understood. But a number of studies suggest that grouping PAHs into fractions by carbon number and assuming that the individual compounds within a fraction share similar properties (in terms of transport and fate) may not be an effective way to assess risk to life-forms. A number of scientists (Incardona et al. 2005 and 2012; Jacob 2008; EPA Draft Document PAHs 2010; ATSDR 1995) underscore the complexity of polycyclic aromatic hydrocarbons: PAHs with similar molecular weight (i.e., the same number of carbon atoms) but different ring arrangements have different capacities for solubility and uptake; the pathways that enable PAHs to bind to receptors (ArR) that control genes encoding enzymes (converting PAHs to water-soluble derivatives) may metabolize and eliminate xenobiotic compounds *or* they may intensify toxic capacity and effect; and the metabolites of distinct PAHs vary in their toxicity depending on the organism, the tissue, and the stage of development of the entity that has metabolized the PAH. The assertion by industry-related science that complex hydrocarbons are immobile and harmless increasingly appears a premature conclusion.

Knowing and Unknowing

Differing opinions among industry and nonindustry scientists as to the behavior and consequence of multiringed petroleum compounds raise questions about the production of scientific knowledge. As a number of scholars (Proctor 1995; Markowitz and Rosner 2002; Michaels 2008) have explored, the production of scientific uncertainty is a time-honored strategy within an assortment of industries in an attempt to preclude unwanted regulation or postpone liability, or both. The tobacco industry—with “doubt-is-our-product” infamy—has been perhaps the most egregious (Proctor 2011). But the petroleum industry is not innocent in this regard.

Even though an association was recognized between chemicals in fossil fuels and cancer in 1775 (Pickering 1999) and medical research had documented a causal link between benzene and fatality beginning in the 1920s (ATSDR 2007, 39) and benzene and leukemia beginning in the 1930s, the oil and gas industry effectively forestalled federal regulation of benzene for fifty years by “manufacturing uncertainty” (Markowitz and Rosner 2002; Michaels 2008, 70–78).

With respect to hydrocarbons more broadly, the industry has more recently been engaged in a complementary strategy: the production of certainty—a certainty that has delegitimized prior regulatory standards in the United States, facilitated more lenient cleanup directives, and sought to foreclose the need for further research. Toward this end, corporate and consulting science has pursued a double tactic. On the one hand, it has repeatedly demonstrated that gross TPH measures are meaningless; that the best way to assess risk from hydrocarbon contamination is by measuring levels of thirteen distinct fractions and assessing toxicity from them; and that multiringed PAHs are inert and pose no risk to human health. On the other, it has demonstrated that soils contaminated with composite crude oil with a TPH level of 41,300 ppm are not deleterious to humans or the environment. The former is an effort to control the science and assert truths in the face of ambiguity. The latter is an effort to reduce the need to assess and analyze exploration and production sites. Both, in turn, promote cost reduction—in terms of analysis, restoration, and reparations. In a self-referencing citational loop, the corporate and consulting science of hydrocarbons has forged a scientific legitimacy and technical protection of oil operations and their collateral damage.

This production of truth claims serves to hide the controversy around petroleum hydrocarbons and the partiality of the industry’s own claims. At one level, industry-related scientists must depict the state of scientific knowledge in constrained and limited terms in order to magnify corporate certainty; that is, they misrepresent by selectively ignoring, even censoring out, other science—those alternative chemical stories that don’t suit industry interests. Not one of the industry-sponsored or -associated studies I examined cited research outside its bubbled industry-science realm. But more profoundly, and insidiously, the laboratory techniques and protocol that industry scientists have standardized produce the inability to apprehend the harmful effects of three-ringed PAHs. That is, their experiments—with the requisite tests and equations—cannot register a consequential value. The life-debilitating capacity of heavy PAHs is made imperceptible; and imperceptibility is inevitable because it is actively produced as such.

The shift in U.S. regulatory policy in the mid-2000s to assess petroleum in the environment on the basis of discreet hydrocarbon fractions (instead

of gross TPH measures) was arguably an industry strategy to contain and stabilize what can be understood as contamination. The historical context is notable. The TPHCWG was officially formed in 1993, only a few years after the *Exxon Valdez* spilled 11,088,000 gallons of crude oil in Alaska's Prince William Sound in 1989. The magnitude of the spill—the largest at that time in U.S. history, spreading over 750 kilometers—and the ensuing scientific investigations, cleanup operations, and legal actions over the following decade gave witness to the impressive financial liability that assessments of contamination could wreak on the oil industry. Among those U.S. states with TPH cleanup regulations on their books at the time, most tended toward the more conservative side (requiring cleanup action when contaminated soil samples registered 100 ppm to 1,000 ppm TPH)—with the majority of state cleanup levels hovering around 100–200 ppm and a handful of other states extending beyond 1,000 ppm (Hamilton, Sewell, and Deeley 2001, 38; Staats, Mattie, and Fisher 1997, 660). Were Alaska to have been among those states mandating cleanup at TPH levels of 100 ppm, or even 1,000 ppm, the consequences of postspill environmental politics and remediation might not have been so devastating for Alaskan wildlife.

Action in the Context of Indeterminacy

In a written rebuttal to one of Chevron's technical reports, the plaintiffs' lawyers noted that Chevron's "expert attempts to confuse and distort the very concept of contamination; he seeks to relativize it—when the very concept of contamination is absolute. The contamination either exists, or does not exist" (FDA Observaciones Sacha-57 2005, 15). One might argue that Ecuador's Executive Decree 1215, Environmental Regulations for Hydrocarbon Operations in Ecuador, promulgated in 2001, concurs. Asserting a logic contrary to regulatory scientific opinion in the United States, Executive Decree 1215 established national legal limits for the quantity of TPH permissible in distinct land uses: 1,000 ppm for sensitive ecosystems, 2,500 ppm for agricultural land, 4,000 ppm for industrial use land, and 10,000 ppm in areas of industrial wastes.⁷ The legal limit for the Amazon—a sensitive ecosystem—is 1,000 ppm TPH.

7. Decree 1215, Environmental Regulations for Hydrocarbon Operations in Ecuador, published in the Official Registry #265 on February 13, 2001. The Unified Text of Secondary Environmental Legislation (Texto Unificado de Legislación Secundaria del Medio Ambiente, TULSMA) by the Ministry of Environment, Executive Decree 2825, published in the Official Registry #623 on July 22, 2002, sets standards for all other analytes in crude oil and the oil process.

In February 2011, the president of the provincial court, Judge Nicolas Zambrano, presented his ruling. Within a carefully reasoned 190-page judgment, Zambrano's discussions on liability and causation are instructive. Because the Ecuadorian judicial system does not allow law to be retroactive—"rules cannot be applied to acts prior to their approval" (2011, 96)—Judge Zambrano reasoned (coinciding with the defense) that Chevron could not be expected to comply with legislation that was passed a decade after it terminated its operations in 1990. As such, the maximum allowable limits for TPH established in 2001 under Decree 1215, or the maximum allowable limits for BTEX and seven PAHs established in 2003 under Executive Decree 3516, could not be used as instruments for determining a violation. Rather, the court would take measures of TPH and distinct hydrocarbons into account as "reference parameters" that offer insight into the "current condition of the environment in question"—Texaco's former oil concession (Zambrano 2011, 74, 96).

However, a number of legal provisions were in effect during the period of Texaco's operations, Judge Zambrano noted, and these provisions did carry the force of law: the earliest was the 1964 concessionary agreement whereby the right that the Ecuadorian state granted Texaco to explore for and exploit oil was conditioned by the company's obligation not to deprive local inhabitants of their livelihood rights (to water, navigation, fishing) or "to deprive the waters of their qualities of potability and purity" (Registro Oficial No. 186 of February 21, 1964, in Zambrano 2011, 61–62, 97). Although TPH values may "not [be] a precise indicator of health risk," Zambrano argued, the impressive measures recorded in samples taken from every waste pit during the fifty-four judicial inspections make TPH measures a "good indicator of the environmental condition in terms of hydrocarbon impacts" (Zambrano 2011, 101) and "gives us certainty that environmental conditions are similar in all of the sites" (Zambrano 2011, 105). And although controversy foreclosed any definitive reading of the potential significance of TPH—the crown jewel of the plaintiffs' argument with the highest level reaching 900,000 ppm—controversy was less problematic in considering PAHs. Zambrano argued that the results of the majority of samples taken from pits by the plaintiffs' and court-appointed experts exhibited high levels of "PAHs, which are potentially carcinogenic" and, as the inspections demonstrated, "can deeply penetrate soils, especially if there is prolonged contact as would be the case with waste pits, putting the soil and groundwater at risk of contamination" (Zambrano 2011, 108). Together, measures of PAH and limited evidence of heavy metals in soil and water samples taken in and near former Texaco waste pits "demonstrates . . . the hazardous presence of polluting agents" (Zambrano 2011, 108), irrespective of the fact that Chevron's analyses determined otherwise.

In response to Chevron's defense that these substances (TPH, PAHs, metals) were not regulated during the time of Texaco's operations, Judge Zambrano retorted that "beyond any irreverent argument of some lawyer who intends to deprive the law of its meaning . . . the lack of regulation" over the dumping of a substance does "not in any way mean an implicit authorization to dump this hazardous substance into the environment" (Zambrano 2011, 99). These substances were known to be hazardous by Texaco, Zambrano concluded, because prior to beginning its operations in Ecuador, the director of the company's Research, Environment, and Safety Department collaborated on a 1962 publication that outlined "extreme care" in handling wastes from oil operations due to their deleterious nature (Zambrano 2011, 81–82). Given this foreknowledge, Zambrano argued, "the defendant had the obligation to foresee and prevent the presence of products that are hazardous to health and/or the ecosystem" (Zambrano 2011, 97) in its oil operations; not only did the company's actions constitute violations of Ecuador's law at the time but also the presence of substances "that may place life and/or the health of people at risk . . . would constitute evidence of legal harm, which, as such, brings with it the obligation to make reparation" (Zambrano 2011, 97).

Citing a 2002 ruling of the Ecuadorian Supreme Court of Justice—and seeming to echo Beck (1992) and Callon, Lascoumes, and Barthe (2009)—Judge Zambrano wrote: "The current world and that of the near future, with its extraordinary and steady accumulation of risks, calls for a more vigorous defense of human values, as a result of a science that is both all-providing and all-threatening at the same time" (Zambrano 2011, 82). This "multiplicity of actual contingencies of dangers and risks," he wrote, had spurred new understandings of liability and causality. "Risk theory" asserts that "whoever uses and takes advantage of any benefit-yielding medium generates social risks, and therefore must assume liability for the injury thereby caused. . . . This is risk' of advantage, with its origin in the Roman maxim *emolumentum ibi llus* (there where the benefit lies is also where the responsibility lies)" (Zambrano 2011, 83). In the context of hazardous industry, because it is "almost impossible" to prove fault for the excesses—or what Callon, Lascoumes, and Barthe (2009) call "overflows"—that the production and use of hazardous elements generate, fault is presumed to reside in "whoever uses and takes advantage of the risky thing through which the harm occurred" (Zambrano 2011, 83). And because of "the irrefutable lack of scientific certainty" (Zambrano 2011, 89) about the effects of elements in our environment, "the court will consider these elements without having to determine precisely which element caused harm. . . . The mere existence of harm would be sufficient to accredit a causal nexus between the harm and the hazard that had been created" (Zambrano 2011, 88–89).

Judge Zambrano's ruling—along with an evolving Ecuadorian regulatory system (as seen in the 2001 and 2003 legislation)—was *not* asserting that “the very concept of contamination is absolute—that contamination either exists, or does not exist” (FDA Observaciones Sacha-57 2005, 15). Rather, an emergent legal logic concerning the environment recognized that relying on limited and contested knowledge about petroleum hydrocarbons (i.e., debate around the significance of high TPH readings, the controversy over the transport and fate of PAHs) might not be the best way to secure care for life-forms. As such, Zambrano's 2011 ruling traced (without invoking) many of the contentions central to an evolving precautionary principle: where an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if cause and effect relationships are not determined scientifically. Like Zambrano's judgment, the precautionary principle's foundational ethic insists on interrupting the onus of proof and on obliging decision makers to take responsibility for addressing plausible dangers despite uncertainty. In this vein, Zambrano's note of “the difference between legal causation and scientific causation” (Zambrano 2011, 89) echoes Latour's discussion of the distinction between law and science. Latour writes: “When Roman lawyers intoned the celebrated adage *res judicata pro veritate habetur*, they were declaring that what had been decided should be taken *as* truth, which means, precisely, that it should in no way be confused *with* the truth” (2010, 238).

Zambrano's judgment did not fixate on the specificities of scientific measures and their significance—as the arguments of the plaintiffs and the defense did. Rather, his judgment rested on the extent to which corporate behavior violated the broader spirit of the law at the time, and the extent to which that violation posed deep uncertainty to the soils and waters, and by extension all human and other-than-human life-forms dependent on them. Zambrano's decision—as well as Ecuador's recent environmental laws—reflected an understanding that scientific knowledge of crude toxicity is inherently open-ended and lacks closure. This emergent Ecuadorian environmental reasoning is the enfolding of knowledge, ignorance, and imprecision—one in which indeterminacy, uncertainty, and probability proffer an expanded platform to those who share a stake in its epistemological rules (cf. Petryna 2002).

By contrast, a corporate risk-management logic expended significant energy seeking to establish certainty about hazard: industry-promoted science could and would accurately analyze and calculate whether a contaminated site posed risk. It sought to claim that only science-based risk could determine danger and legitimize regulation and remedial action. Through the generation of scientific “truths,” industry sought to control the capacity to assess and prove a hazard. But given the complexity of crude oil, it is misleading to claim that assessing the levels of thirteen

hydrocarbon fractions at a site against assigned concentration levels determined toxic is a more scientifically accurate understanding of risk.

As the U.S. Agency for Toxic Substances and Disease Registry states, “Despite the large number of hydrocarbons found in petroleum products and the widespread nature of petroleum use and contamination, only a relatively small number of the compounds are well characterized for toxicity. The health effects of some fractions can be well characterized, based on their components . . . (e.g., light aromatic fraction—BTEX . . .). However, heavier TPH fractions have far fewer well-characterized compounds. Systemic and carcinogenic effects are known to be associated with petroleum hydrocarbons, but [this agency] ATSDR does not develop health guidance values for carcinogenic end points” (ASTRD 1999, 16).

Left out of the story told by the TPHCWG is that many of the unstudied or understudied hydrocarbon compounds within its hypothetical 500 ppm level could be deleterious to well-being and health. We just don’t know. And many of the compounds in the excessively high levels of TPH (most certainly, but not only, the heavy PAHs) in samples gathered during the judicial inspections could likewise be harmful to life-forms. We just don’t know. The toxicological studies—including those underpinning industry-sponsored research on the risk of hydrocarbons—are highly circumscribed. As others have argued (Fortun and Fortun 2005; Jasanoff 2002, 2005; Murphy 2006; Petryna 2002; Sellers 1997), the science of chemical exposure is inherently inexact. In the laboratory, dose-response curves graph the “threshold-limit value” for a unique chemical—the point at which a substance becomes toxic. But outside the laboratory, the effect of chemical exposure is difficult to ascertain given the complexity of the phenomenon. Reactions to combinations of chemicals or to long-term exposure to low levels of chemicals cannot easily be registered in the laboratory. And reactions to chemicals that have never been studied are non-episodes marked by the impossibility of indexing them as a consequence of exposure events.

Widespread, long-term, low-level exposure to hydrocarbon elements (some studied and many not) is precisely what fisheries scientists are confronting as they study the consequences of oil spills years later (Incardona et al. 2005 and 2012; Jacob 2008; Peterson et al. 2003). Widespread, long-term, low-level exposure to hydrocarbon elements (some studied and many not) is precisely the condition that haunts human and nonhuman life in Ecuador’s northern Amazon. It is this predicament that Zambrano’s ruling recognized.

What is increasingly clear is that toxicity and chemical hazard are not inherent properties. Rather, they are probabilities and capacities. As such, toxicity is not merely calculated (as is done conventionally in toxicology) through measures of concentration, dose, exposure pathways,

length of exposure, and the predilections of an organism. The capacity to claim toxicity and chemical hazard is also uniquely determined depending on a laboratory's knowledge production milieu (i.e., industry- versus non-industry-affiliated), differently materialized depending on methods (i.e., gross TPH versus carbon equivalent fractions), distinctly apprehended according to technique (i.e., chemical versus molecular versus genetic analyses), *and* variously adjudicated in accordance to the legal regime through which probabilities and capacities are reckoned (i.e., inquisitorial versus adversarial judicial systems). That is, toxicity and chemical hazard are made to matter through imbricated technical, chemical, and legal work.