

2014-01-01

Environmental Assessment Of Used Motor Oil In The Ciudad Juarez-El Paso Area

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ENVIRONMENTAL ASSESSMENT OF USED MOTOR OIL IN THE
CIUDAD JUAREZ-EL PASO AREA

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2014

ENVIRONMENTAL ASSESSMENT OF USED MOTOR OIL IN THE
CIUDAD JUAREZ-EL PASO AREA

by

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DISSERTATION

Presented to the Faculty of the Graduate School of

The University of Texas at El Paso

in Partial Fulfillment

of the Requirements

for the Degree of

DOCTOR IN PHILOSOPHY

Environmental Science and Engineering Program

THE UNIVERSITY OF TEXAS AT EL PASO

December 2014

ACKNOWLEDGMENTS

I wish to express my gratitude to Dr. Irasema Coronado for the guidance and enthusiasm that supported me throughout the dissertation. Above all, I thank her for believing in me.

I am grateful to Dr. Wen Yee Lee for help with the analytical sections of the dissertation, and for her laboratory instruction.

I thank my family for their moral support. To my children Paloma, Juan, and Luisa, and to my mother, brother and sisters, I say thank you for always being there for me. To my dearest friends of many years, thank you for your encouragement.

My special thanks to my thesis committee members: Dr. Barry Benedict and Dr. Carlos Rincon, also Dr. Russell Chianelli, Dr. Yvonne Santiago, Dr. Alba Corral and Dr. Julia Bader for sharing their experience and knowledge with me, and for being part of this research project.

Words cannot express my gratitude to Ana Cristina Ortiz and Amanda Parra for their invaluable help and companionship in the field work: visiting the auto repair shops, taking numerous soil samples in El Paso, and helping the field work in Ciudad Juarez I want to thank to Alvaro Torres, MS I also want to thank to Ricardo McReary, MS for

helping me with the lab work at UTEP and a lot of thanks to Laura Santana, MS for the UACJ lab work, Antonio Perez, Daniel Guerrero, Mario Rodriguez and Yaz Solis.

My gratitude also goes to Ms. Nora Reyes from the UACJ-ICB Digital Cartographic Unit for developing the results maps for this research, to Ms. Lizette Hernandez, Dr. Antonio De la Mora and to Dr. Alejandro Martinez for their support.

I would like to thank the Mexican Programa de Mejoramiento del Profesorado (PROMEP) that through the Universidad Autonoma de Ciudad Juarez provided me the financial support to earn my Ph.D. I would also like to thank to the UTEP Science and Engineering Ph.D. Program (ESE), the Chemistry Department staff and the Graduate School Dean Dr. Charles Ambler, student Terrence McEneny, Olga Rodriguez B.A. and Olympia Caudillo, A.D.

To everyone who has lent their assistance in any way throughout my research and writing, thank you.

ABSTRACT

As a hazardous waste generated in large amounts worldwide, used motor oil (UMO) is an important issue for environmental science. UMO contains the carcinogenic and mutagenic compounds Polycyclic Aromatic Hydrocarbons (PAHs). Unless properly managed and disposed of PAHs remain in the environment, principally in sediments and soil. From such environmental sinks, PAHs can migrate to watersheds contaminate drinking water, and damage ecosystems and human health.

Generators of used oil include “businesses that handle used oil through commercial or industrial operations or from the maintenance of vehicles and equipment,” (United States Environmental Protection Agency (USEPA), 2013). An example of such a business is an auto repair shop that performs oil changes.

The purpose of this research is to examine the environmental impact of used motor oil generated by auto repair shops in the Ciudad Juarez-El Paso area. To quantify such impact I analyzed PAH contamination in soil samples. The working hypothesis for this research was that the mean concentration of the EPA 16 priority PAHs present in soil samples near car repair shops is different for both El Paso and Ciudad Juarez.

The sample for the research consists of selected auto repair shops. The primary objective are threefold: (1) to survey UMO management and final disposal practices at the repair shops; (2) to perform a comprehensive analytical determination of PAHs released from UMO into soil sampled at the selected locations; and (3) to assess the impact of UMO on the environment and human health in the border region.

Through a questionnaire administered to owners or employees of automobile repair shops I gathered information from them regarding the amount of UMO generated, as well as its management and final disposal. The soil samples gathered information regarding UMO mismanagement and its possible risks for the environment and human health.

This research utilized analytical methods in extracting soil samples: ultrasonic agitation or sonication extraction method, silica-gel clean-up, and the Kuderna-Danish evaporator coupled with gas chromatography and a flame ionization detector (FID) detector for PAHs. The target compounds were the 16 PAH priority pollutants listed by the United States Environmental Protection Agency (USEPA).

The final results of the research are as follows:

- The used motor oil volume generated for El Paso at the 30 car repair shops sampled was 24,522 L/month versus Ciudad Juarez 7,419 L/month, generated at the 60 shops sampled.

- The total PAHs in the soil samples collected in the Ciudad Juarez-El Paso area ranged from 0.01 mg kg⁻¹ to 76.00 mg kg⁻¹ with an average of 63.87 mg kg⁻¹.
- PAH concentration in selected soil samples near the mechanic shops in the Ciudad Juarez-El Paso area exceeds the soil screening levels regulated by the USEPA and the Secretariat of the Environment and Natural Resources (SEMARNAT) in Mexico, values shown in tables 3.12 and 3.13.
- El Paso's most frequent PAH compound found at the soil samples was the LMW compound acenaphthylene with 15.37%, the HMW compounds were: benzo(a)anthracene with 24.00%, benzo(a)pyrene 16.81%, chrysene with 13.40%, indeno(1,2,3-cd)pyrene and dibenz(a,h)anthracene with 5.66%, and Benzo(b)fluoranthene besides Benzo(k)fluoranthene 3.97%.
- In Ciudad Juarez the most frequent PAH compound found was the LMW compound acenaphthylene with 3.00%, the HMW compounds were: benzo(a)anthracene with 30.60 %, Benzo (a) pyrene with 26.43%, Benzo(b) fluoranthene and Benzo(k) fluoranthene 11.11%, chrysene with 8.87%, follows indeno(1,2,3-cd)pyrene and dibenz (a,h) anthracene with 5.14%.
- In both Ciudad Juarez and El Paso, 100% of the quantified and detected values of the HMW PAHs soil samples exceeded the EPA Regional Screening Level (RSL).

- Compliance or non-compliance status refers to final UMO disposal through a collector authorized by Texas Commission on Environmental Quality (TCEQ) or SEMARNAT, for the statistical analyses of the two groups, El Paso Compliance (EPC) vs. Ciudad Juarez Compliance (JZC), and Ciudad Juarez Compliance (JZC) vs. Ciudad Juarez Non Compliance (JZNC). To assess the equality of means for PAH concentration a t-test at 95% confidence was performed. Accordingly, the null hypothesis of equal means was not rejected, and the conclusion is that no difference exists in the PAHs mean concentration from EPC and JZC, nor JZC and JZNC.
- For the risk assessment the Benzo(a)pyrene equivalent (BaPeq) for EPC soil samples mean was 4.69 mg kg⁻¹; for JZC the mean was 6.76 mg kg⁻¹ for JZNC 7.00 mg kg⁻¹. To assess the equality of means for BaPeq concentration a t-test at 95% confidence was performed and it is concluded that no difference exists in the mean concentration between groups. Therefore, the null hypothesis of equal means was not rejected.
- The results of this research will provide current information to hazardous waste researchers, environmental agencies and policymakers regarding the risk of PAHs posed by UMO in the Ciudad Juarez-El Paso area. Such information can

contribute to local and binational management plans for soil remediation, outreach activities and proper UMO management.

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CHAPTER I

1. INTRODUCTION

El Paso, Texas is located across the U.S.-Mexican border from Ciudad Juarez at the intersection of three states: Texas, New Mexico, and Chihuahua. The metropolitan area offers unique opportunities for understanding international and border environmental issues that can affect two countries. As one of the largest bi-national metropolitan areas in the world with a combined population of more than 2.5 million (Sowards, 2012), El Paso and Ciudad Juarez work together to address international environmental issues such as water conservation and the air and soil pollution. However, the limited number of studies on environmental border problems related to understanding transboundary hazardous chemicals demonstrates a clear need for continuing research in the area.

This dissertation unfolds in the following way:

Chapter I: This chapter describes UMO and the risks it poses to soil, air and water in the Ciudad Juarez-El Paso area. The description of UMO includes characteristics, applicable bi-national regulations, and procedures for recycling and

reusing. The literature review examines published research into the effects of UMO on the environment and human health in the region.

Chapter II: This chapter explains the data-collection instruments and methods used to administer the questionnaire and gathered the soil samples for chemical analysis. Tables, figures and maps show how and where the information was obtained as well as concentrations of UMO compounds that are hazardous to the environment and human health.

Chapter III: This chapter explains how auto repair shops in the region become pollution generators by mismanaging UMO. Even when complying with regulations, soil contamination continues to exceed the Regional Screening Levels set by USEPA and SEMARNAT. Statistical analysis demonstrates no significant difference between such concentration levels in Ciudad Juarez and El Paso.

1.1 Literature Review

The cities of El Paso and Ciudad Juarez share several geographical and environmental challenges: a) rapid urbanization and inadequate infrastructure; b) air pollution from open burning, vehicle emissions and industrial processes; c) contamination of surface and groundwater from open sewers and industrial waste; d) overexploited aquifers; e) transport and illegal dumping of hazardous waste; f)

according to the Western Sustainability and Pollution Prevention Network , devastation of natural resources (WSPPN 2014). Government and community groups have undertaken various campaigns to achieve environmental health and sustainability in the border region, primarily attempting to protect border families from air pollution, drinking water contaminants, pesticides and other toxic chemicals.

As Flowers et al. (1925) report, several efforts have been made since 1925 to reduce the waste associated with motor lubricant oil for internal combustion engines. One solution seeks to reduce the need to drain and discard the oil by removing the impurities that would otherwise accumulate and render the oil unfit for further use.

In their case study of the El Paso region, Bath and Petit (1998) identify industrialization and migration, as factors in the increase of population to over 2 million. The region shares not only a flourishing economy and growing population, but also environmental deterioration. As a prelude to The North American Free Trade Agreement (NAFTA) that was signed in 1994, several conferences were held where the problems of air pollution, degradation of natural resources, water quality and quantity issues and waste disposal were discussed (Bath,1991; EPA/SEDUE 1991, 1992).

Another well-known problem is the scarcity of water. The Hueco Bolson, the principal source of water for both El Paso and Ciudad Juarez, will be depleted in the early 21st century (US Bureau of Reclamation, 1995; Niemi and McGuckin, 1997). In response, urgent efforts are underway to acquire surface water from the Rio Grande and other sources.

Hurd et al. (2006) explains how researchers for Southwest Consortium for Environmental Research and Policy (SCERP) study water resources in the Rio Grande/Rio Bravo watershed emphasizing issues of water quality and ecosystem viability which are vital for communities in this vulnerable region.

Rincon and Emerson (2000) examine air quality in the region and identify the principal causes of pollution, such as the increasing number of private automobiles, growing cross-border truck traffic, ever-greater industrial emissions, and urban sprawl with the attendant loss of ground cover and the spread of unpaved roads and open burning.

Cresswell and Navarrete (2009) explain that the Paso del Norte region is an ideal site to evaluate cross-border efforts to reduce air pollution. Comprising three states between Mexico and the United States, the region is what the authors term an “airshed” or “air basin”: that is, an area with shared meteorological and geographic

characteristics, whose residents share the same air mass. The quality of this air is affected by activities on both sides of the border, weather inversions, natural and anthropogenic emissions.

Lee et al. (2013) state that “groundwater is a key issue to watch over the next several years with regards to border region sustainability”. As Carlos de la Parra, Rick Van Schoik and Kristofer Patron point out, “it is the lack of bilateral information sharing or agreements on transboundary groundwater resources that currently stands out.” The authors conclude that joint administration is necessary, and express their hope that recent improvements in shared management of the Colorado River watershed represent a new approach by both nations.

Eaton (2007) describes and assesses used oil management policies in the U.S. and Mexico, with focus on the El Paso-Ciudad Juarez area. The report evaluates the used oil management system, from relevant legislation through data reporting to used oil management practices. Such practices in Texas reflect legislation at both state and federal level. Eaton also reviews the best practices for disposing of used oil, and enumerates the challenges that exist for large-scale re-refining of used oil. The report outlines oil regulations in Mexico at federal, state and municipal levels as they apply to Ciudad Juarez, and present data on used oil collected by the Mexican federal government. The most reliable estimates indicate that the amount of used oil disposed

of improperly in the U.S and Mexico may reach into the hundreds of millions of gallons, posing a significant threat to human health and environmental quality.

The literature review for Ciudad Juarez-El Paso area abounds with examples of management proposals for shared environmental resources, as well as plans for conserving water and improving air quality. Examples include waste management initiatives for scrap tires, ongoing projects by the Texas Commission for the Environmental Quality (TCEQ), sustainability plans for groundwater resources and the Rio Grande basin, a 1925 proposal for managing used motor oil at the national level, and a 2007 binational regulatory approach from the University of Texas at Austin.

The present research is the first to examine the environmental and human hazards posed by auto shop mismanagement of UMO and its 16 EPA-listed priority PAH compounds. This information will assist in developing strategies for the management and final disposal of this abundant global waste product.

1.2 Background

El Paso and Ciudad Juarez form the second largest metropolitan region on the border between the U.S. and Mexico, with a combined population of 2,004,669 people (Instituto Nacional de Estadística y Geografía, 2010; U.S Census Bureau, 2010). These growing desert cities represent an important portion of the binational economy, and their

combined population leads to an increasing demand on resources, products and public service utilities including materials and transnational waste movements, it generates pollution in shared resources including the Paso del Norte Air Shed, and the Hueco Bolson aquifer, limited surface waters supplies, depletion of groundwater, solid and hazardous wastes soil contamination. The public policy response to these border environmental issues are represented mainly by institutions such as the USEPA and Mexico's SEMARNAT in the US-Mexico Environmental Programs Border 2020, the Border Environmental Cooperation Commission / Comision de Cooperacion Ecologica Fronteriza (BECC/COCEF), the Commission for Environmental Cooperation (CEC) on behalf of the North American countries Canada, United States and Mexico among other organizations, established due to concerns for the environmental effects in the border region of NAFTA. (Office of the United States Trade Representative, 1994).

One of the most important sources of non-hazardous and hazardous waste is the vehicular fleet with more than 1,008,357 vehicles in the area (Zietsman, 2009) that generates at least 10,000,000 L of used motor oil (Figueroa, De la Mora, Corral, and López, 2010).

Used oil represents one of the major potential sources of hydrocarbon pollution of water, soil and air. Used oil in cities and towns along the Mexican-U.S. border is an international issue that affects both countries and will continue to be a persistent

concern (Eaton D. , Managing Used Oil Along the Mexico-U.S. Border. Policy Research Project Number 158 Policy Research Project on Cross-Border Environmental Management, 2007). Both countries have identified used oil as a priority environmental issue.

Annex III of the La Paz Agreement (EPA and SEMARNAT, 1983) establishes the importance of cooperation between the United States and Mexico on issues related to hazardous waste and substances across the border region. Waste management capacity at both institutional and infrastructural levels means having the techniques, organizations, expertise and technology to effectively handle and dispose of waste (EPA and SEMARNAT, 2011).

The Commission for Environmental Cooperation (CEC) has expressed a long term commitment to improve chemical management in North America, as articulated in Council Resolution 95-05, Sound Management of Chemicals. This commitment was renewed in the North American agenda for chemicals management and seeks to provide support to the Parties to comply with their commitments under the World Summit on Sustainable Development (WSSD) goal of “aiming to achieve by 2020 that chemicals are used and produced in ways that lead to the minimization of significant adverse effects on human health and the environment” (CEC, 2010).

The Border 2020 US-Mexico Environmental Program is the latest program also implemented under the 1983 La Paz Agreement, and aims to “protect the environment and public health in the U.S.-Mexico border region, consistent with the principles of sustainable development” emphasizing regional, bottom-up approaches for decision making and set priorities to address the environmental and public health problems, implementing new projects and strategies and achieve environmental and public health goals. The new Border 2020 Environmental Program has implemented five strategic goals and goal number three refers to: “Promote Materials and Waste Management and Clean Sites”. (US-Mexico Environmental Program: Border 2020).

Some progress has been achieved in reducing the amount of discards that end up in landfills or are indiscriminately dumped. Measures include life cycle analysis of materials and improved collection to recover, reuse and recycle end-of-life materials. Addressing these issues at binational level is more challenging given that they require a coordinated approach across environmental program sectors, at a multi-government level and the private sector (EPA and SEMARNAT, 2011).

1.3 Problem Statement

Used motor oil (UMO) is particularly important because it is a hazardous waste and large quantities of it are generated globally. The lubricants market indicates that the United States consumes about 25 percent of the total worldwide demand for lube oils,

about 2.5 billion of gallons per year, which reflects the widespread use of the automobile per capita compared to other regions of the world. (Table 1.1) The annual generation of used motor oil reaches approximately 1.37 billion gallons per year as reported in 2006 by the California Environmental Protection Agency (CALEPA); from those, 426 million gallons are disposed of in landfills or improper locations (U.S. Department of Energy, 2005).

In Mexico, the last estimate of the volume of used oil generated from 2004 to 2013 is equivalent to 6,445,111.27 gallons (SEMARNAT, 2014), reported by the National System of Environmental Information and Natural Resources (SNIARN), which constitutes the most recent governmental information on the environment and the natural resources in the country. Data are unavailable regarding the improper disposal amount.

Table 1.1 Total lubricants demand by region (Fitzisimmons, 2005).

Region	Demand (Billions of Gallons per year)	Per capita demand (Gallons per year)
United States	2.5	8.4
Latin America	0.8	1.8
Western Europe	1.4	3.7
Central/Eastern Europe	1.4	3.2
Near/Middle East	0.5	3.1
Africa	0.5	0.7
Asia-Pacific/Oceania	3.2	0.9-5.3*
Total	10.3	1.7

*Wide range of demand in Asia Pacific area with Japan/Australia demand on high end of range.

Petroleum hydrocarbons in urban runoff have been reported to be primarily associated with UMO (Latimer J., Hoffman, Hoffman, Fasching, & Quinn, 1990). Stormwater runoff is the primary transport system moving pollutants around the landscape. Runoff from urban areas has been identified as one of the leading sources of water quality impairment of the nation's surface waters. This determination was based on laboratory analysis of hydrocarbons and the polycyclic aromatic hydrocarbons or the PAHs that they contain (PAH signature, was used to discriminate between virgin and used crankcase oils). The particulate matter in runoff was considerably enriched in UMO compared to street dust, roadside soil and vegetation, and atmospheric deposition (Mazur, Milanes, Randles and Salocks, 2006). If UMO is not properly disposed, some components like PAHs can migrate to watershed areas, contaminate the supply of drinking water, and affect ecosystems and human health.

The Environmental Protection Agency (EPA) identifies the most serious waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Used mineral-based crankcase oil has been found in at least 85 of 1,430 current or former NPL sites.

1.4 International Hueco Bolson at the Paso del Norte Area

The Mexico-U.S. border region is an area of opportunity for management of transboundary water resources. Population and economic growth in the Paso Del Norte region has increased the demand for water resources, surface waters are insufficient, reduced precipitation has affected water volumes in reservoirs and dams, the riparian areas are under stress and consequently groundwater is the most reliable water resource in this region (Granados-Olivas, et al., 2006). The Paso Del Norte area basin-fill aquifer of the southern Rio Grande rift tectonic province is a significant groundwater resource in extent, economic and environmental importance. This international groundwater is fresh with a total dissolved solids (tds) < 1000 mg/L, and brackish, with >1,000 mg/L of total dissolved solids.

The Hueco Bolson is situated in the limit of the Mexican Highland portion of the Basin and Range (B&R) physiographic province. In this part of the B&R province, the distinguishing geomorphic difference is the magnitude of basin floor (bolson-plain) area in comparison to the size of the crest of mountain ranges and piedmont slopes that flank the Hueco Bolson.

On the west (Franklin Mountains) and southwest (Sierra de Juarez, Sierra del Presidio) moderately narrow and low elevations in a range of <6000-8000 ft. (1830-2440 m) contrast with highlands of the upper Rio Grande basin. The hydrogeologic

structure of intermontane-basin and river valley fills together form the Hueco Bolson aquifer system, the most important hydrogeologic influence on groundwater flow and chemical composition inside this multipart arrangement of basin deposits and bedrock-boundary units (Figure 1.1) (Hawley, Kennedy, Granados-Olivas and Ortiz, 2009).

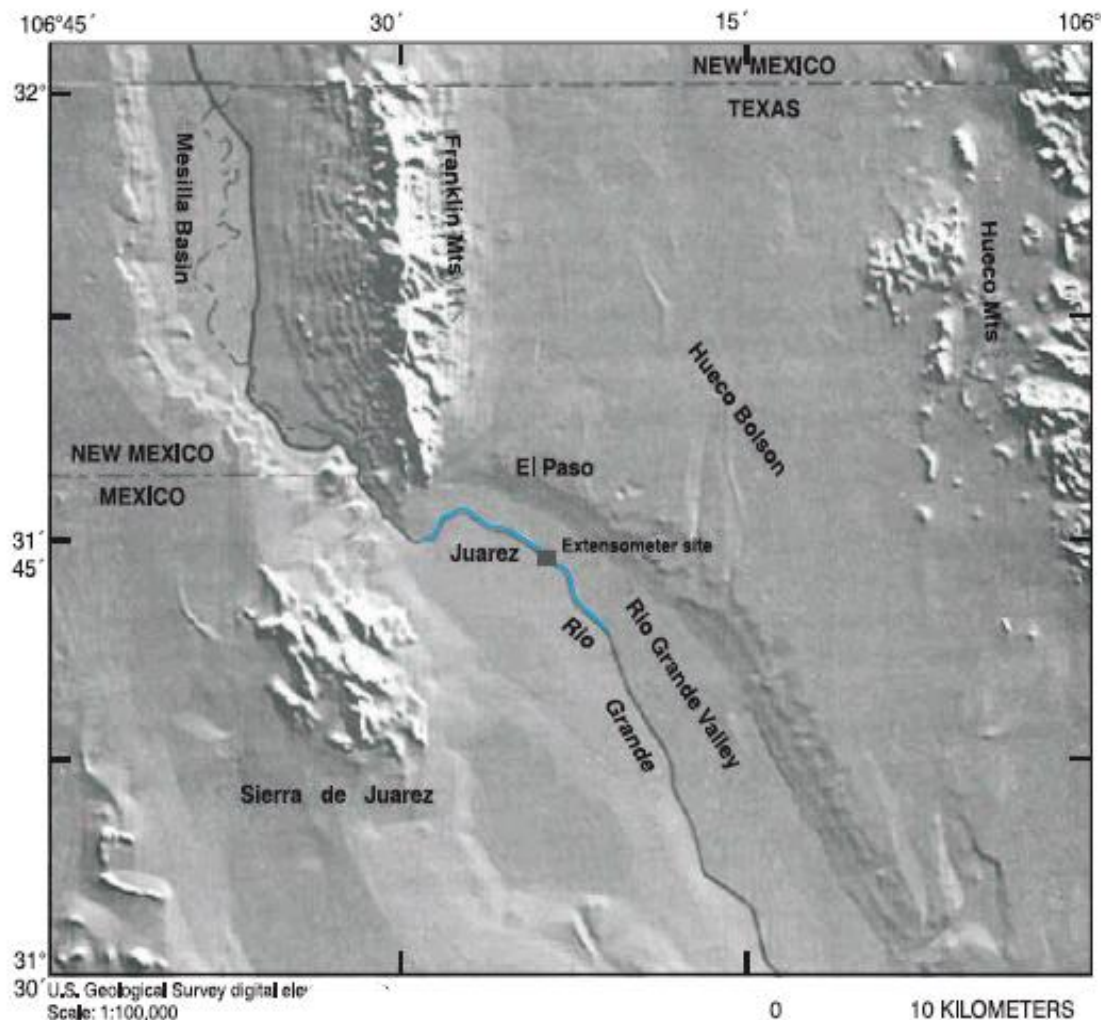


Figure 1.1 Map of southern Hueco Bolson El Paso, Texas and Ciudad Juarez, Chihuahua. (Heywood, 2003).

The Texas Groundwater Protection Committee (TGPC) recognizes that groundwater contamination may result from several sources such as previous and recent oil and gas production and associated practices, agriculture, industrial and manufacturing processes, commercial and business events, domestic activities, and natural sources influenced by human activities (Figure 1.2). The contamination cases

identified are primarily those where contaminants “have been released to the surface, to the shallow subsurface, or directly to groundwater from activities such as the storage, processing, transport, or disposal of products or waste materials” (Texas Groundwater Protection Committee, 2013).

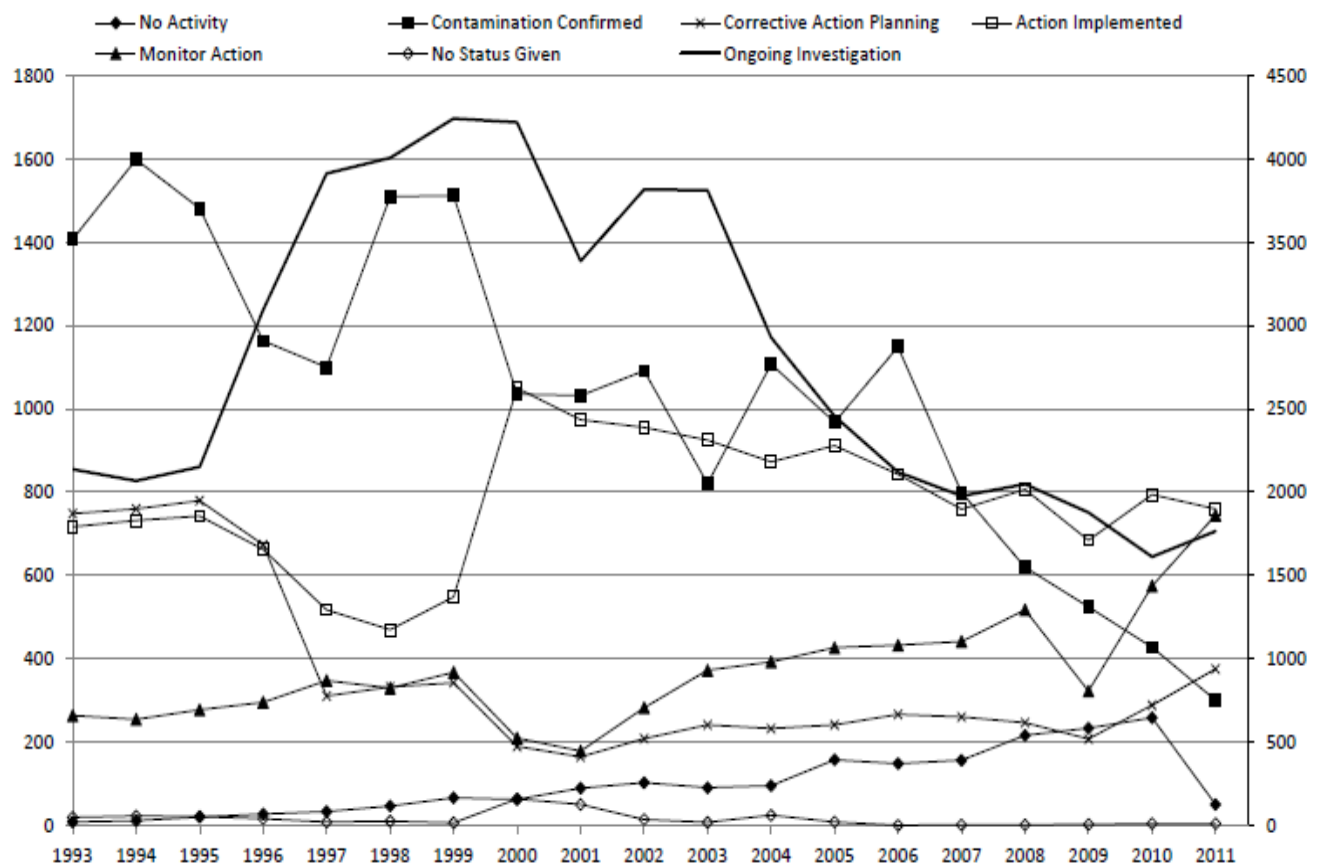


Figure 1.2. History of Groundwater Contamination: Report Trends for Activity Status Codes. Note: Right hand scale for the ongoing investigation. (TCEQ, 2012).

1. 5 El Paso Soil Type Distribution

El Paso County is underlain by intermountain sediments or bolson deposits that were washed from the nearby mountains. They filled the basin that was formed during the uplift of the mountains and the faulting that occurred in the Tertiary Period and lasting into the Quaternary Period. In El Paso County, the basin called the Hueco Bolson at first was enclosed and later drained when the Rio Grande ended its present course. Given that, runoff and rainwater has leached the carbonates and formed the layers of caliche that take place at various depths below the soil surface (U.S. Department Of Agriculture, 1971). Generally speaking, the soils in the region are classified into two soil orders; Entisols of the Rio Grande Valley, and Aridisols in the upland area. Still there are some soils, which are in transition from Entisols to Aridisols, and are nominated as Camborthids. Entisols can show in intermountain arroyos the valley (Table 1.2). The geographical distribution of different soils is shown in Figure 1.3 (Miyamoto, 2012).

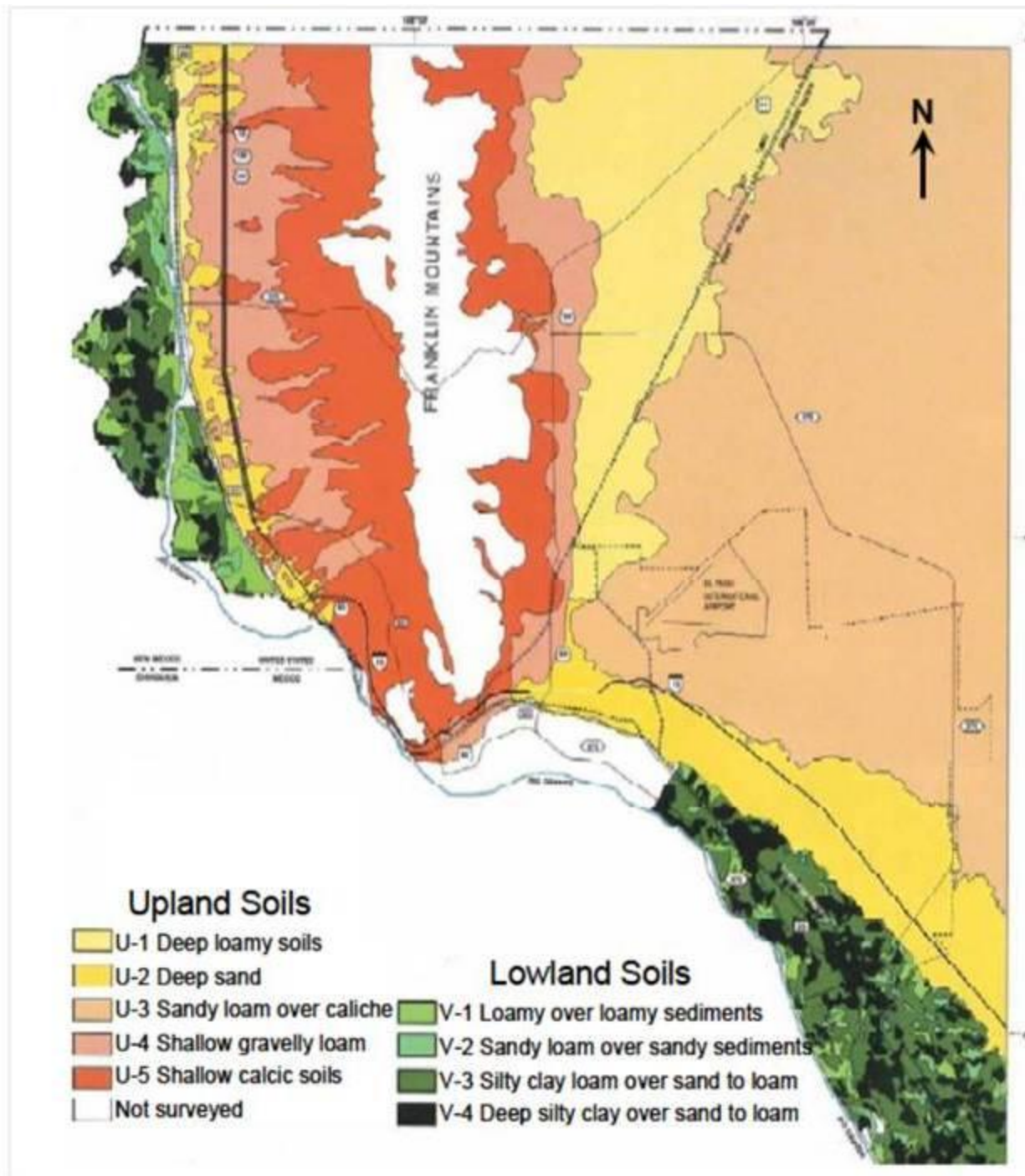


Figure 1.3 Map of geographical distribution of different soils in El Paso, Texas (Miyamoto 2000).

Table 1.2 Soils in the different districts in El Paso, Texas (Miyamoto 2000).

Mapping Units Description	Soil Designation	Subgroup	Soil Classification
Northeast			
U-1 Deep loamy soils	Pajarito (PAA)	Camborthids	Aridisols
	Turney (TBB)	Calciorthids	Aridisols
	Berino (TBB)	Haplargids	Aridisols
	Huecco (HW)	Paleargids	Aridisols
	Wink (WKA)	Calciorthids	Aridisols
East and North Central			
U-2 Deep sand	Bluepoint (BPC, BUC)	Torripsamments	Entisols
U-3 Sandy loam over caliche	Huecco (HW), Wink (WKA)	As above	Aridisols
Northwest			
U-2 Deep sand	Bluepoint (BPC, BUC)	Torripsamments	Entisols
U-3 Sandy loam over caliche	Huecco (HW), Wink (WKA)	As above	Aridisols
U-4 Shallow gravelly loam	Agustin (AGB)	Camborthids	Aridisols
	Canutio (DCB)	Torriorthents	Entisols
	Delnorte (DCD)	Paleorthid	Aridisols
Upper & Lower Valley plus South Central			
V-1 Loam over loamy sediments	Gila (Ga), Harkey (Ha)	Torrifluvents	Entisols
V-2 Sandy loam over sandy sediments	Brazito (Br)	Torripsamments	Entisols
	Gila (Ga), Vinton (Vn)	Torrifluvents	Entisols
V-3 Silty clay loam over sand to loam	Harkey (Hk), Glendale (Ge), Saneli (Sa)	Torrifluvents	Entisols
V-4 Deep silty clay over sand to loam	Saneli (Sc), Glendale (Gs), Tigua (Tg)	Torrifluvents	Entisols

1.6 Ciudad Juarez Soil Type Distribution

Human activities, such as municipalities, industry and agriculture affect the soils and often cause degradation, loss or decrease in soil functions. In order to prevent and to rehabilitate the properties of degraded soils, dependable soil data is an important requirement for the design of proper land-use classification and soil management practices as well as for a better environmental protection the Food and Agriculture Organization of the United Nations (FAO, 2006). The Food and Agriculture Organization of the United Nations (FAO-UNESCO) in its soil classification system published its Soil Map of the World (SMW). In 1998, the International Union of Soil Sciences (IUSS) officially adopted the World Reference Base for Soil Resources (WRB) as the Union's

system for soil correlation. The map in Figure 1.4 was developed by the Unit of Digital Cartography at the Universidad Autonoma de Ciudad Juarez (UACJ) using the existing FAO soil classification system guidelines. The five soil types found in the Ciudad Juarez urban soils are described below:

REGOSOLS: Existing in elevated and/or eroding areas, which occur in unconsolidated materials and which have only superficial profile development, because of low soil temperatures, prolonged dryness or erosion.

SOLONCHAKS: Present in arid and semi-arid regions. Redistribution of calcium carbonate and gypsum is an important mechanism of horizon differentiation in soils in the dry zone. Soluble salts may accumulate at some depth or in areas with shallow groundwater, near the soil surface, with a high content of soluble salts.

LITHOSOL: Any group of shallow azonal soils consisting of imperfectly weathered rock fragments.

SOLONETZ: Present in arid and semi-arid regions. Redistribution of calcium carbonate and gypsum is an important mechanism of horizon differentiation in soils in the dry zone. Soluble salts may accumulate at some depth or, in areas with shallow groundwater near the soil surface with a high percentage of adsorbed sodium ions.

VERTISOLS: Includes mineral soils which formation is conditioned by the particular properties of their parent material. The swelling and shrinking of heavy clay in backswamps, river basins, lake bottoms, and other areas with a high content of expanding 2:1 lattice clays is present (FAO, 2001).

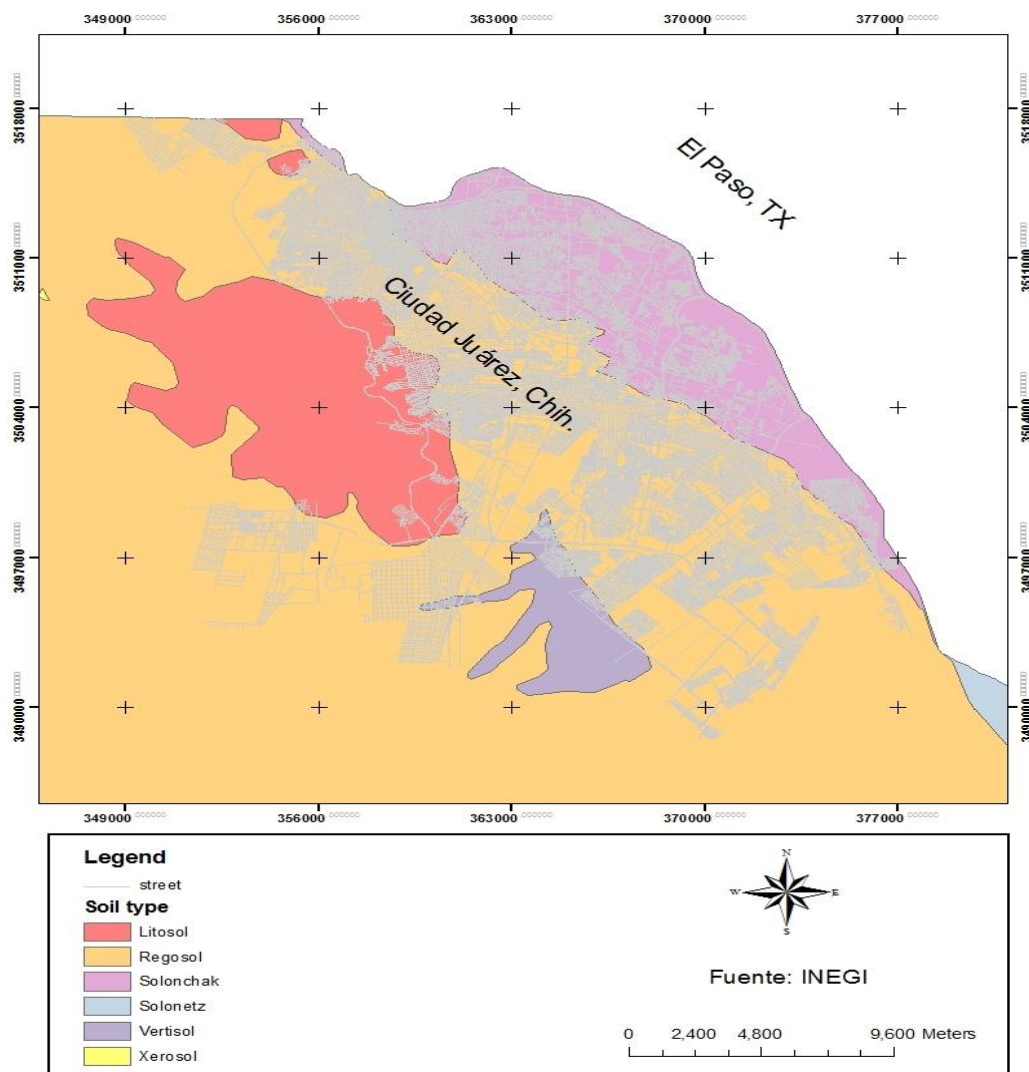


Figure 1.4 Ciudad Juárez Soil Types. De la Mora A. (2013) UCD-UACJ (Unit of Digital Cartography-Universidad Autónoma de Ciudad Juárez).

1.7 Car repair shops as used motor oil generators

Generators are the leading part of the used oil industry; one such form of business would be a car repair shop “businesses that handle used oil through commercial, industrial operations or from the maintenance of vehicles and equipment” (EPA, 2012). Local official data reports about 144 car repair shops in El Paso (Departmental Data Management Specialist, 2010) and a database for Ciudad Juarez listing locations of 1,040 was obtained from the National Geographical and Informatics Institute (INEGI, 2005).

The difficulties associated with environmental management increases when generators are small business such as auto repair shops that are virtually impossible to regulate in the established approach. Car repair shops generate diverse waste streams; whether they are hazardous or nonhazardous, have special requirements for its handling and disposal. The Texas State’s Waste Reduction Policy Act (WRPA) requires businesses that generate more than 1.1 tons of hazardous waste per year to have a source reduction and waste minimization plan. The lubricant mineral-based used oil is an important waste/resource and shops are considered as “used oil generator” if they remove spent engine lubricating oils from a vehicle. The shop must register as a “Used

Oil Collection Center” if the shop collects used oil from other shops or from the public.

The containers utilized to store used oil must be in good condition, not leak, and be clearly marked with the words “Used Oil.” All used oil spills must be cleaned up. Spills of 25 gallons or more have to be reported to the TCEQ local office. For its transport and disposal, only a registered used oil processor may dispose of used oil, shops can transport up to 55 gallons of oil at a time to a registered processor or recycling facility. Only registered used oil transporters may transport larger volumes of used oil (Texas Commission on Environmental Quality, 2003).

1.8 Used Motor Oil composition

The US Environmental Protection Agency (USEPA) defines used oil as “any oil that has been refined from crude oil, or any synthetic oil that has been used, and as a result of such use is contaminated by physical or chemical impurities.”

Motor oil experiences physical and chemical changes during engine operation, the lubricant motor oil function is to protect the engine components by forming a wear-resistant film between moving surfaces, transports chemical additives and inhibits corrosion. Engine oil performs under harsh conditions inside an engine with its combination of high temperature and pressure, combustion function, generation of additives residues and other chemicals break down, the oil gets dirty (Totten, Westbrook and Shah, 2003) PAHs have been identified in UMO, the following

concentrations of two of the 16 EPA priority pollutants because exhibit carcinogenic and mutagenic effects as Benzo (a) pyrene and Benzo (a) anthracene measured in 1071 samples of used motor oil which were reported by Franklin Associated (1984) Table 1.3.

Table 1.3 Carcinogenic and mutagenic PAHs in UMO. (Franklin Associated, 1984).

Positive	Sample%	Mean mgKg ⁻¹	Median	Ranged mgKg ⁻¹
Benzo (a) pyrene	58	24.5	10	< 1 - 405
Benzo (a) anthracene	74	71.3	12	< 5 - 660

Used motor oil may contain small quantities of gasoline, additives, heavy metals nitrogen and sulfur compounds, aromatic and aliphatic hydrocarbons with chain lengths ranging from C₁₅ to C₅₀, PAH's comprise about 4-8 percent of hydrocarbons within used motor oil (Dominguez-Rosado 2003).

Table 1.4 Average constituent concentrations (mg kg⁻¹) of different heavy metals present in UMO (Dominguez-Rosado E., Pichtel J., 2003).

Element	Boughton, 2004	Dominguez, 2003	ATDRS, 1997	Vazquez-Duhalt, 1989	Raymond, 1975	Cotton, 1977
Ba	2.9	4100	-	-	-	-
Pb	49.2	110	240	7000	7500	13
Cd	1.65	9.4	3.0	-	-	-
Cr	3.33	-	6.5	10	21	56
Cu	36	-	-	28	17	2500
Ni	1.5	-	-	-	-	-
Zn	1152	838	480	1100	1500	665
Cl	100	-	-	-	-	-
P	-	-	-	-	-	-
S	3015	-	-	-	-	-
Ash	0.52 wt%	-	-	-	-	-

The metal concentrations reported in used oil depend of the total engine operation time and mechanical conditions. The values are presented in Table 1.4 (Dominguez-Rosado and Pichtel, 2003).

The chemical composition of UMO depends on factors that cannot be anticipated accurately, including the brand and composition of the new motor oil, miles traveled between oil changes, warm or cold climate and the car storage (outside or inside).

Table 1.5 Summarized Characterization of Used Motor Oil (Dominguez-Rosado and Pichtel, 2003).

Component	Mass (kg/h)	Wt %
Sulfur	52.5	1.40
Gasoline	175.0	4.65
Water	350.0	9.30
PAHs	490.0	13.02
Sludge	490.0	13.02
Oil Base Stock	2205.0	58.60
Total	3762.5	-----

Motor oils become “enriched” with PAHs during the operation of an engine. These contaminants are fuel combustion products that are transported into the crankcase and concentrate in lubricating oil. The concentration of PAHs in used oil may

range from 34 to 190 times higher than those in fresh motor oil (Grimmer, Dettbarn, Brune, Deutsch-Wenzel and Misfeld, 1982).

The key characteristics of petroleum-based oils are highly refined, low sulfur, long chain and paraffinic hydrocarbons with excellent lubricant properties. It is a paraffin referred as “basestock” because it is relatively inert not readily vulnerable to oxidation. Motor oils are high technologically oil that requires complex chemical additives (20-25 %) to provide the desired performance (Agency for Toxic Substances and Disease Register (ATSDR,) 1997).

PAH’s in engine oil concentrations increased rapidly with increased miles driven (Pruell and Quinn, 1988). PAH concentrations, predominantly two and three-ring compounds, increased until about 4,000 miles. The more toxic five ring PAHs (benzopyrenes) were only detected at 5,800 miles. At the end of the study, the total PAH concentration in the used oil was 10,300 micrograms per gram ($\mu\text{g/g}$) or about 1 percent of the oil. The Canadian Council of Ministers of the Environment (CCME)(2010) mentioned that crankcase oil that is used as lubricant in internal combustion contains a mixture of petrogenic and pyrogenic PAHs or combustion-derived PAHs that accumulates with increased use.

1.9 UMO Regulations

1.9.1 US Legislation

Used oil management standards have been in place for more than 15 years at the federal level. The U.S. Department of Energy (DOE) and U.S. Environmental Protection Agency (EPA) cooperate to perform a study of the energy and environment benefits of the re-refining of used lubricant oil, raising the environmental implications of used oil for the Energy Policy Act of 2005 (Eaton D. J., 2007).

The EPA established standards for hazardous wastes and includes used oil among wastes considered hazardous. A final decision on used oil was not made until 1992 when the EPA decided that used oil would not be classified as a hazardous waste (EPA, 1992); instead the agency created the used oil management standards to reduce the threat that used oil poses to the environment, including the used oil recycling practices required by the Resource Conservation and Recovery Act (RCRA).

The (RCRA) is a US law that provides guidelines for the waste management. It includes a Congressional mandate requesting that EPA develop comprehensive regulations to implement the law. The hazardous waste program, under RCRA Subtitle C, establishes a system for controlling hazardous waste from the time it is generated until its ultimate disposal.

The EPA encourages states to assume primary responsibility for implementing a hazardous waste program through State adoption, authorization, and implementation of the regulations. Hazardous waste is waste with properties that make it dangerous or potentially harmful to human health or the environment. RCRA hazardous wastes fall into two categories: Waste specifically listed and Waste that has not been specifically listed may still be considered a hazardous waste if it exhibits one of the four characteristics defined in the 40 CFR (Code of Federal Regulations) Part 261 Subpart C- ignitability (D001), corrosivity (D002), reactivity (D003), and toxicity (D004 - D043).

The federal government regulates used oil through the Code of Federal Regulations (CFR), title 40, part 279 entitled "Standards for the Management of Used Oil" that establish standards for used oil generators, collection centers and aggregation points, transporters and transfer facilities, processors and re-refiners, burners of off-specification used oil and used oil marketers (EPA, 1992).

There are two leading environmental considerations regarding lubricating oil (Eaton D., 2006). After use, oil must be collected and properly disposed of. When not properly disposed of, used oil can persist in the environment and even migrate to water where it could affect ecosystems or contaminate drinking water supply (EPA, 1994).

In the United States, both federal and state governments regulate the handling of used oil. Once used oil has been generated, its handling is regulated until it reaches one of six possible disposals: processing or re-refining; burning; reuse; or disposal as a solid waste, hazardous waste or a waste containing polychlorinated biphenyls.

The State of Texas has established regulations found in the Texas Administrative Code (TAC), title 30, part I, chapter 324 (Texas Used Oil Standards) and title 20, part I, chapter 328, subchapter D (Texas Used Oil Filter Management and Recycling). The Texas used oil standards incorporate all of the federal used oil regulations and stipulates how to comply with the registration and reporting requirements of the federal regulations while also expanding the registration and reporting requirements for used oil collection centers.

The Texas used oil standards outlaw the disposal of used oil in landfills, and address other specific situations such as storage of used oil in underground storage tanks or oil spills, while also establishing procedures that are not addressed specifically such as the handling of used oil filters.

1.9.2 Mexico's Legislation

Waste management policies and regulations are contained in two central pieces of legislation: La Ley General para el Equilibrio Ecologico y Proteccion al Ambiente,

(LGEPA) translated into English as the General Law of Ecological Balance and Environmental Protection (hereinafter Ecology Law) and the Reglamento de la LGEPA en Materia de Residuos Peligrosos, translated into English as the, Regulation under the General Law of Ecological Balance Regarding Hazardous Waste (Reglamento de la LGEPA en Materia de Residuos Peligrosos) (hereinafter Hazardous Waste Regulation). Both the Ecology Law and the Hazardous Waste Regulation are implemented through Official Mexican Standards (Normas Oficiales Mexicanas or (NOM). “Jurisdiction over waste management issues is divided among federal, state and municipal authorities. At the federal level, the Secretariat of the Environment and Natural Resources (SEMARNAT) has exclusive jurisdiction over all hazardous waste management. States and municipalities are responsible for the regulation, management, authorization and enforcement of solid and non-hazardous waste standards” (CEC, 2003).

Mexican laws defines waste as “any material generated in an extraction, benefit, transformation, production, consumption, use, control or treatment process which quality does not allow it to be used in the process that generated it.” Hazardous waste is “any waste in any physical form which due to its corrosive, reactive, explosive, toxic, flammable, or biologically-infectious characteristics (CRETIB) , represents a hazard to the environment or environmental equilibrium” (Department of Commerce U.S.A. and SEMARNAT, 2001).

In addition, the Mexican Congress passed the General Law for the Prevention and Integral Management of Waste (2003 Waste Law) published in the Federal Official Gazette in 2003 (SEGOB, 2003) to regulate all aspects of waste management, including used oil within the hazardous waste category.

NOM-052-ECOL-1993 also establishes chemical and physical technical standards for determining whether specific wastes have any of the CRETIB characteristics (Table 1.6).

Table 1.6 Mexican hazardous waste standards related to used oil. Source: SEMARNAT, Gestion de Materiales, Residuos y Actividades de Riesgo.

Title and date Published	Description of the Standard
NOM-052-SEMARNAT-2005 June 23, 2006	Characteristics and list of thresholds above which a waste is considered hazardous due to environment toxicity.
NOM-055-SEMARNAT-2003 November 3, 2004	Requirements for hazardous waste storage facilities.
NOM-056-SEMARNAT-1993 October 22, 1993	Design and construction standards for hazardous waste storage structures.
NOM-057-SEMARNAT-1993 October 22, 1993	Design, construction and operating standards for hazardous waste storage facilities.
NOM-058-SEMARNAT-1993 October 22, 1993	Operating requirements for the hazardous waste storage facilities.
NOM-002-SCT-2003 December 3, 2003	List of commonly transported hazardous substances and material.
NOM-117-SEMARNAT-1998 November 24, 1998	Specifications for installation and maintenance of systems for the transportation and distribution of hydrocarbons and petrochemicals in liquid and gaseous state that transported on existing terrestrial paths in agriculture, cattle raisers, and uncultivated zones.
NOM-138-SEMARNAT/SS-2003 March 29, 2005	Allowable thresholds of hydrocarbons in soils and soils remediation.

1.10. UMO Recycling

Used petroleum hydrocarbons are an environmental and human health hazard if not disposed of correctly. The 1.37 billion gallons per year of used oil generated in the U.S. can be managed in three primary ways: re-refined into base oil for reuse, distilled into marine diesel oil fuel, and marketed as untreated fuel oil, because the wide demand for used oil as fuel has localized impacts in many areas, such methods of UMO management have great impact at local, regional and global levels Figure 1.5.

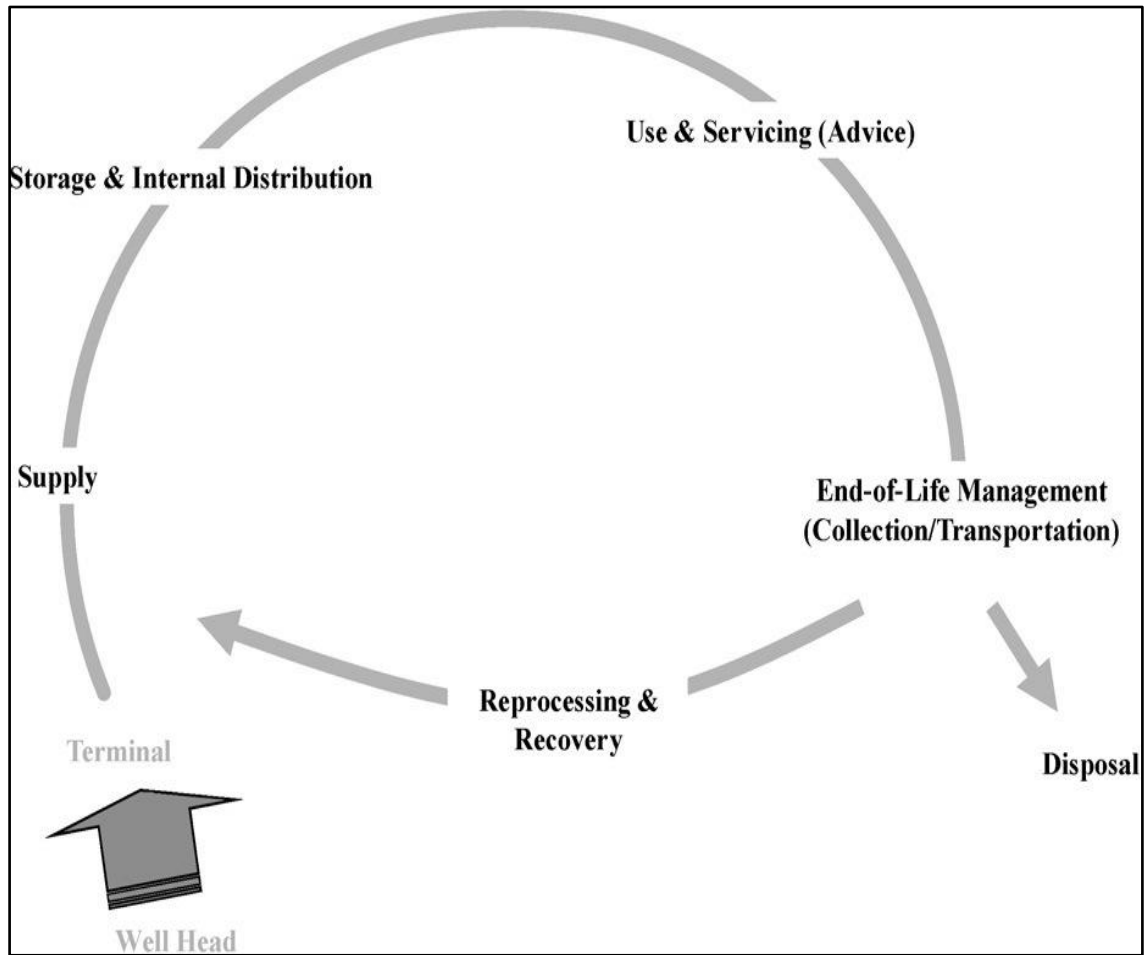


Figure 1.5 Lubricants life cycle. Guerin (2008)

To assess the environmental impact using a lifecycle assessment (LCA) approach, a life-cycle inventory showed that 800 mg of zinc and 30 mg of lead air emissions may result from the combustion of 1 L of used oil as fuel (50-100 times that of crude-derived fuel oils). An impact assessment showed that in toxicity related to heavy metals, emissions of zinc were 150 times higher and emissions of lead were 5

times higher in used oil combusted as fuel than in re-refining or distillation (Boughthon and Horvat, 2004).

Currently, the estimated 945 million gallons of recycled used oil each year, 83 percent is burned and 17 percent is re-refined. Transforming all used oil that is now combusted into lube oil products could save 63 million gallons of fuel oil equivalent to savings of \$63 million annually at current fuel prices (U.S. Department of Energy, 2005).

Standards and specifications for recovered waste oil show the allowable levels of contaminants in Table 1.7 below.

Table 1.7 Maximum values of contaminants for waste oil recovery.

Allowable level	Constituent/property
5 ppm maximum	Arsenic
2 ppm maximum	Cadmium
10 ppm maximum	Chromium
100 ppm maximum	Lead
100 °F minimum	Flash point
4,000 ppm maximum *	Total halogens

*Used oil containing more than 1,000 ppm total halogens is presumed to be a dangerous waste under the rebuttable presumption provided under 40 CFR 279.10(b)(1). Such used oil is subject to 40 CFR Subpart H of Part 266 rather than this section when burned for energy recovery unless the presumption of mixing can be successfully rebutted. Note: Applicable standards for the burning of used oil containing PCBs are imposed by 40 CFR 761.20(e).

1.11. PAHs source and characteristics

PAHs are chemicals formed during the incomplete combustion of oil, gas, wood, garbage, or substances like tobacco and charbroiled meat, released from fossil fuels that cause environmental PAH contamination on a global scale and from natural sources such as plant and bacterial products, forest fires and volcano activity that occur world-wide including air, soil and water (Wick and Daniels, 2011). Anthropogenic activities are primary PAH sources such as power generation, refuse burning and coke manufacture, that account for 50% of the benzo(a)pyrene emissions per year; vehicular PAH emissions account for 35% in populated areas; diesel power is a source of light molecular weight PAHs, whereas gasoline power is a major source of heavy molecular PAH (Juhaz and Naidu 2000) PAHs are usual components of fuels and lubricant oils. Frequent sources of PAHs input to soil are: fuel spills, leaks from under and above storage tanks (Canadian Soil Quality Guidelines, 2010).

UMO that is improperly disposed of in soils can be carried in stormwater runoff. The pollutants in runoff are oil and components such as metals and polycyclic aromatic hydrocarbons (PAHs). Petroleum hydrocarbons in urban runoff as well as in aquatic sediment in municipal areas are primarily associated with UMO (Mazur & Milanes 2006).

Oil and grease in water form a sheen observed in waterways and in parking lots or street runoff this visibility has been the major motivation to control oil and grease in stormwater runoff. Water quality criteria established by the USEPA pursuant to Section 304(a) of the Clean Water Act specify that oil and grease should not be present at levels that produce a visible oily sheen (U.S. EPA, 2004). Oil and grease concentrations less than 1 mg/l can create sheen on surface waters due to the reflection of sunlight (CDS, 2005).

Latimer et al. (1990) analyzed street dust, soil and vegetation to detect sources of hydrocarbons in urban runoff. They found that the mainstream of oil came from oil drips within the driving lanes on road surfaces or deposits in parking areas, and from direct dumping of waste crankcase oil into storm drains.

In the United Kingdom, concentrations of oil and grease of 4.9 mg/L were found in urban runoff at residential sites, while 7.1 mg/L were found at the industrial sites (Ellis and Chatfield, 2006). Hoffman et al. (1984) estimated that 36% of the environmental PAH input was due to urban runoff.

PAHs are organic pollutants, formed by complex hydrocarbons comprising two or more fused aromatic rings, PAHs undergo long-range transportation, and present low solubility and volatility, high lipophilicity and persistence that increase with ring number.

They are considered a health risk due to their potential carcinogenic and mutagenic properties (Yu, et al., 2014).

Higher weight molecular (HWM) PAHs exhibit much greater propensity than lower weight molecular (LWM) PAHs to remain sorbed to soils rather than partition into water or air, and also tend to bioaccumulate (CCME, 2010).

The USEPA has recognized 1,408 hazardous waste sites as the most serious in the nation. These sites constitute the National Priorities List (NPL) of which 600 have been found to contain PAHs (EPA 2012).

PAHs mostly occur as complex mixtures, not as separate compounds, and usually exist as colorless, white, or pale yellow-green solids and can have a faded, pleasant odor. Some of them are used in medicines and to make dyes, plastics, and pesticides; others are used in asphalt, crude oil, coal creosote, roofing tar and coal tar pitch (ATSDR, 2011).

Five PAHs have three rings (acenaphthene, acenaphthylene, anthracene, fluorene, and phenanthrene) and are slightly more mobile in soil. PAHs with four or more rings have very low water solubility and volatility, are strongly sorbed to soil, and resist chemical and biological degradation. Naphthalene, with only two rings, has good water solubility and volatility and is moderately sorbed to soil. These suggest that naphthalene

has a potential to move through soil and to contaminate groundwater more than other PAHs (Joy and VanCantfort, 1999). Figure 1.6 shows all 16 EPA priority PAHs structures.

The USEPA has placed 16 PAH compounds on the Priority Pollutant List created under the Clean Water Act. Pollutants are selected for this list because of potential for toxicity and frequency of occurrence in hazardous waste. Seven of these selected compounds are considered to be possible carcinogens: Benz(a) anthracene, Chrysene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Dibenzo(a,h)anthracene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd)pyrene (ATSDR, 1995).

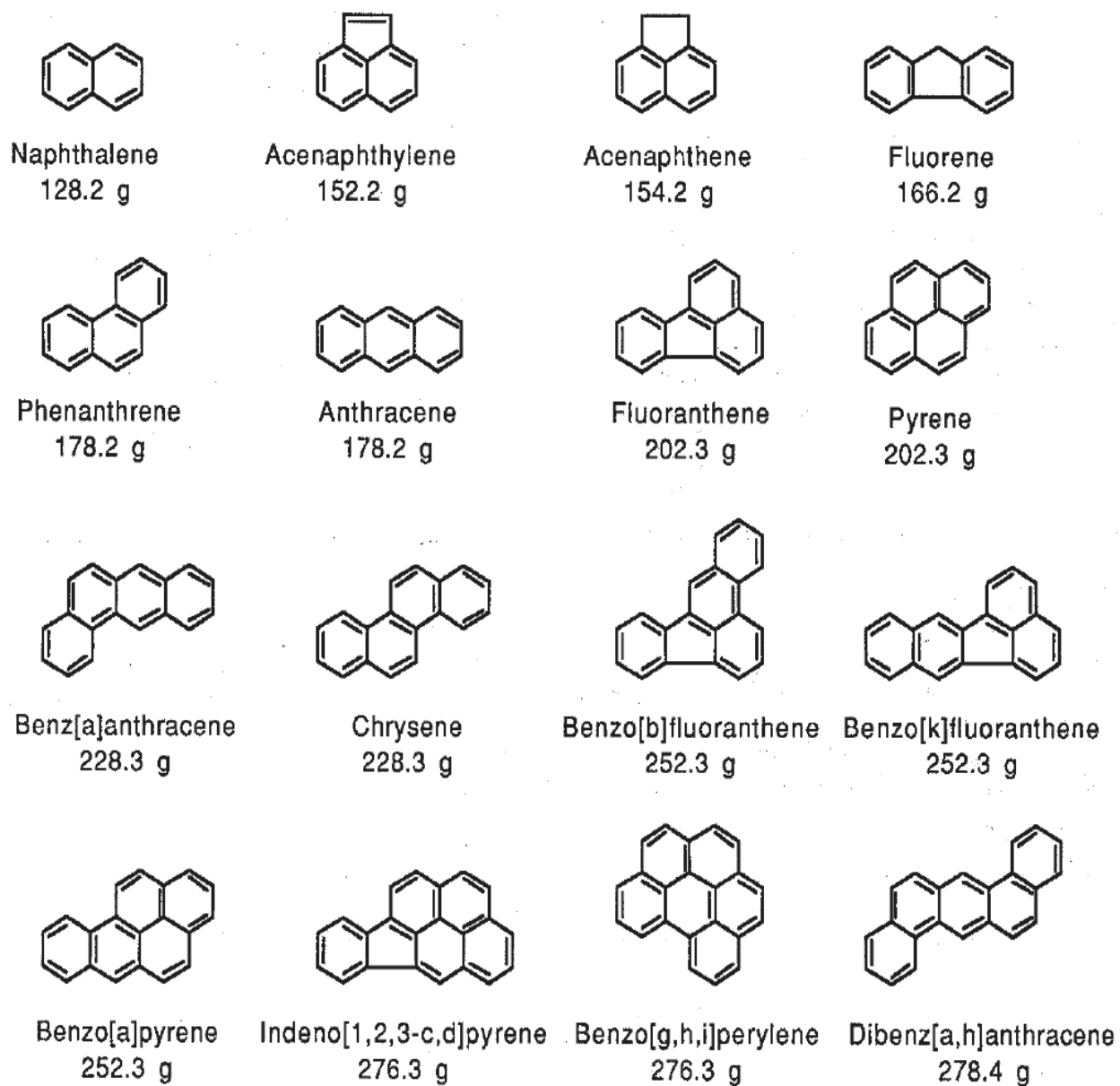


Figure 1.6 Molecular structures of the 16 polycyclic aromatic hydrocarbons (PAHs) selected as priority pollutants by the USEPA. Numbers are molecular weights.

1.12. PAHs in Urban Soils

Most UMO soil contamination results from surface releases. The viscosity of UMO prevents it from penetrating beyond the first few inches of soil. The constituent metals and most of the PAHs demonstrate low volatility, low solubility, and a strong affinity for soil particles.

PAHs in soil can volatilize, undergo abiotic degradation (photolysis and oxidation), biodegrade, or accumulate in plants. PAHs in soil can also enter groundwater and be transported within an aquifer (ATSDR, 1997).

The Resource Conservation and Recovery Act (RCRA), and Risk Assessment methods yield risk based cleanup levels for PAHs that range from 0.1 to 0.7 mg/kg. Given their universal presence in the urban environment, it is important to compare risk-based cleanup levels with typical urban background levels before utilizing unrealistically low cleanup targets (Bradley, Magee and Allen, 1994).

It is very difficult to compare the outcomes among PAHs ranges in urban soil studies to evaluate a site environmental assessment, since a number of variables must be accounted for, including the number of rings in the PAH structure, the non-uniformity of the PAH compounds evaluated, different analytical methods, local weather conditions, and the transport and environmental fate of an individual PAH.

Mauro et al. (2006) through studies in the US and Europe have shown that the concentrations of PAH in surface soils can range from few to hundreds of parts per billion depending on the proximity to and contribution from PAH sources. The studies were implemented in municipalities of New York, Illinois and Pennsylvania, with 319 samples collected from 0-6 inches of depth. The concentration of total PAHs ranged from 84 g kg⁻¹ to 147,000 g kg⁻¹ with an average concentration of 7330 g kg⁻¹ total PAHs and a median concentration of 1960 g kg⁻¹, as shown in Table 1.8. EPA residential risk based concentrations (RBCs) were exceeded for one or more compounds in more than 60% of the samples tested.

Table 1.8 Summary statistics for 319 samples (g kg⁻¹) (Mauro, DeClercq, Siegener, & Coleman, 2006).

Compound	Range	Mean	Median	EPA-RBC	Exceedances
Naphthalene	ND-3010	79	16	-	-
Pyrene	ND-16 600	780	190	-	-
Benz(a)anthracene	ND-9170	460	110	870	42/319
Benzo(a)pyrene	ND-11 700	495	130	87	193/319
Dibenz(a,h)anthracene	ND-3010	125	29	87	91/319
Indeno(1,2,3-cd)pyrene	ND-8240	340	89	870	36/319

ND: Not detected.

This study reveals that PAHs are present in almost all surface soils, specifically: “The concentration of PAHs in urban surface soils are log normally distributed. The concentration of high molecular weight is much higher than low molecular weight PAHs, 60 percent of the sites sampled exceeded the RBC for benzo(a)pyrene” (Mauro, DeClercq, Siegener and Coleman, 2006).

Norhayati et al. (2008) carried out a study to determine the concentration and distribution of 16 priority PAHs in urban soil of Chukai Kemaman, Malaysia. Results generally indicated that the total PAH concentration in soils ranged from 6.27 g kg^{-1} to 547.3 g kg^{-1} . Almost all stations showed the presence of benzo(a)pyrene, a signature PAH compounds known to be associated with vehicular emissions, indicating the importance of vehicular emission as a source of PAHs in these soils. In addition, the contribution of biomass burning to the presence of PAHs in these soils indicated a positive correlation between Benzo(a) pyrene and total PAHs.

Nganje T.N. et al. (2007) The concentrations of polycyclic aromatic hydrocarbons (PAHs) in surface soils from petroleum handling facilities (kerosene tank, generating plant, petrol stations, mechanic workshops, leaking pipeline and airport fuel dump) from Calabar metropolis southeastern Nigeria were determined by gas chromatography/mass spectrometry. The results show that total (PAHs) varied from 1.80 to $334.43 \text{ mg kg}^{-1}$ with a mean of 50.31 mg kg^{-1} . The lowest value of 1.80 mg kg^{-1} was obtained from

a petrol station while the highest value of $334.43 \text{ mg kg}^{-1}$ was obtained from a facility characterized by petrol stations and mechanic workshops. The two to three ring PAHs are the most abundant.

Wang G. et al. (2008) mention that incomplete combustion of petroleum and coal is the primary source of elevated concentrations of urban PAHs. To determine and compare the concentration of PAHs in soils taken from two major US cities, 107 soil samples were taken in New Orleans and 106 soil samples in Detroit to examine the main sources of PAHs in urban soils. The average of total PAH (sum of 17 PAH concentrations) of Detroit soils was $7,843 \text{ } \mu\text{g kg}^{-1}$, compared to $5,100 \text{ } \mu\text{g kg}^{-1}$ for New Orleans soils. PAH concentrations are attributable to pyrolytic sources, mainly vehicle exhaust. Travel and gasoline consumption data in Detroit and New Orleans support these findings.

Jiang et al. (2009) analyzed PAHs in 55 surface soil samples collected from Shanghai urban districts. The total concentrations of 22 PAHs ranged from 442 to $19,700 \text{ } \mu\text{g kg}^{-1}$ with a mean of $3780 \text{ } \mu\text{g kg}^{-1}$, and the sum of 16 priority PAHs varied from 347 to $17,900 \text{ } \mu\text{g kg}^{-1}$ with a mean of $3290 \text{ } \mu\text{g kg}^{-1}$ and the seven possible carcinogenic PAHs accounted for 36-58% of the sum of 16 priority PAHs. The composition of PAHs was characterized by the high molecular weight PAHs, among

which fluoranthene, pyrene, benzo(b)fluoranthene and chrysene were the most dominant components (Jiang et al. , 2009).

Zhang (2011) analyzed 16 EPA priority PAHs in urban surface soils from Jiaying city using HPLC. Total concentration ranged from 18.73 to 441.34 $\mu\text{g g}^{-1}$. The analysis demonstrates that four-ring PAHs comprise as much as 44.16% and were the prevalent compounds, while other components were two-ring PAHs (7.36%), three-ring (17.28%), five-ring (16.16%) and six-ring (15.04%).

These results are supported by the research of De La Torre et al. (2009) in El Paso, Texas: the total PAHs in El Paso soil ranged from 0.1 to 2225.5 $\mu\text{g kg}^{-1}$. Although the majority of PAH concentrations did not exceed the soil screening levels regulated by the United States Environmental Protection Agency, the existence of PAHs in this ecosystem is ubiquitous. “The results ruled out the possibility of petroleum refining as the significant source of local soil-borne PAH contamination, but they suggested that the PAHs found in El Paso soil were closely linked to human activities and possible other industrial processes”. (De La Torre, et al. 2009, p.946). Table 1.9 shows examples of PAH levels found in non-industrial and industrial sites by different authors.

Table 1.9 Levels of PAHs found in non-industrial and industrial soils. (Wick 2011)

Site	Total PAHs Concentration	Source	Author
Remote areas	1-10 g kg ⁻¹	Forest fires Airborne pollution	Edwards (1983)
Welsh soils (England and Wales)	0.1-55 mg kg ⁻¹	Atmospheric deposition	Jones et al. (1989)
Creosote production site	5,863 mg kg ⁻¹	Industrial process	Juhaz and Naidu (2000)
Wood preserving site	18,704 mg kg ⁻¹	Industrial process	Juhaz and Naidu (2000)
Petrochemical site	821 mg kg ⁻¹	Industrial process	Juhaz and Naidu (2000)
Gas manufacturing plant	451 mg kg ⁻¹	Industrial process	Juhaz and Naidu (2000)

1.13 Used Motor Oil PAHs: Environmental and Human Risk

1.13.1 Environmental Risk

The global movement of PAHs can be explained as follows: PAHs released to the atmosphere undergo short- and long-range transport and can be removed by wet and dry deposition onto soil, water, and vegetation.

Once in surface water bodies, PAHs can volatilize, photolyze, oxidize, biodegrade, bind to suspended particles or sediments, or accumulate in aquatic organisms (with bioconcentration factors often in the 10-10,000 range) (ATSDR, 1995). In sediments, PAH can biodegrade or accumulate in aquatic organisms. PAHs in soil can volatilize, undergo abiotic degradation (photolysis and oxidation), biodegrade, or

accumulate in plants; they can also be transported by runoff, enter groundwater or aquifers (DHHS and ATSDR, 1995).

PAHs are ubiquitous in the environment, and present an affinity for sediments and soils as principal environmental sinks (Juhaz and Naidu, 2000). Once released into the soil PAHs will adsorb to particulate matter where they will be biodegraded by microbial activity or transported by runoff. In air and water, PAHs are found adsorbed to particulate matter where they tend to persist.

1.13.2. Terrestrial Plants and Invertebrates

In general, the presence of hydrocarbons including PAHs can reduce or augment heterotrophic microbial activity in soils. Several microbial and fungi groups can utilize some PAHs (naphthalene, phenanthrene and pyrene) as their only carbon source, as at high concentrations the toxic effect can suppress the microorganisms activities (Canadian Soil Quality Guidelines, 2010).

The extent to which a contaminant in soil enters the plant root depends on several factors; these include water solubility, Henry's Law constant (linking the partial pressure of the compound and its gas concentration in solution), and the octanol-water partition coefficient K_{ow} (degree to which an organic compound prefers lipid over water),

organic matter content, moisture, pH, temperature, species and stage of plant growth and lipid content (Duarte –Davidson and Jones, 1996).

Terrestrial plants present a wide range in tolerance to PAH contamination (Table 1.10). Lower molecular weight PAHs with a log K_{ow} less than 4.0 to 4.6 tend to be toxic to plants at high concentrations, while high molecular weight PAHs have limited potential for phytotoxicity, likely due the limited potential for PAHs desorption from soil and consequently limited bioavailability (Duarte –Davidson and Jones, 1996).

Table 1.10 Plant species identified growing on three ancient gaswork plant sites (Henner, Schiavon, Druelle and Lichrfouse, 1999).

Family	Genus and species
Apiaceae Asteraceae	Daucus carota Artemisa vulgaris Cirsum arvensis Erigeron canadiensis Matricaria perforata Sonchus oleracerus Tanacetum vugare
Boraginaceae Brassicaceae	Echium vulgare Diplotaxis tenuifolia Sinapis arvensis Sysimbrium officinale
Caryophyllaceae Chenopodiaceae	Silene dioica Chenopodium hybridum Chenopodium murale
Hypericaceae Crassulaceae	Hypericum perforatum Sedum acrum Sedum album Loganiaceae buddleia
Onagraceae	Epilobium angustifolium Epilobium perforatum
Papaveraceae Poeaceae	Papaver rhoeas Cynodon dactylum Digitaria sanguinalis Festuca rubra Poa annua
Ranunculaceae Rosaceae Solanaceae	Clematis vitalba Ronce Solanum dulcamara Solanum nigrum
Vervasceae Betulaceae Salicaceae	Verbascum thapsus Betula alba Populus tremula

Soil sorption properties and aging of contaminants in soil represent the potential bioavailability and hence toxicity from the hydrophobic organic contaminants to soil

plants and invertebrates based on direct contact paths or soil ingestion (Reeves, McDonald, Bordelon, George and Donnelly, 2001).

PAH bioavailability is affected by: physical properties (LMW and HMW), soil properties (clay and organic matter content and structure), receptor organisms (bacteria, earthworms, arthropods, etc.) (Wick and Daniels, 2011).

Bioconcentration aspects for uptake by earthworms of anthracene, fluoranthene and pyrene from soil range from 0.99 to 2.34 depend of the age and kind of PAH (GRI/PERF, 2000).

While PAHs are accumulated in terrestrial and aquatic plants, fish, and invertebrates, many animals are capable of metabolizing and eliminating these compounds. Bioconcentration factors (BCFs), which express the accumulation in tissues compared to concentration in media, are commonly in the 10-10,000 range for fish and crustaceans. Food chain uptake does not seem to be a main source of exposure to PAHs for aquatic animals (Department of Health and Human Services, (DHHS) and ATSDR, 1995).

PAHs pose an environmental hazard for non-vertebrates, plants and microbes, as well as for short - lived vertebrates with carcinogenesis and toxicological endpoints as likely factors for individual and population health.

For the non-human environment protection soil quality guidelines are recommended as follows Table 1.11.

Table 1.11 Recommended soil quality guidelines for non-human environment (Canadian Soil Quality Guidelines, 2010).

For Agricultural and Residential/Parkland sites	
Anthracene	2.5 mg Kg ⁻¹
Benzo(a)pyrene	20 mg Kg ⁻¹
Fluoranthene	50 mg Kg ⁻¹
For Commercial and Industrial Sites	
Anthracene	32 mg Kg ⁻¹
Benzo(a)pyrene	72 mg Kg ⁻¹
Fluoranthene	180 mg Kg ⁻¹

1.13. 3. Human Risk

The EPA classifies PAHs as priority pollutants because of their carcinogenic and mutagenic requiring effects. PAH are difficult to measure in environmental matrices requiring complex procedures for chemical (EPA, 2013).

The principal sources of human exposure to PAHs for population are active or passive inhalation in tobacco smoke, wood smoke and contaminated air, additionally foods that are grilled or smoked pose higher concentration than background levels. Humans may also be exposed to PAHs in drinking water and by skin contact with soot and tars. Estimations of total daily intake of PAHs by a common person has been estimated to be 0.207 g from air, 0.027 g from water, and 0.16-1.6 g from food, the total potential exposure to carcinogenic PAHs for adult males was calculated to be 3 g/day (DHHS and ATSDR, 1995).

Based on a personal lifestyle (Table 1.12), the life-long intake (e.g. 70-78 years) of benzo(a)pyrene for a non-occupationally exposed person may add up to 29 mg together with respiratory, gastrointestinal and percutaneous absorption. Placental transmission of PAHs seems to be limited; therefore fetal levels are not as high as maternal levels (Canadian Soil Quality Guidelines, 2010).

Table 1.12 Estimation of total PAH intake for humans (DHHS and ATSDR, 1995).

Estimated by	Concentration	Observations
Santodonato et al. (1981)	0.2 to 20 g/day	
De Kok and van Maanen (2000)	25 to 300 g/day	Excluding individuals occupationally exposed
CCME Canadian Soils Quality Guidelines (2010)	29 mg benzo(a) pyrene	Lifelong intake (70-78 years) for non-occupational exposed humans.

Human exposure to PAHs has been linked to an increased risk of developing cancer in a variety of tissues such as lung, bladder, stomach and skin together with the scrotum based on the type of exposure and the form of PAH (International Agency for Research on Cancer (IARC)-World Health Organization (WHO) 2014). Lung cancer have been associated with PAH exposure in an occupational settings as well as coal gasification, coke production, paving and roofing.

Mechanics and autoworkers exposed to used mineral-based crankcase oil in a daily basis have developed skin rashes, blood effects (anemia), headaches and tremors. However, these workers are also exposed to other chemicals, which may have caused these health effects (DHHS and ATSDR, 1995).

In reference to UMO, several factors will establish the harmful effects, type and severity. These factors include the dose, duration, route, other chemicals present and the individual characteristics such as age, gender, nutritional status, family traits, lifestyle and state of health (DHHS and ATSDR, 1995).

For the protection of human health, Soil Quality Guidelines for the protection of potable water (SQGpw), that are the same for all the land uses, derived component values were derived for the individual carcinogenic PAHs have been incorporated into the Index Additive Cancer Risks (IARC) equation to account for the combined effects of individual PAHs in the mixture Table 1.13.

Table 1.13 Component values for potable water, and all land uses (Canadian Soil Quality Guidelines, 2010).

Benz(a)anthracene	0.33 mg kg ⁻¹
Benzo(a)pyrene	0.16 mg kg ⁻¹
Benzo(b,j,k) fluoranthene	6.8 mg kg ⁻¹
Benzo(g,h,i)perylene	0.37 mg kg ⁻¹
Chrysene	2.1 mg kg ⁻¹
Dibenz(a,h)anthracene	0.23 mg kg ⁻¹
Indeno(1,2,3-c,d)pyrene	2.7 mg kg ⁻¹

For assessing human health risks of PAH-containing mixtures includes the use of potency equivalence factors (PEFs) or toxicity equivalence factors (TEFs) that are used to relate the carcinogenic potential of other PAHs to that of benzo(a)pyrene.

Table 1.14 Benzo(a)pyrene Potency Equivalence Factors. Canadian Soil Quality Guidelines (Canadian Soil Quality Guidelines, 2010).

Compound	PEF
Benz(a)anthracene	0.1
Benzo(a)pyrene	1
Benzo(b,j,k) fluoranthene	0.1
Benzo(g,h,i)perylene	0.01
Chrysene	0.01
Dibenz(a,h)anthracene	1
Indeno(1,2,3-c,d)pyrene	0.1

Note: Since these three isomers closely co-elute using most contemporary analytical methods, the PEF applies specifically to the total of the three co-eluting PAHs

1.14 Risk Assessment

Risk assessment has become a leading public policy instrument. The toxicity of PAHs represents a risk to human health, and there are different risk assessment approaches based on exposure routes and scenarios. People can be exposed to UMO when changing the engine oil of their cars, breathing the chemicals from the UMO in exhaust fumes, touching contaminated soil or drinking contaminated water (ATSDR, 1995).

The evidence in humans occurs mostly from occupational survey of workers exposed to mixtures containing PAHs as coke production, roofing, oil refining, or coal

gasification. PAHs also may contribute to the pathogenesis of atherosclerosis in humans, a risk for those individuals who are exposed to high levels of PAHs in the environment and who also smoke cigarettes (DHHS and ATSDR, 1995).

PAHs are contaminants that are assessed for risk based on their toxicity and exposure. Low molecular weight (LMW) PAHs are considered directly toxic. High molecular weight (HMW) PAHs are considered genotoxic, able to cause DNA damage (Lijinsky, 1991). Toxicity is the consequence of PAH metabolic changes in human body in a complex mixture of quinones, quinines, cis-and trans-dihydrodiols, phenols, epoxides and other metabolites (Volkerine and Breure, 2003). These reactive metabolic intermediates can covalently bind to nucleic acids to produce filament interruptions and Deoxyribonucleic Acid (DNA) damage, leading to mutation and tumor origination.

The USEPA recommends that a toxicity equivalency factor (TEF) be used to change concentrations of carcinogenic polycyclic aromatic hydrocarbons (cPAHs) to an equivalent concentration of benzo(a)pyrene to assess the risk posed by these compounds. For the database toxicity value, these TEFs have been used so that toxicity values could be generated for each cPAH, compound. However, if the adjusted toxicity values are used, the user will need to sum the risks from all cPAHs compounds to get a total risk from cPAHs. A total risk from all cPAHs is what is derived when the TEFs are applied to the environmental concentrations of cPAHs and not to the toxicity

values (Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons, 1993). Table 1.15 shows the recommended TEFs for cPAHs.

For a full risk assessment, information is needed on the impact of various levels on human health. However, that is not fully available and EPA specifically addresses this issue.

As PAHs are common environmental contaminants, it is important that EPA have a scientifically justified, consistent approach to the evaluation of human health risk from exposure to these compounds. For the majority of PAHs classified as B2, probable human carcinogens, data are insufficient for calculation of an inhalation or drinking water unit risk. Benzo(a)pyrene (BaP) is the most completely studied of the PAHs, and data, while problematic, are sufficient for calculation of quantitative estimates of carcinogenic potency. Toxic Equivalency Factors (TEF) have been used by USEPA on an interim basis for risk assessment of chlorinated dibenzodioxins and dibenzofurans. Data for PAHs do not meet all criteria for the use of TEF. This official EPA document presents a somewhat different approach to quantitative estimation for PAHs using weighted potential potencies. These estimates are recommended only for evaluation of risk from oral exposure and are proposed only for the assessment of potential carcinogenicity of PAHs (EPA, 2014).

Table 1.15 Toxicity Equivalency Factors for Carcinogenic PAHs (EPA, 1993).

Compound	TEF
Benzo(a)pyrene	1.0
Benz(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Chrysene	0.001
Dibenz(a,h)anthracene	1.0
Indeno(1,2,3-c,d)pyrene	0.1

Soils containing $< 0.1 \text{ mg Kg}^{-1}$ BaP are considered uncontaminated, soils containing $0.1\text{-}1.0 \text{ mg Kg}^{-1}$ BaP are considered slightly contaminated and soils containing $1\text{-}10 \text{ mg Kg}^{-1}$ BaP are considered to be significantly contaminated (Canadian Soil Quality Guidelines, 2010).

Humans can be exposed through ingestion, inhalation and dermal exposure. For example, this can happen by drinking contaminated water, breathing PAH particulates, or holding PAH contaminated soil in the hands. After contact, PAHs can be distributed, metabolized, stored in the human body, or excreted. PAHs can affect respiratory, reproductive, and neurological systems, besides causing birth defects and cancer (Figure 1.7).

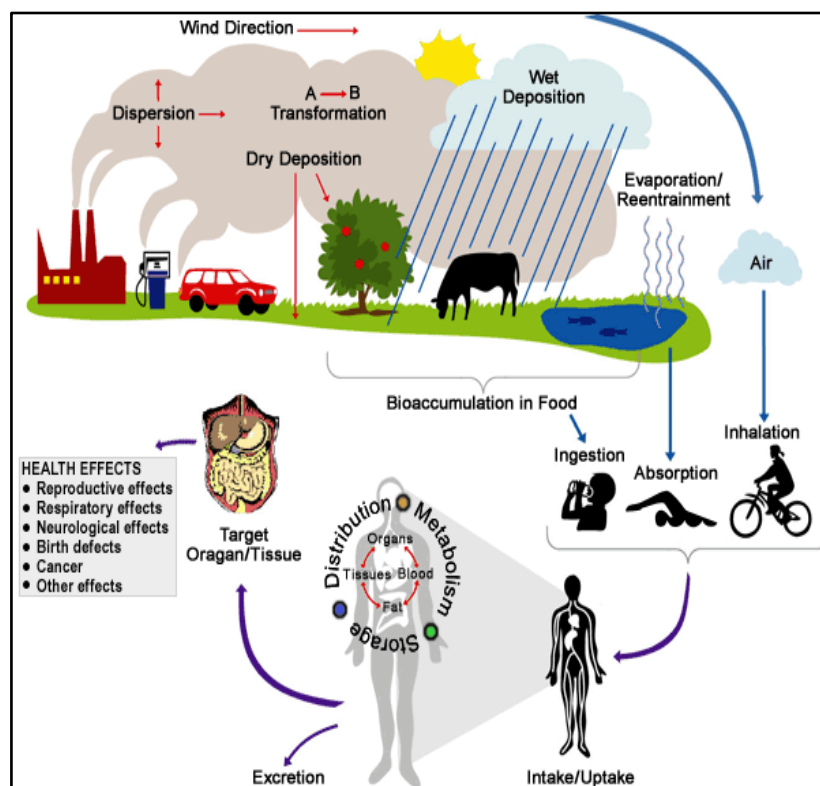


Figure 1.7 Risk based exposure to contaminants. (Indiana Department of Environmental Management, 2012).

1.15 Remediation Alternatives

PAHs released on the soil will be slowly degraded by microbial activity or carried by surface runoff (Table 1.16). Naphthalene was the most mobile PAH reported below a creosote contaminated site in the United States, found at 3 m depth (Canadian Soil Quality Guidelines, 2010). The principal mechanism for removal of PAHs from soil is biodegradation, meaning the biological transformation of PAHs molecules into smaller ones with less toxicity, depending on numerous conditions (Harmsen et al., 2007).

- Reduced amount of carbon sources or bacterial nutrient.
- Inappropriate conditions of temperature, pH, salts, oxygen and toxins concentrations.
- Reduced bacterial species that can degrade PAHs compounds.
- Low PAH bioavailability to degrading organisms.
- PAHs physiochemical characteristics.

Table 1.16 Some general PAH-degrading microorganisms (Wick and Daniels, 2011).

Bacteria	PHA compound degraded
Acidovorax	phenanthrene, anthracene
Alcaligenes	phenanthrene, florene, flornanthene
Arthrobacter	Benzene, naphthalene, phenanthrene
Mycobacterium	Phenanthrene, pyrene, benzo(a)pyrene
Pseudomonas	Phenanthrene, fluoranthene, fluorine, benzo(a) Pyrene
Rhodococcus	Pyrene, benzo(a)pyrene
Sphingomonas	Phenanthrene, fluoranthene, anthracene

The final objective of degradation is the mineralization of PAHs to CO₂, water, microbial carbon and other inorganic compounds, bioremediation processes are effective and economically possible remediation approach but tend to be slow, and have demonstrated limited capacity to degrade HMW PAHs (Lundsted, 2003).

Phytoremediation is an on-site remediation scheme utilizing plants through microbial activity (Table 1.17) augmentation at the rhizosphere zone (rhizosphere is the small volume of soil immediately surrounding plant roots which has higher concentrations of CO₂ pressures and microbial activity) to break down PAHs compounds by metabolic processes (Dzantor and Beauchamp, 2002).

Moreover, phytoremediation helps reduce the of-site transfer of contaminants by controlling runoff, wind erosion and leaching, and is a non-disruptive self-sustaining activity that needs little management; however, it is a very lengthy process (1-3 years) (Joner, Corgie, Amellal and Leyval, 2002) and require soil conditions such as the supply of oxygen, water, nutrients, pH, texture and electric conductivity (EC).

Table 1.17 Phytoremediation species and select research citations on success of these species.

Common Name	Latin Name	Select Successful Research on PAH Degradation
Alfalfa	<i>Medicago sativa</i>	Schwab and Banks, 1994; Reilley et al., 1996; Pradhan et al., 1998; Olson et al., 2007
Annual rye grass	<i>Lolium multiflorum</i>	Schwab and Banks, 1994; Hutchinson et al., 2003; Rezek et al., 2008
Annual sunflower	<i>Heliantus annuus</i>	Olson et al., 2007
Barley	<i>Hordeum vulgare</i>	Kucerova et al., 2000
Bermuda grass	<i>Cynodon dactulon</i> L.	Ferro et al., 1994; Banks et al., 1998; Hutchinson et al., 2003; Olson et al., 2007
Big bluestem	<i>Andropogon gerardii</i>	Aprill and Sims, 1990; Schwab and Banks, 1994; Rugh et al., 2004; Olson et al., 2007
Blue grama	<i>Bouteloua gracillis</i>	Aprill and Sims, 1990
Bottlebrush grass	<i>Hystrix patula</i>	Rugh et al., 2004
Birdsfoot trefoil	<i>Lotus corniculata</i>	Olson et al., 2007
Buffalograss	<i>Buchloe dactyloides</i>	Qui et al., 1997
Canada wild-rye	<i>Elymus Canadensis</i>	Aprill and Sims, 1990
Carrot	<i>Daucus carota</i>	Wild and Jones, 1992
Green bulrush	<i>Scirpus atrovirens</i>	Rugh et al., 2004
Hybrid poplar	<i>Populus deltoides</i> X <i>nigra</i>	Jordahl et al., 1997
Joe pye weed	<i>Eupatorium purpureum</i>	Rugh et al., 2004
Kleingrass	<i>Panicum coloratum</i>	Wrenn and Venosa, 1996; Qui et al., 1997; Olson et al., 2007
Little bluestem	<i>Schizachyrium scoparius</i>	Aprill and Sims, 1990; Pradhan et al., 1998
Maximilian sunflower	<i>Helianthus maximiliani</i>	Olson et al., 2007
Meadowsweet	<i>Spiraea alba</i>	Rugh et al., 2004
New England Aster	<i>Aster novae-anglicae</i>	Rugh et al., 2004
Perennial ryegrass	<i>Lolium perenne</i> L.	Gunther et al., 1996; Wrenn and Venosa, 1996; Binet et al., 2000; Nedunuri et al., 2000; Olson et al., 2007
Prairie chordgrass	<i>Spartina pectinata</i>	Rugh et al., 2004
Red clover	<i>Trifolium pretense</i>	Olson et al., 2007
Side oats grama	<i>Bouteloua curtipendula</i>	Aprill and Sims, 1990
Sorghum	<i>Sorghum bicolor</i>	Nedunuri et al., 2000
St Augustine grass	<i>Stenotaphrum secundatum</i>	Schwab and Banks, 1994; Nendunuri et al., 2000
Sticky geranium	<i>Geranium viscosissimum</i>	Olson et al., 2007
Stiff goldenrod	<i>Solidago rigida</i>	Olson et al., 2007
Sudangrass	<i>Sorghum vulgare</i> L.;	Schwab and Banks, 1994; Lee, 1996; Reilley et al., 1996
Switch grass	<i>Panicum virgatum</i>	Aprill and Sims, 1990; Reilley et al., 1996; Pradhan et al., 1998; Chen et al., 2003; Rugh et al., 2004

Tall fescue	<i>Festuca arundinacea</i> Schreb	Ferro et al., 1994; Schwab and Banks, 1994; Gunther et al., 1996; Reilley et al., 1996; Wrenn and Venosa, 1996; Banks et al., 1998; Banks et al., 1999; Chen et al., 2003; Hutchinson et al., 2003; Robinson et al., 2003; Huang et al., 2004; Olson et al., 2007
Western wheatgrass	<i>Agropyron smithii</i>	Aprill and Sims, 1990; Olson et al., 2007
Wheat	<i>Triticum aestivum</i>	Kucerova et al., 2001
Yellow sweetclover	<i>Melilotus officinalis</i>	Olson et al., 2007

1.16 Previous Study: “Used Motor Oil Management in the Ciudad Juarez Area” (Figueroa, De la Mora, and Corral, 2010).

The project “Used Motor Oil Management in the Ciudad Juarez Area” was a collaborative project, among the Universidad Autonoma de Ciudad Juarez, The University of Texas at Austin and the United States Environmental Protection Agency (USEPA). This research was developed to provide an inventory and information regarding the generation, handling and disposal practices of used motor oil in the municipality of Ciudad Juarez, Chihuahua, as well as to provide a framework for ensuring better used oil handling and management practices.

The project conducted a 20-part questionnaire to ask each mechanic shop owner or employee about the UMO management practices. The purpose of these questions was to learn about the UMO management in each car repair shop, the amount of used oil generated, residue-handling procedures, final disposal alternatives, and training.

The results indicate that only 23.52 % of the shops have authorized oil recollection service. The authorized recollection service agencies are those registered businesses with the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) whose main activity is to collect, transport, recycle, and/or dispose of hazardous waste. Only 48 % of respondents reported having technical training to handle used oil. The 65.35 % of respondents reported awareness of the Mexican legislation that applies to this issue (Questionnaire below).

Questionnaire

(Administered to person working in car repair shop on a face to face basis)

Date _____

No. _____ GPS coordinates _____

Shop name _____

Shop address _____

1. Main shop activities:

a) Only mechanics Yes _____ No _____

b) Brakes Yes _____ No _____

c) Other Yes _____ No _____

2. Volume generated each month _____

3. Have you had training in UMO managing practices? _____

4. Number of oil changes performed each month? _____

5. Volume of used oil generated per oil change _____

6. How do you manage the used motor oil:

a) Delivered to an authorized collector Yes _____ No _____

b) Delivered to an non-authorized collector Yes _____ No _____

c) Dropped into the city sewage Yes _____ No _____

d) Dropped into the soil Yes _____ No _____

e) Other Yes _____ No _____

7. How often is the 200 L container filled up? _____

8. How often the authorized collector picked up? _____

9. If is not picked up, what do you do with used oil collected? _____

10. How much do you pay for the UMO collection per liter? _____

11. Do you know that are free of charge authorized collectors? _____

12. Do you generate other kind of waste fluids? Yes _____ No _____

13. What are they and what do you do with them? _____

14. Will you offer recycled oil to your clients? Yes _____ No _____

15. Would you be interested in attending a workshop for the UMO management?

Yes _____ No _____

More than half of the respondents stated that they do not dispose of oil properly by hiring authorized services. However, 60.45% of respondents reported being interested in receiving handling and disposal training, a result which reinforces the idea that an environmental education program to improve used oil management could be effective in improving the process of transportation and the reuse and disposal of used oil (Figure 1.8).

This study suggest that a large amount of the oil in Ciudad Juarez appears to be disposed of through inappropriate procedures, and soil is the primary reservoir for semi-volatile compounds mostly from stationary and mobile sources that could represent a risk to the environment and human health for the Ciudad Juarez - El Paso international area that shares the Hueco Bolson as the common source of drinking water.

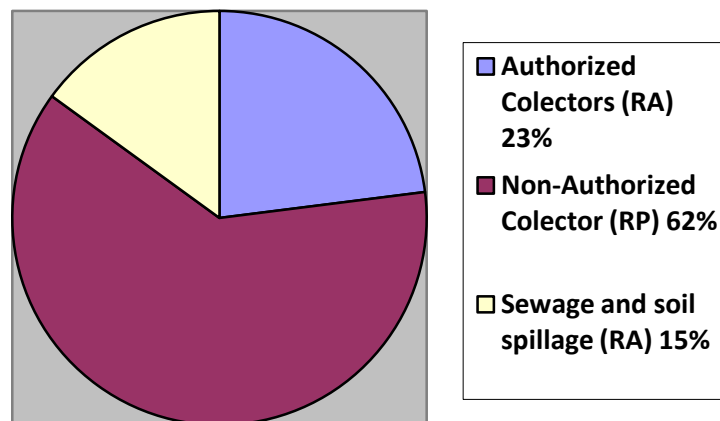


Figure 1.8 UMO disposal by car repair shops in Ciudad Juarez.

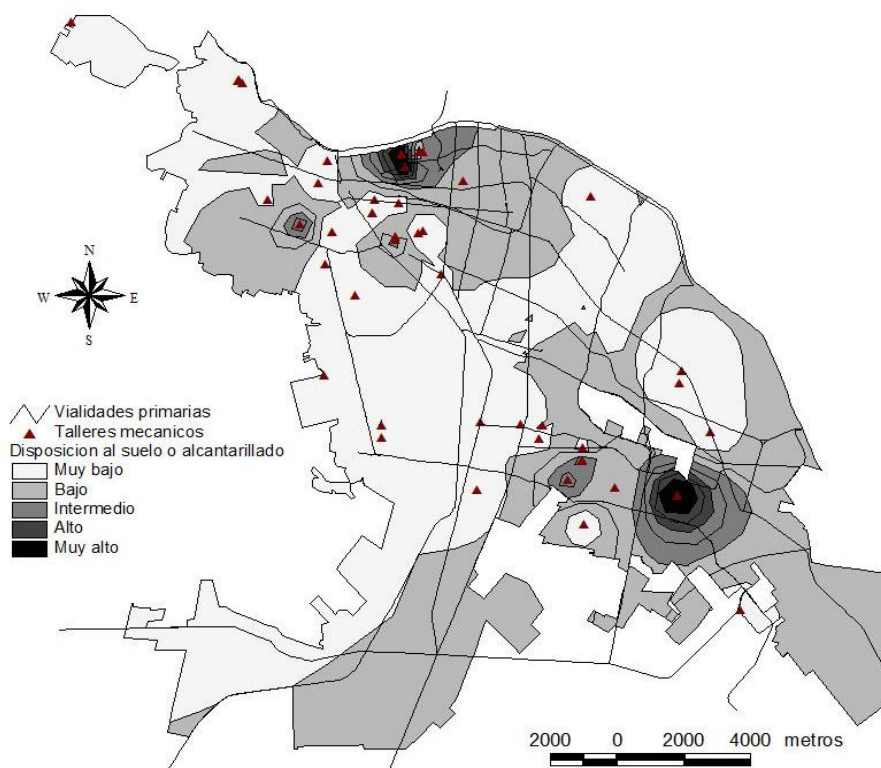


Figure 1.9 Ciudad Juarez map, where the questionnaire was administered in red, dark areas are for the UMO mismanagement.

A workshop on Used Oil Management was held during January 2010 in Ciudad Juarez to present the research findings; and provide training to used motor oil generators and handlers, local mechanic shops, junk yard workers and stakeholders attended the event. The outcomes of the in-depth discussions involving participants from all relevant sectors and levels were recorded and public policy recommendations emanated from that discussion. On the first day of the event, 48 individuals attended and on the second day 78 persons were present.

Training materials were developed and shared with stakeholders in a training workshop in Ciudad Juarez on January 25 and 26, 2010. The educational materials were presented at the Meeting of the Global Environmental Education Partnership (GEEP) on April 14, 2014 in Taipei, Taiwan (Figure 1.11).



Figure 1.10 Poster with the management plan distributed at the workshop on Used Oil Management. (Varela, Figueroa and Tarin, 2010).

Results show inadequate management and final disposal of UMO in 62% of auto repair shops. This widespread problem combined with the properties of hazardous waste, make UMO a risk for the environment and human health.

CHAPTER II

EXPERIMENTAL

2. Materials and Methods

2.1 Materials

A PAH standard mixture in methylene chloride/benzene was purchased from ULTRA Scientific (Kingstown, RI, USA). Cat #US-106N. 2000 g mL⁻¹. The Internal Standard Mixture in methylene chloride (dichloromethane) was purchased from ULTRA Scientific (Kingstown, RI, USA). Cat. #ISM-560. 2000 g mL⁻¹. Surrogate Standards, in Dichloromethane was purchased from AccuStandard, Inc. (New Haven, CT, USA) Cat # M-8270-SS 4000 g mL⁻¹ Dichloromethane/methilene chloride Sigma Aldrich, Chromasolv for HPLC 99.8%. Sodium sulfate ACS reagent, 99.0%, anhydrous, granular Sigma Aldrich. Silica gel 60-200 mesh for chromatographic column. Solvents used in this study were HPLC or higher grade: Methanol: Burdick & Jackson (Muskegon, MI, USA); Acetone: VWR International (West Chester, PA); Hexane: J. T Baker (Phillipsburg, NJ, USA).

2.2. Methods

2.2.1 Description of sampling

The soil sampling was performed from June 2011 to June 2012, across the Ciudad Juarez and El Paso area. The original randomly selected sites grid had to be modified at time due to the lack of soil at the car repair shops or permission refusal by the shop owners; 90 sites or car repair shops, 30 for El Paso and 60 for Ciudad Juarez, were sampled by taking three composite soil samples at each, near the mechanic auto repair shops, at a distance of no more than 10 m (thus yielding 270 samples). Each sample consisted of four sub-samples in an area of approximately 1m x 1m from the 10-15 cm depth, and at least 500 g of surface soil waste collected from each site. All samples were gathered with pre-cleaned trowels and store in 500 cc labeled amber glass containers.

The field data recorded for each sample was: altitude and coordinates with a hand held Global Position System receiver (Trimble GPS Pathfinder XC receiver 5m.). Relative humidity, soil temperature and dew point were measured with mobile field equipment (Fisher Scientific; Traceable Hygrometer, Thermometer, Dew Point). Back at the laboratory, the soil samples were sieved to 1 mm for aggregates discard, and then stored at 4°C. Pictures of the auto repair shops and the UMO general management were taken at each site.

Sampling sites were categorized into Compliance and Non-Compliance types depending on whether or not they deliver or not the used motor oil to an authorized collector for final disposal, Figure 2.1 shows the 60 sampled sites in the Ciudad Juarez area, 30 at the Compliance and 30 for the Non-Compliance category, and 30 site samples for the El Paso area in the Compliance category. The green dots stands for the compliant sites, the red dots for the non-compliant sites, and the blue dots represent the field or reference soil sample. Tables 2.1 and 2.2 summarize the geographic coordinates and compliance status from each site where the soil samples were taken for research purposes.

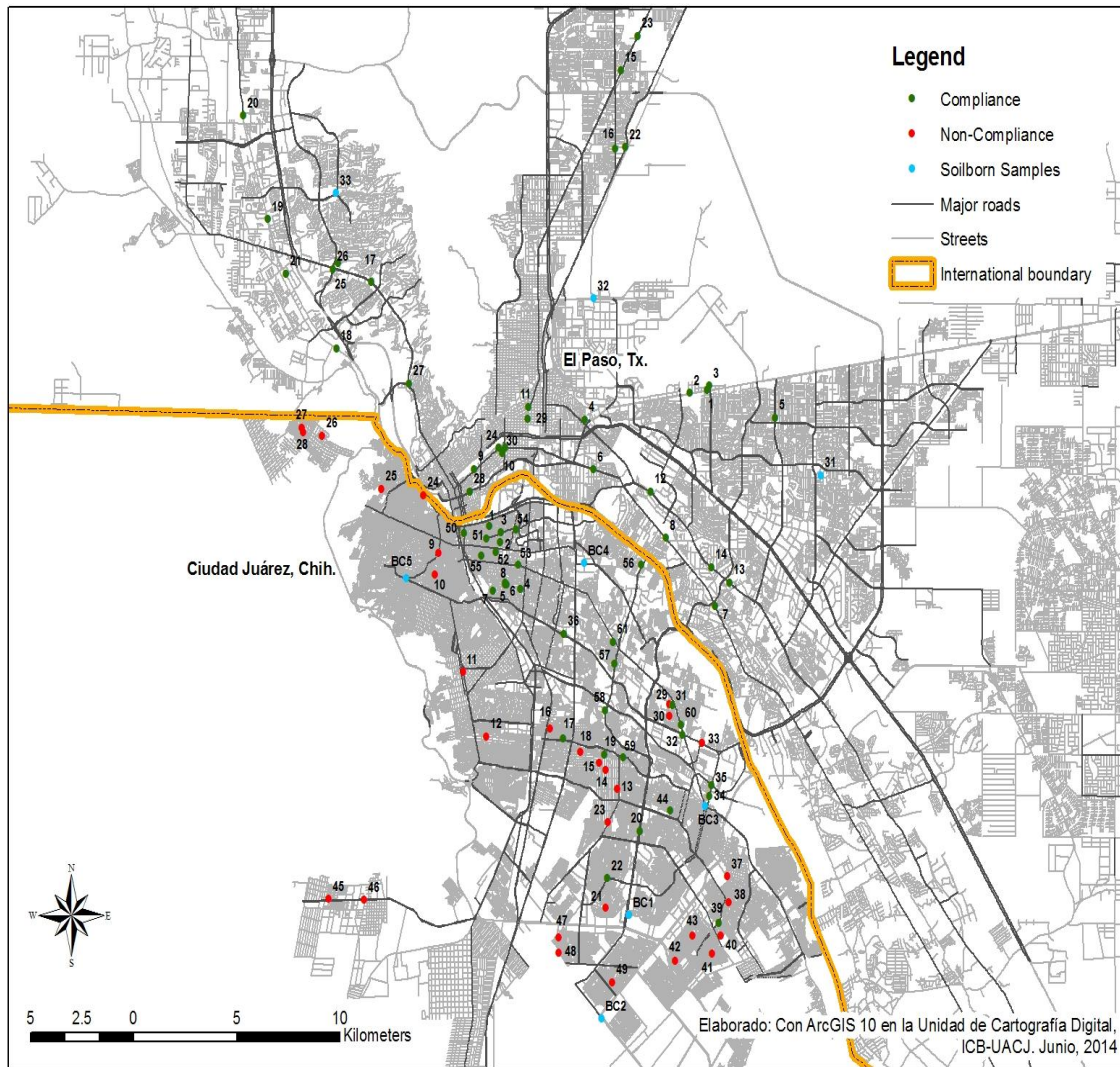


Figure 2.1 Location of sampling sites throughout Ciudad Juárez-El Paso area. Green dots are compliant sites; red dots are non-compliant sites; blue dots are the field reference sites (Figueroa, 2014).

Eight reference soil samples were sampled, five for Ciudad Juarez and three for El Paso, using the same analysis as for the rest of the research samples to compare soil-borne PAHs.

Table 2. 1 El Paso mechanic shops research register number, coordinates and compliance status. (Figueroa, 2014).

No	X Coordinate*	Y Coordinate*	Status
EP 1	371445,5646	3518499,8466	C
EP 2	370602,7138	3518383,3923	C
EP 3	371565,0615	3518663,0281	C
EP 4	365512,1155	3517345,3211	C
EP 5	374741,3044	3517407,1416	C
EP 6	365949,2753	3515392,1536	C
EP 7	371840,0457	3510080,3111	C
EP 8	369441,3371	3512722,4834	C
EP 9	360151,3691	3515404,2008	C
EP 10	361321,4364	3516244,6014	C
EP 11	362767,1402	3517842,2072	C
EP 12	368694,6611	3514537,2178	C
EP 13	372543,9258	3510981,0049	C
EP 14	371660,2428	3511581,9590	C
EP 15	367256,1799	3530969,8816	C
EP 16	366979,2340	3527904,7115	C
EP 17	355141,2305	3522691,3249	C
EP 18	353472,7239	3520119,2648	C
EP 19	350139,0794	3525150,9063	C
EP 20	348946,8362	3529193,2892	C
EP 21	351006,4295	3523024,8042	C
EP 22	367468,1535	3527966,4100	C
EP 23	368064,7320	3532303,7322	C
EP 24	361655,2525	3516240,8893	C
EP 25	353542,3968	3523428,4384	C
EP 26	353280,7571	3523202,2874	C
EP 27	356977,0571	3518740,6941	C
EP 28	359936,5120	3514543,6773	C
EP 29	362757,9102	3517379,1179	C
EP 30	361519,1778	3516030,5363	C

*Reference number for mechanic shops is assigned according to GIS position and compliance status. El Paso sample contains only sites with compliant status.

Table 2. 2 Ciudad Juarez mechanic shops research register number, coordinates and compliance status (Figueroa, 2014).

No	X Coordinate*	Y Coordinate	Status	No	X Coordinate	Y Coordinate	Status
JZ 1	360866.0000	3513197.0000	C	JZ 31	369762.3658	3506198.9439	C
JZ 2	361441.4737	3512953.0266	C	JZ 32	370251.0000	3505038.0000	C
JZ 3	361396.7390	3512564.8102	C	JZ 33	371213.0000	3504727.0000	NC
JZ 4	362393.1047	3510749.7343	C	JZ 34	371549.0000	3502663.0000	C
JZ 5	361636.6873	3510992.7610	C	JZ 35	371654.9162	3503078.2124	C
JZ 6	361732.7408	3510906.0226	C	JZ 36	364511.0000	3508977.0000	C
JZ 7	361064.2018	3510649.4201	C	JZ 37	372430.3097	3499522.3673	NC
JZ 8	361643.2419	3510904.4119	C	JZ 38	372501.4227	3498526.9900	NC
JZ 9	358408.8303	3512143.9728	NC	JZ 39	372024.9374	3497707.8789	C
JZ 10	358245.5168	3511301.0707	NC	JZ 40	372132.2873	3497211.1944	NC
JZ 11	359601.0000	3507499.0000	NC	JZ 41	371684.1115	3496507.1912	NC
JZ 12	360742.5223	3504993.2416	NC	JZ 42	369896.0249	3496235.2342	NC
JZ 13	367106.5631	3502951.4412	NC	JZ 43	370729.0000	3497217.0000	NC
JZ 14	366549.0000	3503660.0000	NC	JZ 44	369652.0000	3502103.0000	C
JZ15	366216.3865	3503950.3384	NC	JZ 45	353097.0000	3498646.0000	NC
JZ 16	363832.0198	3505280.9317	NC	JZ 46	354795.0000	3498613.0000	NC
JZ 17	364460.0000	3504904.0000	C	JZ 47	364235.7960	3497143.8623	NC
JZ 18	365315.0000	3504381.0000	NC	JZ 48	364263.0000	3496534.0000	NC
JZ 19	366462.6837	3504290.3036	C	JZ 49	366833.0000	3495390.0000	NC
JZ 20	368169.3164	3501288.2226	C	JZ 50	360726.3222	3512717.1134	C
JZ 21	366528.5742	3498315.2784	NC	JZ 51	361203.6618	3512180.8598	C
JZ 22	366589.4651	3499457.9613	C	JZ 52	362298.0000	3511686.0000	C
JZ 23	366644.0000	3501656.0000	NC	JZ 53	362177.0000	3513043.0000	C
JZ 24	357681.0408	3514386.2561	NC	JZ 54	360507.0000	3512033.0000	C
JZ 25	355643.4227	3514631.7573	NC	JZ 55	368261.7234	3511684.3361	C
JZ 26	352766.1537	3516707.5122	NC	JZ 56	366952.0000	3507825.0000	C
JZ 27	351790.0000	3517020.0000	NC	JZ 57	366504.0000	3506000.0000	C
JZ 28	351861.0000	3516852.0000	NC	JZ 58	367369.0000	3504177.0000	C
JZ 29	369634.0000	3506256.0000	NC	JZ 59	370189.0000	3505415.0000	C
JZ 30	369638.0000	3513197.0000	NC	JZ 60	366899.0000	3508673.0000	C

*For Ciudad Juarez Table 2.2 includes mechanics shop register number, GIS position and compliance or non-compliance status.

2.2.2 Sample preparation: ultrasonic extraction coupled with GC/FID

In order to make the most efficient use of time and solvents, the three individual composite samples per site (each consisting of 10 g of soil minus 1 g for analysis) were mixed, yielding one composite soil sample for each site with a final sample size of 90.

Using 1 g of each soil sample, 5 g anhydrous sodium sulfate was extracted in 15 mL of Acetone:Hexane 1:1 (v/v) added into 50 mL amber glass vial plus 15 μ L of 2000 ppm stock solution of the surrogate standard (SS), to obtain a final concentration of 30 ppm. The soil was ultrasonically extracted (Branson Sonifier 250) at room temperature for 20 min to extract PAHs.

After ultrasonication, the soil samples extracts were centrifuged 5 minutes at 4000 rpm, the supernatant obtained was cleaned up with 0.5 mg of silica gel and 40 mL of dichloromethane HPLC, then transferred to a Kuderna-Danish (K-D) 24/40 Kontes 500 mL evaporator to concentrate to 0.5 mL, then transferred to a 1 mL volumetric flask, adding 15 μ L of 2000 ppm stock internal standard until reaching 1 mL to obtain an internal standard concentration of 30 ppm. The obtained extract was transferred to a Perkin Elmer 2mL clear vial for the GC/FID analysis.

2.2.3 GC–FID analysis

The PAHs analyses were carried out using a Perkin Elmer Clarus 500 Gas-chromatograph (GC) with a Flame Ionization Detector (FID); this detector senses analytes by measuring an electrical current generated by electrons from burning carbon particles in the sample. The separations of 16 priority polycyclic aromatic hydrocarbons were performed using a DB-5 (60 m length x 0.25 mm I.D. x 0.25 μ m Film) capillary column from J&W Scientific. The GC oven temperature was programmed as follows: initial temperature of 70 $^{\circ}$ C was held for 2 minutes and then increased to 300 $^{\circ}$ C at 6 $^{\circ}$ C/min ramp held for 6 min and then 10 $^{\circ}$ C / min to 325 $^{\circ}$ C. The carrier gas was high purity helium at a constant flow of 1.3 mL min⁻¹. The injector temperature was set at 280 $^{\circ}$ C and the detector temperature at 300 $^{\circ}$ C. Voltage 1.13 mV, running time was 58 min.

As Kannan et al. (2014) observe, co-elution complicates the detection of target compounds among overlapping co-contaminants. In the present study, despite UMO's complex matrix with hundreds of hydrocarbons and the partial co-elution of target compounds, the samples of UMO were successfully separated through a process of cleanup, K-D concentration and injection into a GC FID system, thereby allowing accurate determination of the target compounds.

2.2.4 Quality Assurance and Quality Control (QA/QC)

Five-point calibration curves were constructed. The linear response for the determination coefficient (r^2) exhibited values of 0.957 and higher for all 16 PAHs. Two replicates of each soil sample extract were performed and the relative standard deviation (RSD) of the two replicates average was less than 25%.

The procedural blanks, spiked blanks, and sample duplicates were routinely analyzed for every batch of 15 samples with field samples. Limit of Detection (LOD) and Limit of Quantitation (LOQ) as established in this study for each individual PAH are reported in Table 2.5.

The recovery average for the deuterated PAH surrogate standards added to soil samples to monitor the procedures of sample extraction, cleanup, and analysis ranged from 68 to 114% (Table 2.3).

The method was tested for recovery efficiencies by analyzing uncontaminated soil spiked with PAH standards, and the average recoveries ($n = 3$) ranged from 69 to 122% (Table 2.4).

Table 2. 3 Recovery average for deuterated PAH surrogate standards.

Compound	% Recuperation
2-Fluorofenol	68
Fenol d-5	65.0
Nitrobenceno d-5	83.21
2-Fluorobifenilo	113.56
2,4,6-Tribromofenol	97.10
Para-terfenil d-14	88.50

Table 2. 4 Average recoveries for uncontaminated soil spiked with PAH standards.

Compound	% Recuperation
Acenaphthylene	91.82
Acenaphthene	95.69
Fluorene	113.10
Phenathrene	109.31
Anthracene	116.19
Fluoranthene	104.40
Pyrene	104.50
Benz (a) anthracene	68.76
Chrysene	104.22
Benzo (b) fluoranthene	93.11
Benzo (k) fluoranthene	
Benzo (a) pyrene	85.15
Indeno (1,2,3-cd) pyrene	121.78
Dibenz (a,h)anthracene	
Benzo(g,h,i) perylene	131.31

Table 2. 5 LODs and LOQs for the EPA 16 priority PAHs in mg kg⁻¹.

PAH	LOD	LOQ
Naphthalene	ND	ND
Acenaphthylene	2.88	4.81
Acenaphthene	4.41	7.35
Fluorene	5.09	8.48
Phenathrene	4.61	7.69
Anthracene	6.05	10.09
Fluoranthene	5.82	9.70
Pyrene	5.58	9.29
Benz (a) anthracene	5.75	9.58
Chrysene	5.54	9.23
Benzo (b) fluoranthene Benzo (k) fluoranthene	4.56	7.61
Benzo (a) pyrene	7.35	12.24
Indeno (1,2,3-cd) pyrene Dibenz (a,h)anthracene	8.06	13.43
Benzo(g,h,i) perylene	4.09	6.82

CHAPTER 3

3. Results and Discussion

The study comprises of three objectives; 1) the questionnaire results for the UMO management and final disposal at the mechanic shops in the Ciudad Juarez-El Paso area; 2) the analytical PAH concentrations in each soil sample site and the comparison of the mean concentration between Ciudad Juarez and El Paso; 3) the environmental and health risk for the Ciudad Juarez-El Paso area posed by possible mismanagement of UMO by mechanic car shops.

3.1.1 UMO Management at the Mechanic Shops

Regarding the UMO volume generated at the mechanic shops, the questionnaire results reveal is a significant disparity among individual mechanic shops and the total UMO volume generation for Ciudad Juarez: For 60 sampled mechanic shops in Ciudad Juarez, the UMO volume was 7,419 L/month; for 30 sampled shops in El Paso, the volume was 24,522 L/Month. Taking into account the relatively equal vehicular fleet numbers for both cities, specifically 450,000 in Ciudad Juarez and 568,357 in El Paso according to Zietsman (2009), the fact that the El Paso volume is nearly 3 times higher suggests that El Paso follows better car maintenance practices and stricter enforcement of UMO disposal regulations.

On the other hand, Table 3.1 also indicates that the monthly volume between the groups is different: for El Paso compliance is 817.40 L/month, much higher than the Juarez compliance of 206.63 L/month and 40.66 L/month for Ciudad Juarez non-compliance.

For Ciudad Juarez, the non-compliance car repair shops present the lowest UMO volume generation, possibly because the smaller shops perform fewer motor oil changes per month.

Figure 3.1 and Figure 3.2 show the UMO generation in each mechanic shop for the El Paso area, ranging from 20 to 8,316 L/month, and in Ciudad Juarez from 15 to 1,400 L/month.

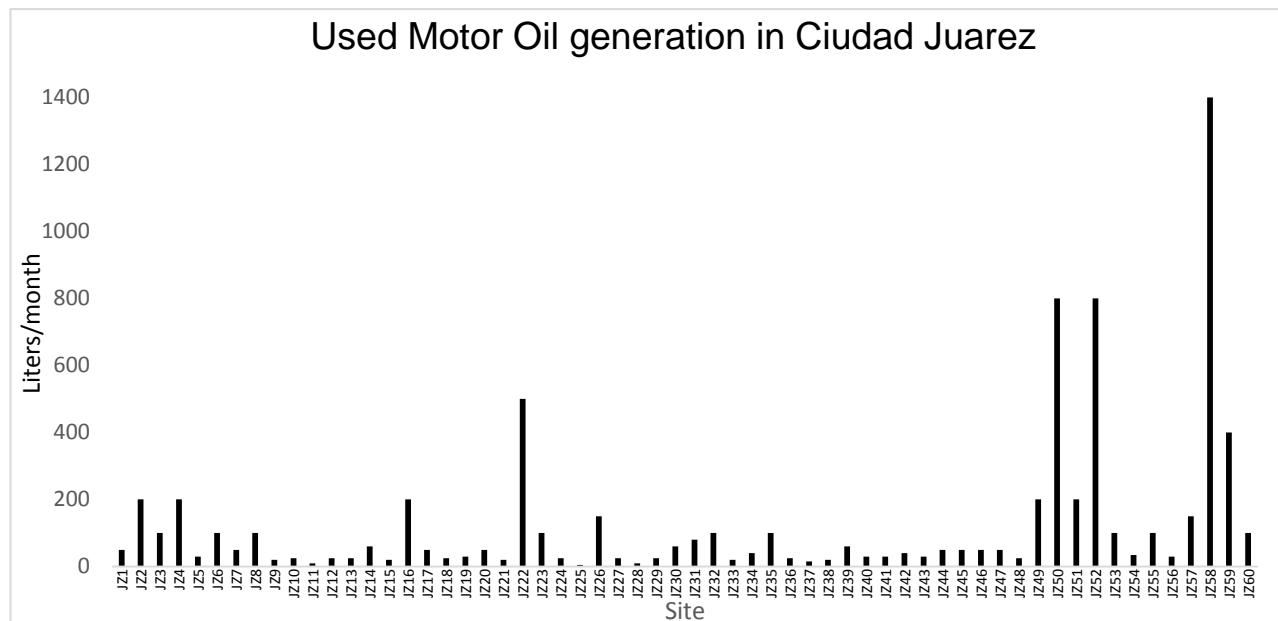


Figure 3.1 Volume of UMO generated by mechanic shops in Ciudad Juarez.

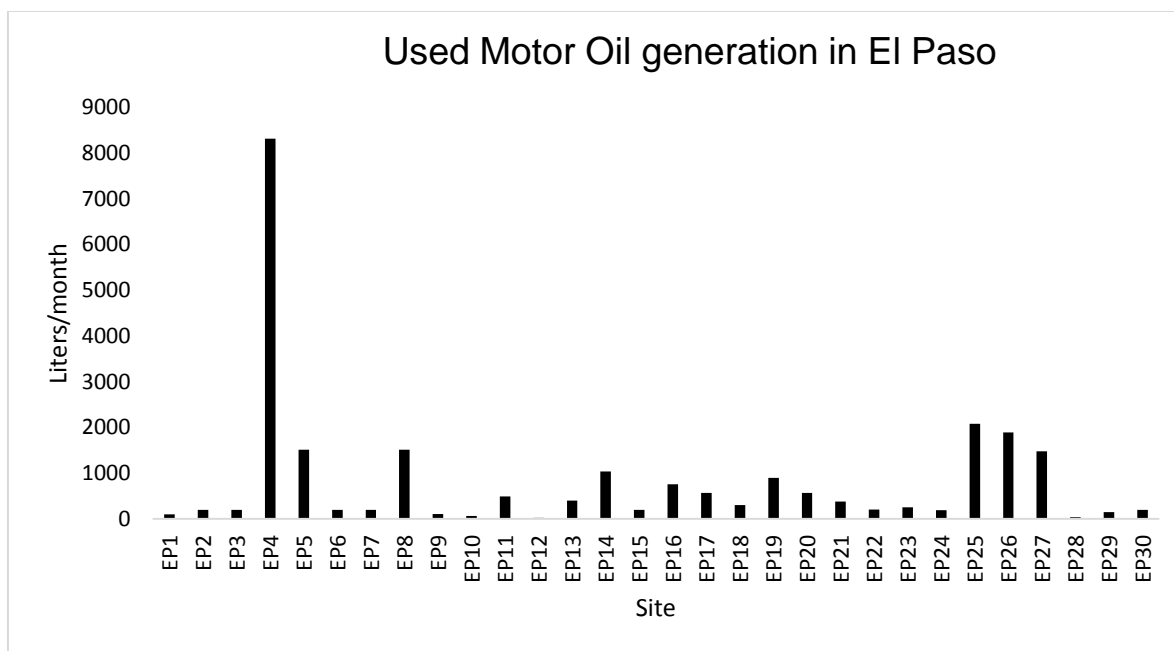


Figure 3.2 Volume of UMO generated by mechanic shops in the El Paso area.

Table 3. 1 Comparison of the each site total liters/month between EPC, JZC and JZNC.

El PASO C	Liters/Month	JUAREZ C	Liters/Month	JUAREZ NC	Liters/Month
EP 1	100	JZ1	50	JZ5	30
EP 2	200	JZ2	200	JZ9	20
EP 3	200	JZ3	100	JZ10	25
EP 4	8316	JZ4	200	JZ11	10
EP 5	1514	JZ6	100	JZ12	25
EP 6	200	JZ7	50	JZ13	25
EP 7	200	JZ8	100	JZ14	60
EP 8	1514	JZ17	50	JZ15	20
EP 9	104	JZ19	30	JZ16	200
EP 10	63	JZ20	50	JZ18	25
EP 11	491	JZ22	500	JZ21	20
EP 12	20	JZ31	80	JZ23	100
EP 13	400	JZ32	100	JZ24	25
EP 14	1040	JZ34	40	JZ25	5
EP 15	200	JZ35	100	JZ26	150
EP 16	757	JZ36	25	JZ27	25
EP 17	568	JZ39	60	JZ28	10
EP 18	302	JZ44	50	JZ29	25
EP 19	900	JZ49	200	JZ30	60
EP 20	568	JZ50	800	JZ33	20
EP 21	378	JZ51	200	JZ37	15
EP 22	208	JZ52	800	JZ38	20
EP 23	253	JZ53	100	JZ40	30
EP 24	190	JZ54	34	JZ41	30
EP 25	2082	JZ55	100	JZ42	40
EP 26	1890	JZ56	30	JZ43	30
EP 27	1475	JZ57	150	JZ45	50
EP 28	38	JZ58	1400	JZ46	50
EP 29	151	JZ59	400	JZ47	50
EP 30	200	JZ60	100	JZ48	25
Sum	24,522.00	Sum	6199.00	Sum	1220.00
Average	817.40	Average	206.63	Average	40.67
SD	1530.79	SD	302.82	SD	41.6209

Results show no difference between the cities, concerning regulation awareness, used motor oil storage, recycling practices or training interest. None of the mechanic shops pay for final disposal of UMO, nor do they use or offer the recycled oil to their customers, as shown in Table 3.2.

Table 3. 2 Questionnaire comparative results among El Paso and Ciudad Juarez.

Questions	El Paso	Ciudad Juarez	Total
UMO L/month mechanic shops	24,522	7,419	31,941
Regulation awareness	15 Yes 15 No	32 Yes 28 No	47 Yes 43 No
UMO Storage compliance	30 Yes 0 No	42 Yes 18 No	72 Yes 18 No
UMO disposal payment	0 Yes 30 No	0 Yes 60 No	0 Yes 90 No
Training interest	21 Yes 9 No	57 Yes 3 No	78 Yes 12 No
Other fluids generation	18 Yes 12 No	14 Yes 46 No	32 Yes 58 No
Uses recycle oil	0 Yes 30 No	0 Yes 60 No	0 Yes 90 No

The field data is summarized in Table 3.3. The soil temperature measurements were obtained between June 2011 and June 2012, and range from 59 °F to 136 °F. The altitude for the 90 sites fluctuated from 822 to 1,289 meters above sea level (Figure 3.3). For the Relative Humidity measurements, the minimum was 0.00 and maximum 20.37; the Dew Point measurements were -40.05°F or -40.09°F for all the samples. Vapor pressure defines the point at which PAHs in the solid state either evaporate into

a gaseous form or condense back to a solid state. The higher the vapor pressure (at normal temperatures) the more volatile the compounds.

Using data from Osaka, Japan, the results of relative humidity (RH) on measured gas/particle partition coefficients over the range 42%–95% found that for seven PAHs or groups of PAHs (including phenanthrene + anthracene, fluoranthene, and pyrene), sorption decreased inversely to RH (Pankow, Storey, & Yamasaki, 1993). PAHs vapor pressures are important to determine risk, transfer between two resources, soil and air as well as field sampling and lab safety (Table 3.4).

Table 3. 3 Field data for the soil sampling sites in Ciudad Juarez-El Paso area.

Parameter	Maximum	Minimum
Temperature	136°F (57°C)	59°F (15°C)
Relative humidity (RH) %	20.37	0.00
Dew Point (DP)	-40.09°F	-40.05°F
Altitude (masl)	1,289	822

Table 3. 4 USEPA 16 priority pollutant PAHs and selected properties.

PAH compound name	Number of rings	Molecular weight (g mole ⁻¹)	Solubility in water (mg L ⁻¹)	Vapor pressure (Pa)	Log Kow
Naphthalene	2	128.17	31	11.866	3.37
Acenaphthene	3	154.21	3.8	0.500	3.92
Acenaphthylene	3	152.2	16.1	3.866	4.00
Anthracene	3	178.23	0.045	3.40 x 10 ⁻³	4.54
Phenanthrene	3	178.23	1.1	9.07 x 10 ⁻²	4.57
Fluorene	3	166.22	1.9	0.432	4.18
Fluoranthene	4	202.26	0.26	1.08 x 10 ⁻³	5.22
Benz[a]anthracene*	4	228.29	0.011	2.05 x 10 ⁻⁵	5.91
Chrysene	4	228.29	0.0015	1.04 x 10 ⁻⁶	5.91
Pyrene	4	202.26	0.132	5.67 x 10 ⁻⁴	5.18
Benzo[a]pyrene*	5	252.32	0.0038	6.52 x 10 ⁻⁷	5.91
Benzo[b]fluoranthene*	5	252.32	0.0015	1.07 x 10 ⁻⁵	5.80
Benzo[k]fluoranthene*	5	252.32	0.0008	1.28 x 10 ⁻⁸	6.00
Dibenz[a,h]anthracene*	6	278.35	0.0005	2.80 x 10 ⁻⁹	6.75
Benzo[g,h,i]perylene*	6	276.34	0.00026	1.33 x 10 ⁻⁸	6.50
Indeno[1,2,3-cd]pyrene*	6	276.34	0.062	1.87 x 10 ⁻⁸	6.50

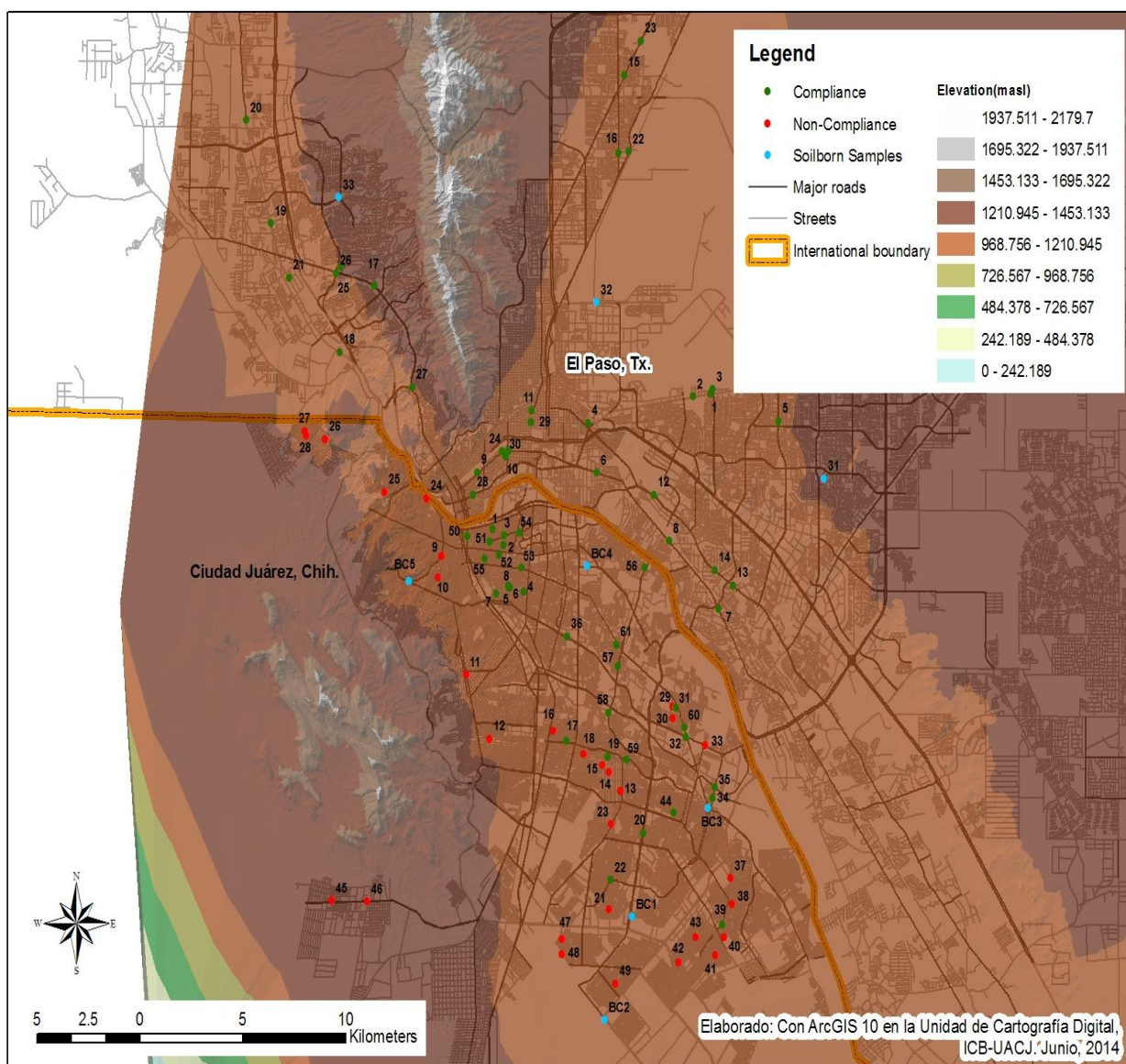


Figure 3.3 Map of soil sample altitudes in the Ciudad Juárez-El Paso region.

Sampling sites altitude data suggests that the runoff tendencies are toward the river lower altitude, and may pose a higher concentration of PAHs than upland soils. (Figure 3.3) Dredge materials have been found to contain elevated PAH levels as

metals and other organics. Due to the nature and risk associated with dredge materials, highland placement is regulated either through standards specific to dredge material or solid waste. When addressing PAH leaching or the transport of water soluble or colloidal PAHs laterally or downflows through soils, the factors to be considered are the soil water content, soil properties and rainfall intensity (Wick, 2011).

The El Paso and Ciudad Juarez area are bounded on the west by the Franklin Mountains and to the southwest by two mountain ranges, the Sierra de Juarez and Sierra del Presidio, moderately narrow and low elevations ranging from 1,830-2,440 m (6,000-8,000 ft.). The Hueco Bolson is situated at the edge of the Mexican Highland portion of the Basin and Range physiographic province, in which the distinctive geomorphic difference is the extent of basin floor or bolson-plain area (Hawley, 2009).

Table 3.5 shows the motor oil brand preferences of both cities, with differences: in Ciudad Juarez, these figures are 53% for Quaker Oil and 30% for Castrol; in El Paso the client preference was 30%, with another 30% for Walmart.

Table 3.5 New oil preferences in the mechanic shops.

New Oil Brand	El Paso	Ciudad Juarez	Total
Quaker	0	32	32
Castrol	6	12	18
Client selection	10	2	12
WalMart	9	0	9
Penzoil	5	3	8
Mexlub	0	6	6
Mobil	0	5	5

3.1.2 PAH analytical results

The 16 priority polycyclic aromatic hydrocarbons were analyzed in the soil samples from the selected mechanic shops for the Ciudad Juarez and El Paso area. Among the 90 samples analyzed the total PAH concentration in the soil for the three groups EPC, JZC and JZNC ranges from a minimum concentration of 0.1 mg kg^{-1} to a maximum of 76.0 mg kg^{-1} with an average of 18.86 mg kg^{-1} .

The results of the PAH total average concentrations between groups were as follows: 18.35 mg Kg^{-1} for EPC, 19.52 mg Kg^{-1} for JZC and 18.71 mg Kg^{-1} for JZNC. The arithmetic mean between EPC and JZNC shows similar values: for JZC the figure was slightly higher, resulting in no statistical difference between the mean concentration of PAHs in EPC and JZC (Table 3.6).

Nganje et al., (2007) from Calabar, Nigeria report concentrations of 1.80 to 334.43 mg kg⁻¹ with a mean of 50.31 mg kg⁻¹. The lowest value of 1.80 mg kg⁻¹ was obtained from a petrol station while the highest value of 334.43 mg kg⁻¹ was obtained from facility characterized by petrol stations and mechanic workshops.

The concentration range found in Adelaide, Australia, greatly exceeded the concentrations found in the present study, Juhasz and Naidu, (2000), reported total PAH concentrations of 5,863 mg kg⁻¹ at a creosote production site, 18,704 mg kg⁻¹ at a wood preservative site, 821 mg kg⁻¹ at a petrochemical site, and 451 mg kg⁻¹ at a gas manufacturing plant site.

Concentrations of PAHs in urban, rural, agricultural and industrial areas has been widely investigated, in urban soils polycyclic aromatic hydrocarbons can be 10 to 100 times higher than in remote soils (Wick, 2011).

Soil is the primary steady reservoir and sinks for PAHs in the terrestrial environment, because PAHs are readily absorbed in soil and difficult to degrade and may lead to contamination of food chains, which could cause a potential carcinogenic risk to residents (Yang, 2014).

It has been demonstrated that PAHs contamination from UMO occurs in soil near the auto repair shops. The data range found in the present research is within the levels

reported in the literature review and is likely to be introduced into the environment from anthropogenic sources.

Table 3. 6 Comparison of the total PAHs concentration per site between EPC, JZC and JZNC.

El PASO C	* Σ PAH ppm	JUAREZ C	Σ PAH ppm	JUAREZ NC	Σ PAH ppm
EP 1	76.00	JZ1	12.13	JZ5	19.00
EP 2	16.26	JZ2	4.25	JZ9	ND**
EP 3	31.98	JZ3	ND	JZ10	22.24
EP 4	45.82	JZ4	ND	JZ11	5.98
EP 5	38.67	JZ6	45.48	JZ12	12.23
EP 6	32.50	JZ7	5.14	JZ13	ND
EP 7	33.39	JZ8	ND	JZ14	50.68
EP 8	26.92	JZ17	ND	JZ15	13.92
EP 9	12.39	JZ19	40.35	JZ16	ND
EP 10	3.94	JZ20	6.61	JZ18	5.12
EP 11	15.22	JZ22	ND	JZ21	13.12
EP 12	4.27	JZ31	27.11	JZ23	18.10
EP 13	21.07	JZ32	20.93	JZ24	6.69
EP 14	15.51	JZ34	20.86	JZ25	14.10
EP 15	20.88	JZ35	29.26	JZ26	13.62
EP 16	34.62	JZ36	22.63	JZ27	6.63
EP 17	12.31	JZ39	21.56	JZ28	7.43
EP 18	ND	JZ44	21.10	JZ29	6.25
EP 19	13.52	JZ49	22.89	JZ30	16.67
EP 20	ND	JZ50	16.46	JZ33	26.66
EP 21	ND	JZ51	26.41	JZ37	36.03
EP 22	ND	JZ52	21.65	JZ38	23.99
EP 23	ND	JZ53	22.64	JZ40	26.58
EP 24	ND	JZ54	22.21	JZ41	21.79
EP 25	ND	JZ55	21.50	JZ42	43.60
EP 26	41.96	JZ56	21.33	JZ43	16.30
EP 27	29.99	JZ57	30.27	JZ45	21.83
EP 28	7.48	JZ58	57.28	JZ46	21.91
EP 29	4.17	JZ59	23.88	JZ47	58.33
EP 30	10.93	JZ60	21.27	JZ48	32.06
Average	18.35	Average	19.52	Average	18.71
SD	17.981	SD	13.756	SD	14.380

*The total PAH concentration for each site was calculated considering all values above LOD.

**For those sites with ND (Not Detected), a 0.1 ppm value was assigned for calculating the average and SD for statistical purposes.

Table 3. 7 Comparison of the total PAHs concentration and UMO volume (L/month) generation per site between EPC, JZC and JZCNC.

EPC	* Σ PAH	Liters	JZC	Σ PAH	Liters	JZCNC	Σ PAH	Liters
EP 1	76.00	100	JZ1	12.13	50	JZ5	19.00	30
EP 2	16.26	200	JZ2	4.25	200	JZ9	ND**	20
EP 3	31.98	200	JZ3	ND	100	JZ10	22.24	25
EP 4	45.82	8316	JZ4	ND	200	JZ11	5.98	10
EP 5	38.67	1514	JZ6	45.48	100	JZ12	12.23	25
EP 6	32.50	200	JZ7	5.14	50	JZ13	ND	25
EP 7	33.39	200	JZ8	ND	100	JZ14	50.68	60
EP 8	26.92	1514	JZ17	ND	50	JZ15	13.92	20
EP 9	12.39	104	JZ19	40.35	30	JZ16	ND	200
EP 10	3.94	63	JZ20	6.61	50	JZ18	5.12	25
EP 11	15.22	491	JZ22	ND	500	JZ21	13.12	20
EP 12	4.27	20	JZ31	27.11	80	JZ23	18.10	100
EP 13	21.07	400	JZ32	20.93	100	JZ24	6.69	25
EP 14	15.51	1040	JZ34	20.86	40	JZ25	14.10	5
EP 15	20.88	200	JZ35	29.26	100	JZ26	13.62	150
EP 16	34.62	757	JZ36	22.63	25	JZ27	6.63	25
EP 17	12.31	568	JZ39	21.56	60	JZ28	7.43	10
EP 18	ND	302	JZ44	21.10	50	JZ29	6.25	25
EP 19	13.52	900	JZ49	22.89	200	JZ30	16.67	60
EP 20	ND	568	JZ50	16.46	800	JZ33	26.66	20
EP 21	ND	378	JZ51	26.41	200	JZ37	36.03	15
EP 22	ND	208	JZ52	21.65	800	JZ38	23.99	20
EP 23	ND	253	JZ53	22.64	100	JZ40	26.58	30
EP 24	ND	190	JZ54	22.21	34	JZ41	21.79	30
EP 25	ND	2082	JZ55	21.50	100	JZ42	43.60	40
EP 26	41.96	1890	JZ56	21.33	30	JZ43	16.30	30
EP 27	29.99	1475	JZ57	30.27	150	JZ45	21.83	50
EP 28	7.48	38	JZ58	57.28	1400	JZ46	21.91	50
EP 29	4.17	151	JZ59	23.88	400	JZ47	58.33	50
EP 30	10.93	200	JZ60	21.27	100	JZ48	32.06	25
Average	18.35	817.40	Average	19.52	206.63	Average	18.71	40.67

*The total PAH concentration for each site was calculated considering all values above LOD.

**For those sites with ND, a 0.1 ppm value was assigned for calculating the average and SD for statistical purposes.

Although the UMO volume generated for EPC was 817.40 L/month, nearly fourfold the JZC amount of 206.63 L/month and the JZNC amount 40.67 L/month, the total mean PAH concentrations for EPC and JZNC were very similar. The higher PAH total mean concentration was for JZC (Table 3.7).

It is very likely that EPC had better management and law enforcement, JZNC were the smallest shops with lower UMO volume generation. Accordingly, the focus could be the JZC group with the higher PAH contamination.

Observations during the visiting and sampling process suggest little difference between some car repair shops in Compliance status (hired an authorized collector for the UMO final disposal) versus Non-Compliance status shops (did not hire an authorized collector for the UMO final disposal). Specifically, some observed UMO handling practices failed to guarantee appropriate UMO management, resulting in PAH contamination of nearby soil from UMO.

It is desirable that before issuing any permits for mechanic shops to begin or continue operations, local authorities should first require training and awareness sessions for all technicians/employees in the proper handling and disposal of UMO.

Table 3. 8 Concentrations of PAHs compounds in soils from El Paso and Ciudad Juárez in mg kg⁻¹.

Compound	El Paso (n=30)			Ciudad Juárez (n=60)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Acenaphthylene	2.95	9.59	2.82	3.90	26.02	0.57
Acenaphthene	ND	ND	ND	ND	6.26	0.11
Fluorene	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	5.24	0.18	ND	ND	ND
Anthracene	ND	ND	ND	ND	ND	ND
Fluoranthene	ND	8.9	0.30	ND	8.24	0.14
Pyrene	5.84	7.93	0.46	ND	ND	ND
Benzo (a) anthracene	10.12	15.21	4.40	10.03	11.20	5.85
Chrysene	6.27	12.68	2.46	6.19	13.92	1.70
Benzo (b) fluoranthene	4.68	7.18	0.73	4.58	13.27	2.12
Benzo (k) fluoranthene						
Benzo (a) pyrene	6.33	9.34	3.08	5.97	9.44	5.06
Indeno (1,2,3 cd) pyrene	8.32	13.63	1.04	8.49	15.03	0.98
Dibenz (ah) anthracene						
Benzo (ghi) perylene	4.17	14.82	2.87	4.12	19.80	2.59
ΣPAH ₁₅	0.1	76.0	18.35	0.1	58.33	19.11

ND= Non Detected

For the PAHs soil analyses a working data set was generated as shown in Table 3.8. The summary description of the minimum, maximum and mean for all 90 samples also includes the detected values and the status of non-detected (ND) for each compound.

Among the LMW PAH compounds, naphthalene could not be quantified since it was too close in the chromatogram to its internal standard (naphthalene-d₈). Only Acenaphthylene showed a minimum value of 2.95 mg kg⁻¹ and a maximum of 9.59 mg kg⁻¹ for El Paso and minimum of 3.90 and maximum value of 26.02 mg kg⁻¹ for Ciudad Juárez. The rest of the PAHs found correspond to the HMW compounds for both cities

as: benzo(a)anthracene, benzo(b)fluoranthene and benzo(k)fluoranthene, crysene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene dibenz(a,h)anthracene, benzo(g,h,i)perylene. benzo(b)fluoranthene and benzo(k)fluorantene were reported as a sum, since they were closed together in the chromatogram (Chung, 2007).

All the PAH HMW compounds found in this research are recognized as PAHs of interest defined as carcinogenic by authorities such as Health Canada, the International Agency for Research on Cancer (IARC) or the USEPA, except for benzo(g,h,i)perylene (CCME, 2010), also above the SSL-NOM-138-SEMARNAT/SS-20 and the Canadian Soil Quality Guidelines.

In Table 3.8, the average value of the HMW compounds above the RSL (Table 3.10) for El Paso were: benzo(a)anthracene 4.40 mg kg^{-1} , benzo(a)pyrene 3.08 mg kg^{-1} , indeno(1,2,3-cd)pyrene 1.04 mg kg^{-1} and dibenz(a,h)anthracene 1.04 mg kg^{-1} . For Ciudad Juarez: benzo(a)anthracene 5.85 mg kg^{-1} , benzo(b)fluoranthene and benzo(k)fluoranthene with a mean of 2.12 mg kg^{-1} , benzo(a)pyrene with a mean of 5.06 mg kg^{-1} , indeno(1,2,3-cd)pyrene and dibenz(a,h)anthracene with a mean of 0.98 mg kg^{-1} .

For Ciudad Juarez and El Paso the PAH compound with the highest average concentration was benzo(a)anthracene with 5.85 mg kg^{-1} and 4.40 mg kg^{-1} respectively.

Benzo(a) pyrene and benzo(a)anthracene are contaminants of concern known as chemical carcinogens and mutagenic (CCME, 2010), found for this research in urban soils contaminated with UMO in ranges similar to those found by Franklin Associated (1984), which analyzed 1071 measured samples of UMO and found the following concentrations; for benzo(a) pyrene a range of $< 1\text{--}405 \text{ mg kg}^{-1}$ and for benzo(a) anthracene $< 5\text{--}660 \text{ mg kg}^{-1}$ (Table 1.3) (ATSDR, 1995). It is very likely that these levels of benzo(a)pyrene in the soil samples came from UMO mismanagement at the car repair shops. PAH analysis in complex matrices such as soil contaminated by a complex hazardous waste like used motor oil, can be relatively complicated due to soil characteristics and the physical and chemical properties of PAH compounds (CCME, 2010).

PAH contaminants are assessed for risk based on their toxicity and exposure. Low molecular weight PAHs are considered directly toxic and high molecular PAHs are considered genotoxic, capable of causing damage to DNA (Wick, 2011).

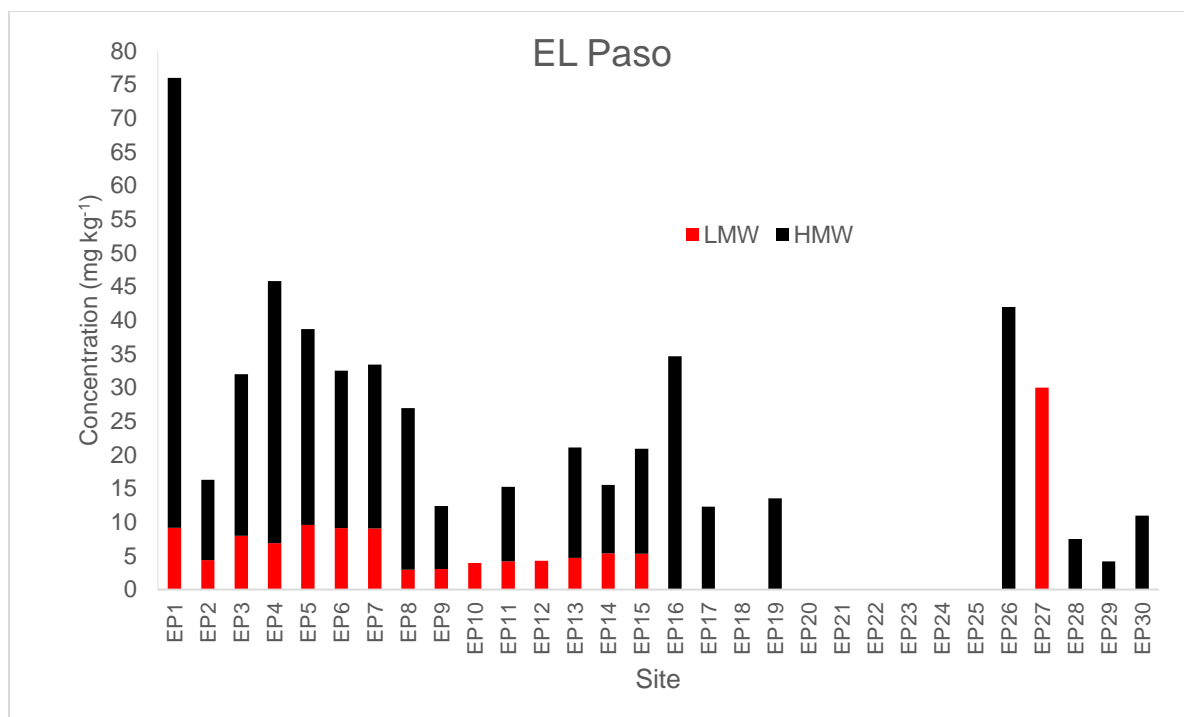


Figure 3.4 Prevalence of low molecular weight (LMW) and high molecular weight (HMW) PAHs in soils from El Paso.

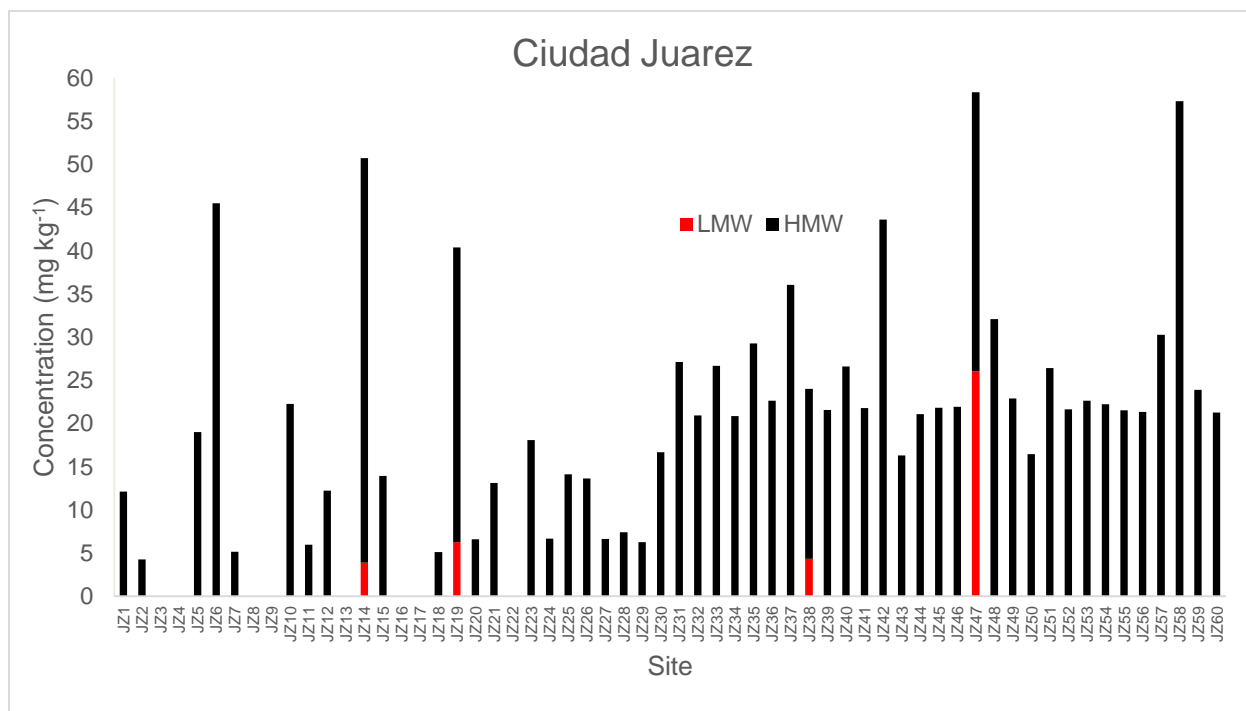


Figure 3.5 Prevalence of low molecular weight (LMW) and high molecular weight (HMW) PAHs in soils from Ciudad Juarez.

The concentration and arrangements of PAHs in soils could reflect the source characteristics (Yang, 2014). Figure 3.4 for El Paso and Figure 3.5 for Ciudad Juarez summarize the data showing that HMW PAHs accounts for 90.55% of the total quantified compounds, LMW PAHs accounts for 9.45% in the soil samples.

In general PAHs from a petrogenic source have lower molecular weight (2-3 ring), whereas higher molecular weight PAHs are mainly from pyrogenic sources (ATSDR, 1995).

Table 3. 9 Percentage of LWM and HMW PAHs compounds found in El Paso and Ciudad Juarez samples.

PAH Compound %	El Paso	Ciudad Juarez	El Paso + Ciudad Juarez
LMW	21.79	3.54	9.45
HMW	78.21	96.46	90.55
LMW/HMW Ratio	0.28	0.037	0.10

For El Paso, the ratio LMW/HMW is 0.28; for Ciudad Juarez, the ratio LMW/HMW is 0.03. The data in Table 3.9 strongly suggest presence of HMW in Ciudad Juarez soil, most likely from pyrogenic sources.

For this research the combined total value of LMW/HMW lower than 1 indicates the soil contamination was probable due to pyrogenic processes (hydrocarbon compounds associated with the combustion of petroleum, wood and coal, residential heating and vehicle emissions).

PAHs can also be released to the environment as a result of petrogenic sources, such as emissions from petrochemical refining and chemical manufacturing.

Once the value of PAHs with four or six rings is higher than 50% of the total concentration it suggests a dominance of combustion; when the value of PAH with two or three rings is greater than 50% it indicates a dominance of petroleum pollution. (De La Torre-Roche, 2009). These results suggest that the PAHs found in El Paso-Ciudad Juarez area were likely to be from pyrogenic processes rather than from petrogenic sources as De La Torre-Roche (2009) report for El Paso soil-borne PAHs.

HMW compounds resulting in an augmentation of the hydrophobicity and lipophilicity, have a recalcitrant structure (difficult to degrade) low volatility, are resistant to leaching, and persist in the environment, thereby increasing the soil contamination and human risk.

The map in Figure 3.6 exhibits the total PAH concentration at all sampled sites in Ciudad Juarez and El Paso, from zero (green) to 76.0 mg Kg⁻¹ (red) as the concentration increases.

For El Paso, the sites with the highest concentrations were: The EP1 76.00 mg kg⁻¹ on Montana St., EP4 45.82 mg kg⁻¹ in the downtown area on Montana St., EP26 41.96 mg kg⁻¹ on Resler St., EP5 38.67 mg kg⁻¹ on Lee Trevino St, EP16 34.62 mg kg⁻¹ in the northeast on McCombs Dr., EP7 on Alameda St had a concentration of 33.39 mg

kg⁻¹, EP6 on Alameda St. 32.50 mg kg⁻¹, EP3 31.98 mg kg⁻¹ on Montana St., EP27 29.99 mg kg⁻¹ on Executive St., EP 8 26.92 mg kg⁻¹ on Alameda St.

For Ciudad Juarez, the higher PAH concentration were found for JZ47 58.33 mg kg⁻¹ on Calle Paseo de La Gloria, JZ58 located on Calle Jilotepec 57.28 mg kg⁻¹, on Calle Tuna JZ 14 50.68 mg kg⁻¹, JZ6 on Calle Montemayor 45.48 mg kg⁻¹, JZ42 on Calle Ma. Teresa Rojas 43.60 mg kg⁻¹, JZ19 on Calle Trigo 40.35 mg kg⁻¹, JZ37 on Calle Puerto de Palos 36.03 mg kg⁻¹, JZ 48 on Calle Hacienda de Cornelias 32.06 mg kg⁻¹, JZ35 on Calle Ramon Rayon 29.26 mg kg⁻¹, JZ31 on Calle Marte 27.11 mg kg⁻¹, JZ40 on Calle Armando Esparza 26.58 mg kg⁻¹, JZ51 on Calle Costa Rica 26.41 mg kg⁻¹.

For El Paso all the 30 sampled sites are in compliance status and it can be said that the Montana St., Alameda St. and downtown area, it appeared that car repair shops and automobile sales are clustered in this area and perhaps it is a strategy for economic development. The Fort Bliss sector presents heavy aircraft and vehicle traffic, including the maintenance and repair facilities. The lower concentrations were found at the north-west area of El Paso.

For Ciudad Juarez the higher concentrations were in the southwest where it is highly populated, and numerous automobile businesses are located, and in the

colonias, represented by the red dots (Figure 3.6) or non-compliance status sampling sites/ car mechanic shops.

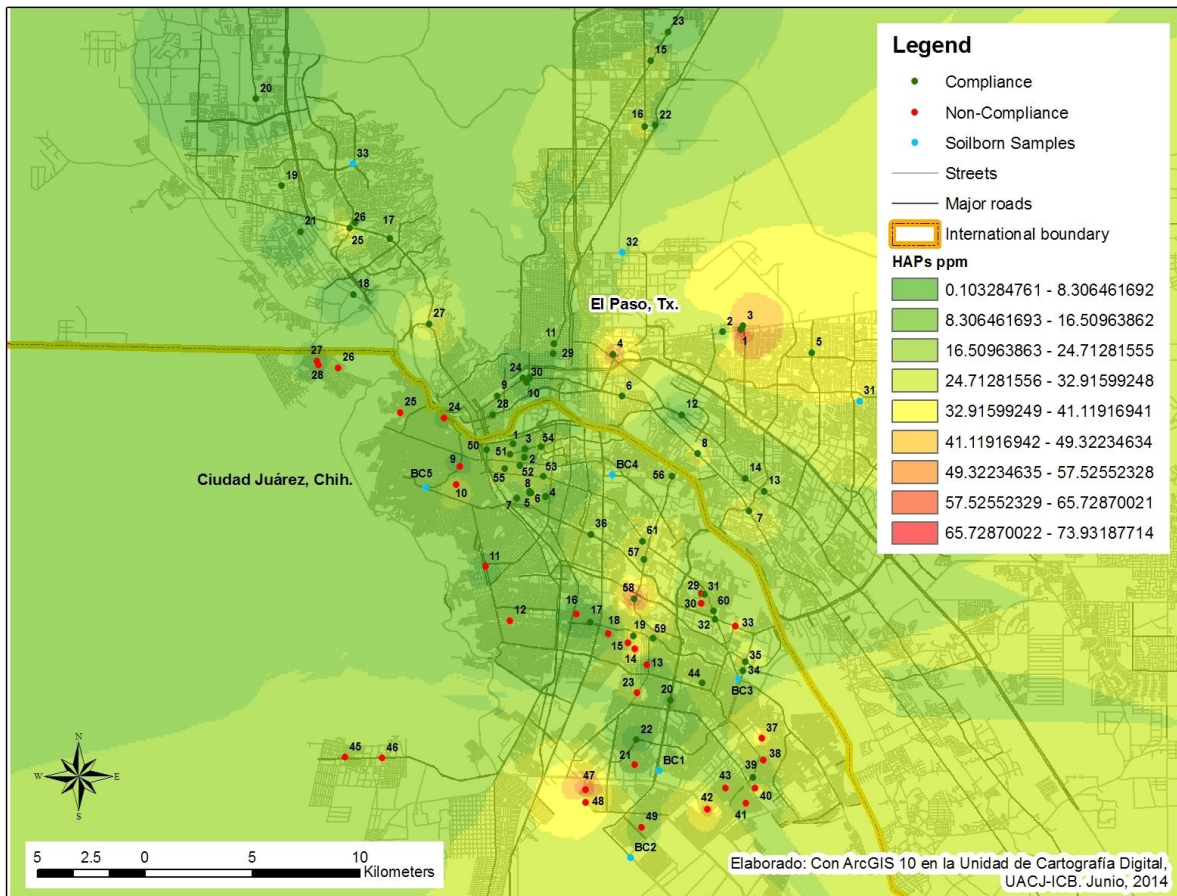


Figure 3. 6 Map of the total PAH concentration for the 90 soil sample sites at the Ciudad Juárez-El Paso in mg kg⁻¹.

3.1.3 Environmental and human risk assessment

The 90 soil samples analyzed for this project were gathered from surficial urban soils near residential areas, mostly in Ciudad Juárez to assess the used motor oil risk.

The EPA recommends the use of Soil Screening Levels (SSLs) as a tool to facilitate prompt identification of contaminants and risk exposure areas of concern (EPA, 1996), as shown in Table 3.10.

Table 3. 10 Regional Screening Level (RSL) for PAHs (mg kg⁻¹) chemical contaminants at superfund sites (USEPA 2009).

Compound	Residential soil	Industrial soil
Acenaphthylene	NA	NA
Acenaphthene	350	4500
Fluorene	230	3000
Phenanthrene	NA	NA
Anthracene	1700	23000
Fluoranthene	230	3000
Pyrene	170	2300
Benzo (a) anthracene	0.15	2.9
Chrysene	15	290
Benzo (b) fluoranthene	0.15	2.9
Benzo (k) fluoranthene	1.5	290
Benzo (a) pyrene	0.015	0.29
Indeno (1,2,3 cd) pyrene	0.15	2.9
Dibenz (ah) anthracene	0.015	0.29
Benzo (ghi) perylene	NA	NA

Table 3. 11 Legislation Maximum Permissible Limits for PAHs in soils (mg kg⁻¹) NOM-138-SEMARNAT/SS-20.

PAHs Compounds	Residential mg Kg ⁻¹	Industrial mg Kg ⁻¹
Benzo [a] pyrene	2	10
Dibenzo [a,h] anthracene	2	10
Benz [a] anthracene	2	10
Benzo [b] fluoranthene	2	10
Benzo [k] fluoranthene	8	80
Indeno [1,2,3 cd] pyrene	2	10

For the Mexican Legislation Maximum Permissible Limits for PAHs in soils (mg kg⁻¹). NOM-138 SEMARNAT/SS-20 in Table 3.11 shows the permissible limits for PAHs in residential soils from SEMARNAT. Such values are higher than the EPA values since NOM-138-SEMARNAT/SS-20 is not proposed for the purpose of remediating contaminated soil.

Table 3. 12 Frequency and contribution of individual PAHs compounds to the total sum of PAHs and samples exceeding EPA criteria in El Paso.

Compound	El Paso (n=30)			
	Frequency of samples above LOD (%)	Frequency of samples above LOQ (%)	Contribution to the total sum of PAHs (%)	Samples exceeding EPA's RSL (%)
Acenaphthylene	26.67	23.33	15.37	NA
Acenaphthene	0.00	0.00	0.00	0.00
Fluorene	0.00	0.00	0.00	0.00
Phenanthrene	3.33	0.00	0.96	NA
Anthracene	0.00	0.00	0.00	0.00
Fluoranthene	3.33	0.00	1.63	0.00
Pyrene	6.67	0.00	2.51	0.00
Benzo (a) anthracene	36.67	3.33	24.00	40.00
Chrysene	30.00	3.33	13.40	0.00
Benzo (b) fluoranthene	13.34	0.00	3.97	13.34
Benzo (k) fluoranthene				
Benzo (a) pyrene	40.00	3.34	16.81	43.34
Indeno (1,2,3 -cd) pyrene	6.67	3.33	5.66	10.00
Dibenz (a,h) anthracene				
Benzo (g,h,i) perylene	26.67	13.33	15.66	NA

LOD= Limit of Detection

LOQ= Limit of Quantification

RSL= Regional Screening Level

NA= RSL not available for that compound

For El Paso the percentage of samples above the LOD and the LOQ exceeding the SSL were benzo (a) pyrene 43.34%, benzo(a) anthracene 40%, benzo(b) fluoranthene and benzo(k) fluoranthene 13.34%, indeno (1,2,3-cd) pyrene and

dibenz(a,h) anthracene 10% the results clearly shows the higher occurrence of benzo(a) pyrene 43.34% and benzo(a) anthracene 40%.

Table 3. 13 Frequency and contribution of individual PAHs compounds to the total sum of PAHs and samples exceeding EPA criteria in Ciudad Juarez.

Compound	Ciudad Juarez (n=60)			
	Frequency of samples above LOD (%)	Frequency of samples above LOQ (%)	Contribution to the total sum of PAHs (%)	Samples exceeding EPA's RSL (%)
Acenaphthylene	3.33	1.67	3.00	NA
Acenaphthene	1.67	0.00	0.55	0.00
Fluorene	0.00	0.00	0.00	0.00
Phenanthrene	0.00	0.00	0.00	NA
Anthracene	0.00	0.00	0.00	0.00
Fluoranthene	1.67	0.00	0.72	0.00
Pyrene	0.00	0.00	0.00	0.00
Benzo (a) anthracene	56.67	0.00	30.60	56.67
Chrysene	20.00	1.67	8.87	0.00
Benzo (b) fluoranthene	33.34	3.33	11.11	36.67
Benzo (k) fluoranthene				
Benzo (a) pyrene	68.34	5.00	26.43	73.34
Indeno (1,2,3- cd) pyrene	5.00	3.34	5.14	8.34
Dibenzo (a,h) anthracene				
Benzo (g,h,i) perylene	31.67	8.33	13.57	NA

LOD= Limit of Detection

LOQ= Limit of Quantification

RSL= Regional Screening Level

NA= RSL not available for that compound

For Ciudad Juarez, Table 3.13 shows the percentage of soil samples above LOD and the LOQ exceeding the SSL were benzo(a) pyrene with 73.34%, benzo(a) anthracene 56.67% benzo(b) fluoranthene and benzo(k) fluoranthene 36.67%, Indeno(1,2,3-cd) pyrene and dibenz (a,h) anthracene with 8.34%.

For El Paso and Ciudad Juarez the most frequently detected PAHs among the 16 compounds were benzo(a)pyrene, benzo(a) anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, Indeno (1,23-cd) pyrene and dibenz (a,h) anthracene with an occurrence average of 58.34%, 48.33%, 25%, 9.17% respectively.

Risk Based Criteria (RBC) and Soil Screening Levels (SSLs) were developed by EPA to determine and minimize the risk associated with contaminants. RBC equations combine routes of human exposure and EPA toxicity data to determine SSLs for contaminated sites (EPA, 1996). For this study the PAHs compounds that exceed the SSLs are the cPAHs that pose carcinogenic risk for human health.

Table 3. 14 Benzo(a)pyrene equivalents (BaPeq) profiles for groups EPC, JZC, JZNC (mg kg⁻¹).

El PASO C	ΣBaPeq*	JUAREZ C	ΣBaPeq	JUAREZ NC	ΣBaPeq
EP 1	19.49	JZ1	0.58	JZ5	7.72
EP 2	6.40	JZ2	0.042	JZ9	ND**
EP 3	8.39	JZ3	ND	JZ10	7.65
EP 4	9.44	JZ4	ND	JZ11	5.98
EP 5	8.41	JZ6	22.44	JZ12	6.04
EP 6	7.76	JZ7	0.051	JZ13	ND
EP 7	1.30	JZ8	ND	JZ14	17.63
EP 8	9.30	JZ17	ND	JZ15	0.14
EP 9	0.097	JZ19	9.08	JZ16	ND
EP 10	0.004	JZ20	0.066	JZ18	0.51
EP 11	1.11	JZ22	ND	JZ21	6.29
EP 12	0.004	JZ31	8.31	JZ23	1.11
EP 13	1.08	JZ32	7.58	JZ24	6.69
EP 14	1.02	JZ34	7.64	JZ25	7.31
EP 15	1.07	JZ35	8.45	JZ26	6.73
EP 16	21.32	JZ36	8.24	JZ27	6.63
EP 17	6.48	JZ39	8.15	JZ28	7.42
EP 18	ND	JZ44	7.50	JZ29	6.25
EP 19	6.54	JZ49	8.44	JZ30	7.46
EP 20	ND	JZ50	7.33	JZ33	8.58
EP 21	ND	JZ51	10.11	JZ37	9.66
EP 22	ND	JZ52	8.36	JZ38	10.47
EP 23	ND	JZ53	8.52	JZ40	8.53
EP 24	ND	JZ54	7.85	JZ41	8.27
EP 25	ND	JZ55	7.88	JZ42	19.61
EP 26	9.10	JZ56	7.83	JZ43	7.28
EP 27	8.20	JZ57	9.15	JZ45	8.11
EP 28	7.48	JZ58	23.74	JZ46	8.30
EP 29	0.042	JZ59	7.59	JZ47	9.12
EP 30	6.62	JZ60	7.81	JZ48	10.13
Average	4.69	Average	6.76	Average	7.00
SD	5.671	SD	5.820	SD	4.509

*The total BaPeq concentration for each site was calculated considering all values above LOD.

**For those sites with ND, a 0.0172 ppm value was assigned for calculating the average and SD for statistical purposes.

Table 3.14 shows BaPeq for the total sum of PAHs compounds found in each soil sample site, the average values comparisons between EPC, JZC and JZNC were

4.69 mg kg⁻¹, 6.76 mg kg⁻¹ and 7.0 mg kg⁻¹ respectively. JZC and JZNC are very similar values but for EPC are slightly lower.

To assess risk from PAHs can be converted to benzo(a)pyrene equivalents (BaPeq) using Total Equivalency Factors (TEFs). The total BaPeq concentration is used to calculate risk and can be compared to ambient PAH levels. The PAHs average values for the three groups (EPC, JZC and JZNC) are above the TEF sum for cPAHs (Table 3.15).

Table 3. 15 TEF values and El Paso and Ciudad Juarez 90 soil samples BaPeq.

Compound	TEFs*	El Paso BaPeq	Ciudad Juarez BaPeq
Acenaphthylene	0.001	0.0028	0.00057
Acenaphthene	0.001	ND	0.000104
Flourene	0.001	ND	ND
Phenanthrene	0.001	0.00017	ND
Anthracene	0.01	ND	ND
Flouranthene	0.001	0.0003	0.000138
Pyrene	0.001	0.00046	ND
Benzo (a) anthracene	0.1	0.44	0.5848
Chrysene	0.01	0.025	0.01694
Benzo (b) floranthene	0.1	0.072	0.2122
Benzo (k) flouranthene	0.1		
Benzo (a) pyrene	1	3.0822	5.05
Indeno (1,2,3 -cd) pyrene	0.1	1.037	0.9815
Dibenz (a,h) anthracene	1		
Benzo (g,h,i) perylene	0.01	0.0288	0.0259
Σ BaPeq ₁₅ **		4.69	6.88
Σ CarcTEF ₇ ***		4.66	6.85

*Source: EPA (2010).

** Σ BaPeq₁₅= Σ PAH₁₅ X TEF

*** Σ CarcTEF₇= Σ PAH₇ X TEF of (BaA, Chr, BbF+BkF, BaP, IcdP+Dah).

For benzo(a)pyrene residential soils the Canadian Council of Ministers of the Environment (CCME) (1999b) adopted human health-based soil quality guidelines of 0.7 mg kg^{-1} . Soil criteria for more than one media derived in Denmark, New Jersey and the USEPA (PGR) were 0.1, 0.27, 0.66, and 0.62 mg Kg^{-1} benzo(a)pyrene respectively (Canadian Council of Ministers of the Environment(CCME, 2010)).

The main approach by regulatory agencies such as the USEPA (1993; 1999) California EPA (OEHHA, 1992), Netherlands (RIVM,2000), the UK (UK Environment Agency, 2002), or Provinces of British Columbia and Ontario for assessing the human health risk of PAH-containing mixtures involves the use of “potency equivalence factors” (PEFs), also referred to as “relative potency factors” (RPFs) or “toxicity equivalence factors” (TEFs). These factors are used to relate the carcinogenic potential of other PAH to that of benzo(a)pyrene (BaP) (CCME 2010).

According to Environment Canada 1999, in general soils containing $< 0.1 \text{ mg kg}^{-1}$ B(a)P are considered uncontaminated, soils containing $0.1\text{-}1.0 \text{ mg kg}^{-1}$ B(a)P are considered slightly contaminated and soils containing $> 1.00 \text{ mg kg}^{-1}$ B(a)P are considered to be significantly contaminated (Canadian Soil Quality Guidelines, 2010).

Table 3. 16 Sites classification for EPC, JZC and JZNC groups according to Candian Soil Quality Guidelines, (2010).

Range	Clasification	%EPC	%JZC	%JZNC
< 0.1 mg kg ⁻¹ B(a)P	Uncontaminated	36.67	26.67	3.00
0.1-1.0 mg kg ⁻¹ B(a)P	Slightly contaminated	0	3.33	6.67
> 1.0 mg kg ⁻¹ B(a)P	Significantly contaminated	63.33	70.0	83.33

The 90 soil samples sites for total BaPeq concentration of EPC, JZC and JZNC groups in Table 3.14 are represented in Figure 3.7.

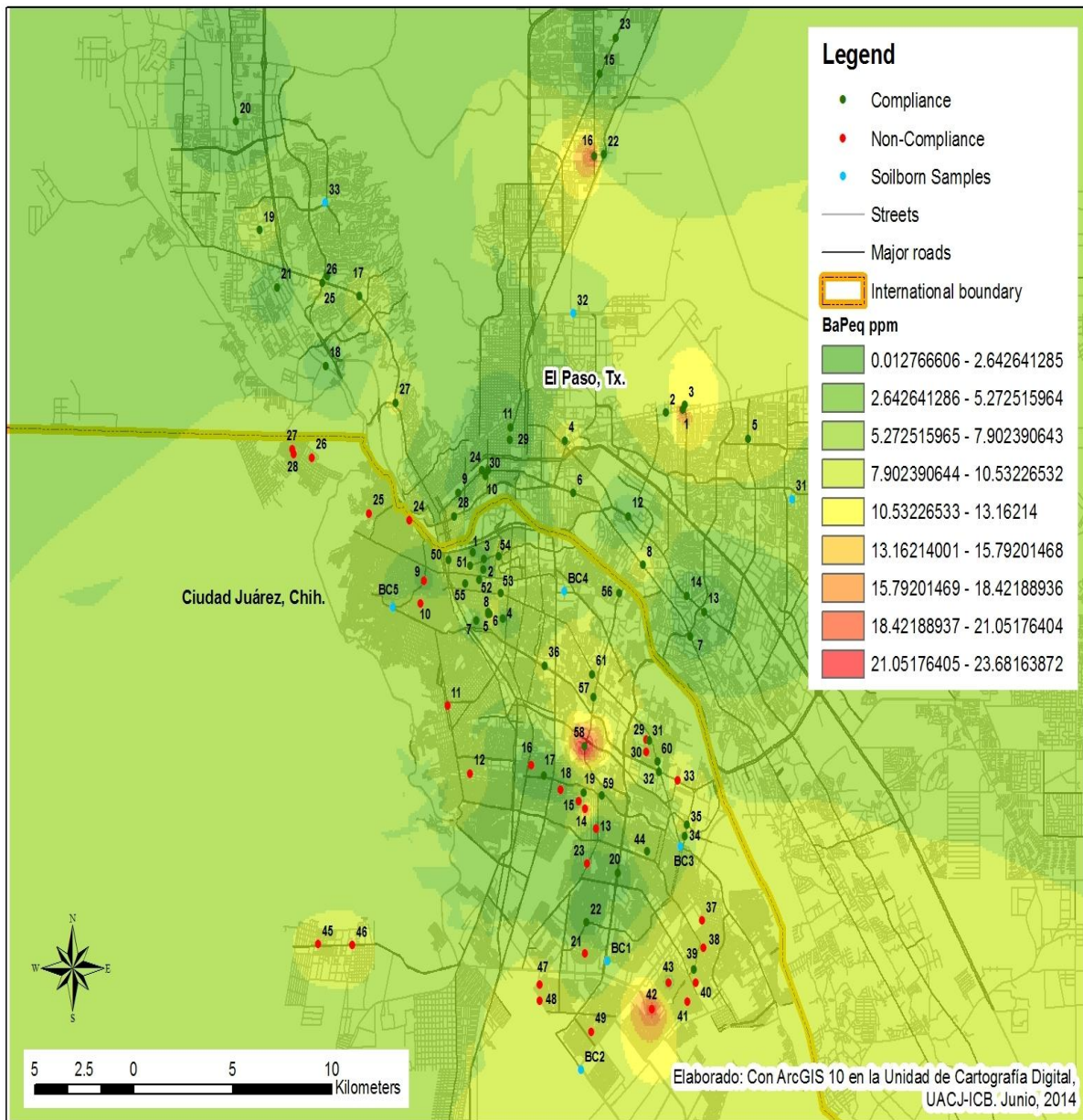


Figure 3.7 The 90 sampled sites map for the El Paso and Ciudad Juárez showing Total BaPeq risk.

Figures 3.8 for EPC, Figure 3.9 for JZC and Figure 3.10 for JZNC, graphically compares the target cleanup levels for BaP of 0.1 mg kg^{-1} with the total B(a)Peq per site measured in urban environments. The profiles for each group are different.

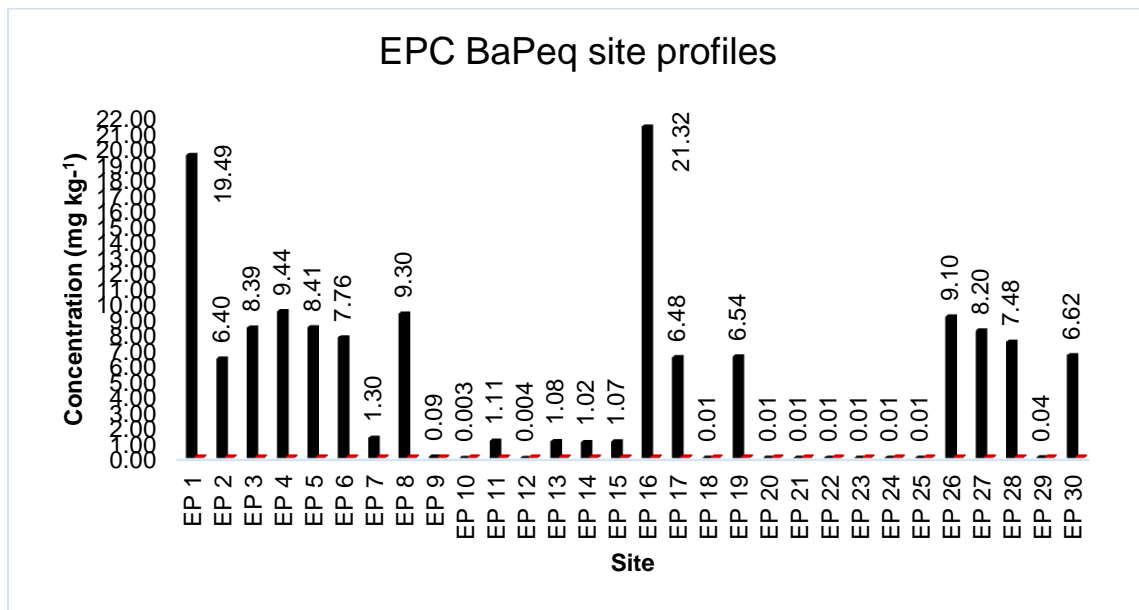


Figure 3.8 For EPC 30 samples BaPeq concentration per site, against the CCME (2010) risk based concentration and cleanup levels for BaPeq of 0.1 mg kg^{-1} (Bradley, 1994).

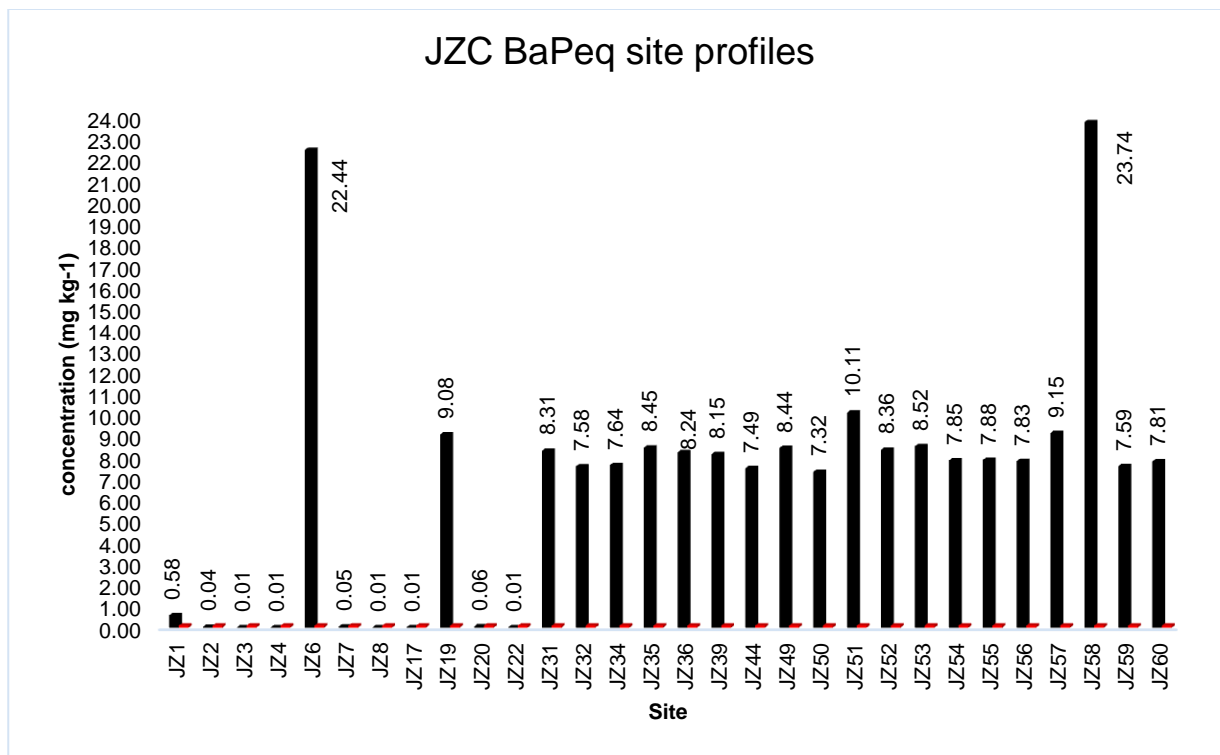


Figure 3.9 The JZC 30 samples BaPeq concentration per site, against the CCME (2010) risk based concentration and cleanup levels for BaPeq of 0.1 mg kg⁻¹ (Bradley, 2014).

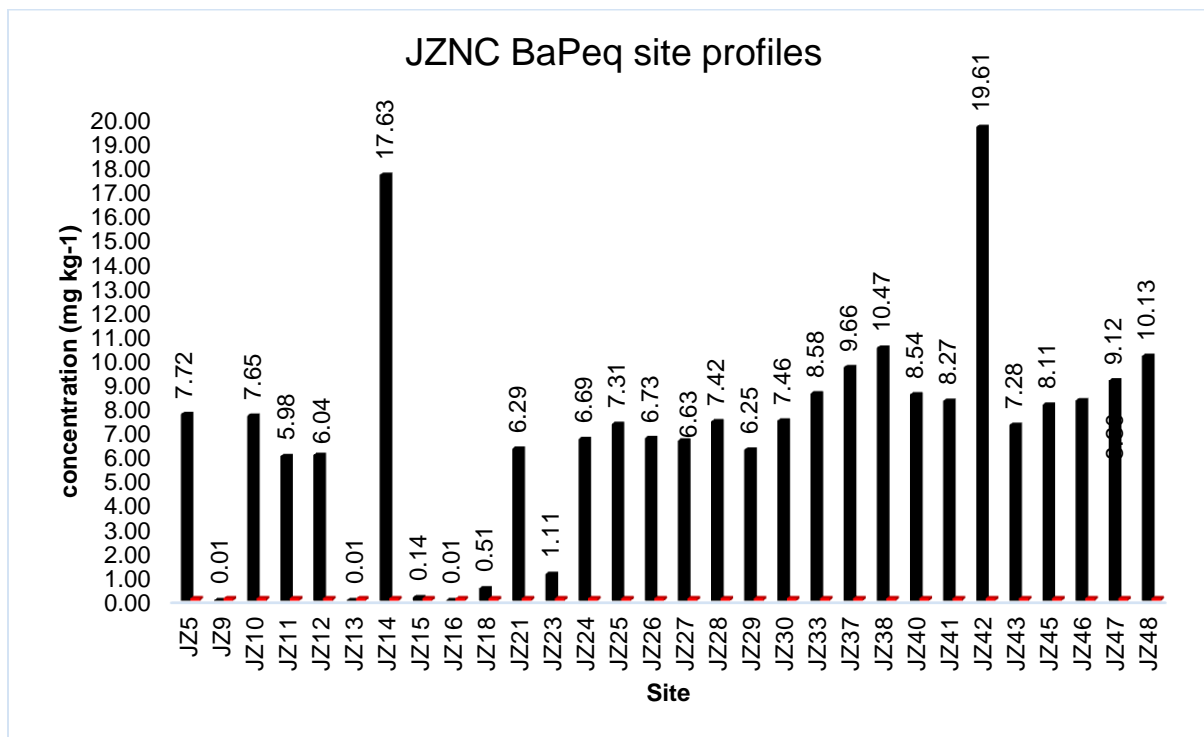


Figure 3. 10 The JZNC 30 samples BaPeq concentration per site, against the CCME (2010) risk based concentration and cleanup levels for BaPeq of 0.1 mg kg⁻¹ (Bradley, 2014).

The Benzo(a)pyrene equivalent (BaPeq) mean concentration for EPC, JZC and JZNC groups were: 4.69 mg kg⁻¹, 6.76 mg kg⁻¹ and 7.00 mg kg⁻¹ respectively, values were above the soil screening level (SSL). These values from UMO contaminated soils are higher than the background levels as the literature showed: Wang (2013) report in the megacity Shanghai, 52 soil samples collected in urban areas to assess the potential risk to human health. The (BaPeq) concentrations nearly half of the soil samples showed concentrations above the safe BaPeq value of 0.6 mg kg⁻¹. Exposure to these soils could pose a significant risk to human health from the carcinogenic effects of soil PAHs. Bradley (1994) In urban soils from New England the background level of BaPeq of 3.3 mg kg⁻¹ is approximately 30 times greater than the target cleanup level of 0.1 mg kg⁻¹.

3.1.4 Statistical comparison of PAH concentrations in urban soils of El Paso-Ciudad Juarez area.

This research considered comparing the mean concentration of PAHs of the groups established at 1) compliant sites in Ciudad Juarez (JZC) versus compliant sites in El Paso (EPC) and 2) compliant sites in Ciudad Juarez (JZC) versus non-compliant sites in Ciudad Juarez (JZNC). The working hypothesis for this research was that the mean concentration of the EPA 16 priority PAHs present in soil samples near car repair shops is different for both El Paso and Ciudad Juarez. Indeed, the null hypothesis was

not rejected. The IBM SPSS version 22 software was used to perform the statistical analysis to compare the groups. In Table 3.17 the descriptive statistics is showed.

Table 3. 17 Summary of statistical analysis from the PAHs concentration in EPC, JZC and JZNC.

Group	Sample size	Mean	Variance	Minimum	Maximum
EPC	30	18.35	323.32	0.1	76.00
JZC	30	19.52	189.23	0.1	57.28
JZNC	30	18.71	206.78	0.1	58.33

For the comparison of the two groups EPC vs. JZC for PAHs concentration a working data set was generated to assess the equality of means, and a t-test at 95% confidence was performed. Although the EPC and JZC means, 18.35 mg kg⁻¹ and 19.52 mg kg⁻¹ respectively and there was no statistical difference between them; the difference in variance data indicates the disparity between sites concentration.

Table 3. 18 Two groups, EPC vs. JZC t-test comparison for PAHs statistical mean.

Comparison	t-test for equality of means (0.05)			Statistically significance at 0.05 level of significance
EPC vs JZC	t-stat	df	p-value	No
	-0.284	58	0.7775	

Thus, the null hypothesis of equal means was not rejected and it is concluded that there is no difference between the means of the two groups (EPC vs JZC).

The results of the comparison of Ciudad Juarez compliance and non-compliance groups (JZC vs. JZNC) to assess the equality of means a t-test at 95% confidence was performed, as shown in Table 3.19. In the test, the null hypothesis was not rejected and the conclusion was that no difference existed between the PAHs mean concentrations.

Table 3 .19 The t-test comparison of JZC vs. JZNC for PAHs mean concentration.

Comparison	t-test for equality of means (0.05)			Statistically significance at 0.05 level of significance
	t-stat	df (n-2)	p-value	No
JZC vs JZNC	0.225	58	0.8227	

For the JZC and JZNC, PAH concentrations were 19.52 mg kg⁻¹ and 18.71 mg kg⁻¹ and the UMO volume generated 212.93 and 40.66 L/Month respectively; it seems similar for the PAHs samples concentration and different for the UMO volume generated, influenced by the socio-economic factors.

The Benzo(a)pyrene equivalence (BaPeq) was calculated by the sum of BaPeq for each PAH compound using the toxicity equivalent factor (TEF) developed by the EPA (Table 3.15). Table 3.20 shows the summarized data for the three groups.

Table 3 .20 Descriptive statistics for EPC, JZC and JZNC of the concentration of BaPeq.

Group	Sample size	Mean	Variance	Minimum	Maximum
EPC	30	4.69	32.16	0.0172	21.32
JZC	30	6.76	33.88	0.0172	23.74
JZNC	30	7.00	20.34	0.0172	19.61

Table 3. 21 Two groups, EPC vs. JZNC t-test comparison for BaPeq statistical mean.

Comparison	t-test for equality of means (0.05)			Statistically significance at 0.05 level of significance
EPC vs JZC	t	df (n-2)	p-value	No
	-1.3931	58	0.1689	

For the comparison of BaPeq mean concentration between EPC and JZC a t-test at 95% confidence was completed, the results are presented in table 3.21. The null hypothesis was not rejected, and it can be concluded that there are no differences between the BaPeq mean concentration of EPC and JZC groups of 4.69 mg kg⁻¹ and 6.76 mg kg⁻¹ respectively.

Table 3. 22 Two groups, JZC vs. JZNC t-test comparison for BaPeq statistical mean.

Comparison	T-test for equality of means (0.05)			Statistically significance at 0.05 level of significance
	t-stat	df (n-2)	p-value	
JZC vs JZNC	-0.1707	58	0.8651	No

The results of the comparison between JZC and JZNC for the BaPeq concentration are displayed in table 3.22. The t-test was performed at 95% confidence. The results showed the BaPeq mean concentrations were not statistically different, the null hypothesis was not rejected, and the BaPeq concentration was not different for the Ciudad Juarez groups. Even though JZC (212.93 L/month) group generated 5 times more UMO per month than JZNC (40.66 L/month), there was no difference in the BaPeq mean concentration; this could be because the JZNC mechanic shops had no appropriate UMO management and there is no effective enforcement of environmental laws.

3.1.5 Conclusions

For the first time a research study considered the car repair shops as a source of PAH contamination in soil from used motor oil (UMO). The total detected PAH concentration for the 90 sites sampled in the groups EPC, JZC and JZNC present a ratio of minimum 0.01 mg kg^{-1} and a maximum of 76.00 mg kg^{-1} with an average of 63.87 mg kg^{-1} ; such amounts could pose an environmental and health risk, and it has been demonstrated that no statistical difference exists between Ciudad Juarez-El Paso soil samples PAH mean concentrations.

The used motor oil volume generated from 60 shops sampled in Ciudad Juarez 7,420 L/month compared to 24,338 L/month in the 30 shops sampled in El Paso, suggests that the car maintenance for El Paso is higher and also more efficient and effective enforcement of environmental laws at mechanic shops by the authorities. The JZNC sites were smaller car repair shops and generate the lowest UMO amount.

Concentrations and patterns of PAHs in soils can reveal the nature of the source. For El Paso and Ciudad Juarez the high molecular weight (HMW) PAHs accounts for 78.21% and 99.46% respectively, the ratio $\text{LMW}/\text{HMW} = > 1$ that indicated that the contamination is largely due to the pyrogenic sources (combustion derived).

El Paso's most frequent PAH compound found at the soil samples was the LMW compound acenaphthylene with 15.37%, the HMW compounds were: benzo(a)anthracene with 24.00%, benzo(a)pyrene 16.81%, chrysene with 13.40%, indeno(1,2,3-cd)pyrene and dibenz (a,h) anthracene with 5.66%, and Benzo(b) fluoranthene besides Benzo(k) fluoranthene 3.97%.

In Ciudad Juarez the most frequent PAH compound found was the LMW compound acenaphthylene with 3.00%, the HMW compounds were: benzo(a)anthracene with 30.60 %, Benzo (a) pyrene with 26.43%, Benzo(b) fluoranthene and Benzo(k) fluoranthene 11.11%, chrysene with 8.87%, follows indeno(1,2,3-cd)pyrene and dibenz (a,h) anthracene with 5.14%.

In this study the total Benzo(a)pyrene equivalent (BaPeq) mean concentration for EPC samples was 4.69 mg kg⁻¹, 6.76 mg kg⁻¹ for JZC, and JZNC 7.00 mg kg⁻¹. The statistical analysis demonstrated that there is no significant difference between Ciudad Juarez and El Paso soil samples BaPeq mean concentrations.

The Risk assessment methods will yield risk-based cleanup levels for PAHs that range from 0.1 to 0.7 mg kg⁻¹ therefore the soils near mechanic shops in El Paso and Ciudad Juarez area could pose an environmental and human health risk CCME (2010).

The sampling sites altitudes suggest that the possible runoff tendencies to the river lower altitude may pose a higher concentration of PAHs; it is therefore recommended to research PAHs at the river area.

It is highly recommended to develop a restoration program to recover the contaminated areas and reduce the environmental and health risk by bioremediation that is effective and economical, but which also tends to be slow.

It can be said that the highest human health risk found during this research process was for the car repair shops workers, who are exposed on a daily basis to the PAH compounds contained in the UMO by inhalation and dermal exposure routes. The PAH compounds found were high molecular weight above the soil screening levels (SSL) that could pose a health risk for those mechanic shops workers and their families; additionally it can be observed that they neglect to use any kind of personal protection gear. This data will be available at the UTEP library for public health professionals to help them to address the needs of persons living or working near hazardous waste sites.

ANNEX 1

El Paso Compliance car mechanic shop



El Paso Non Compliance car mechanic shops



(Figueroa, 2011)

Ciudad Juarez Compliance car mechanic shop



Ciudad Juarez Non Compliance car mechanic shops



(Figueroa, 2011)

Bibliography

- Agency for Toxic Substances and Disease Registry. (1995). *Toxicological profile for Polycyclic Aromatic Hydrocarbons (PAHs)*. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.
- Agency for Toxic Substances and Disease Registry. (1997). *Toxicological Profile for Used Mineral-Based Crankcase Oil*. Atlanta, Georgia: Department of Health and Human Services, Public Health Service.
- Bath, R., & Petit, A. (1998). *Who Owns the Water? A Case Study of El Paso Del Norte*. University Wisconsin-Madison: Land Tenure Center.
- Boughton, B., & Horvat, A. (2004). Environmental Assessment of Used Oil Management Methods. *Environmental Science and Technology* .
- Bradley, L. J., Magee, B. H., & Allen, S. L. (1994). Background Levels of Polycyclic Aromatic Hydrocarbons (PAH) and Selected Metals in New England Urban Soil. *Journal of Soil Contamination* , 1-13.
- Canadian Soil Quality Guidelines. (2010). *Carcinogenic and other polycyclic aromatic hydrocarbons*. Canada: Canadian Council of Ministers of the Environment.
- CEC. (2003). Protection of Environment Chapter I. Environmental Protection Agency. *Solid Wasters Part 279. Standards for the Management of Used Oil* . Mexico: CEC.
- CEC. (2010). SMOC Renewed Agenda. *A Renewed North American Agenda for Chemicals Management* .
- CEC. (2003). Summary of Environmental Law in Mexico.
- Chung, M., Hu, R., Cheung, K., & Wong, M. (2007). Pollutants in Hong Kong soils: Polycyclic aromatic hydrocarbons. *Chemosphere* , 67 (3), 464-473.
- Continuous Deflective Separation Technology. (2005). *Oil and Grease in Stormwater Runoff*. Retrieved from CDS Technologies: www.cdstech.com
- Cresswell, A., Burke, B., & Navarrete, C. (2009). *Mitigating Cross-Border Air Pollution: The Power of A Network. Center for Technology in Government*. New York: University at Albany. The Research Foundation of State University of New York.
- De La Torre-Roche, R. J., Lee, W. Y., & Campos-Diaz, S. (2009).) Soil-borne polycyclic aromatic hydrocarbons in El Paso, Texas: Analysis of a potential problem in the United States/Mexico border region. *J Hazard Matter* , 946-958.
- Departmental Data Management Specialist. (2010). *Estadistical data for the car mechanic shop* . El Paso City: EL Paso Development Services Department.
- Department of Commerce & SEMARNAT. (2001). *Framework of Mexican Enviromental Law*. Retrieved from Ventan Ambiental Mexico: http://www.ventanambientalmexico.com/flat_files/Other/info.htm

DHHS & ATSDR. (1995). Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs). *Peer Reviewed* , 163-4.

Dominguez-Rosado, E., & Pichtel, J. (2003). Chemical Characterization of Fresh, Used and Weathered Motor Oil Via GC/MS, NMR and FTIR Techniques. *Proceedings of the Indiana Academy of Science* , 1-8.

Duarte-Davidson, R., & Jones, K. (1996). Screening the environmental fate of organic contaminants in sewage sludges applied to agricultural soils: II. The potential for transfers to plants and grazing animals. *Sci. Total Environ* , 21;185(1-3):59-70.

Dzantor, E. K., & Beauchamp, R. (2002). Phytoremediation, part I: fundamental basis for use of plants in removal of organic and metal contamination. *Environmental Practice* , 4(2): 77-87.

Eaton, D. (2006). *Dump, Burn or Recycle? Used Oil Management in Texas*. Austin, Texas : Lyndon B. Johnson School of Public Affairs.

Eaton, D. J. (2007). *Managing Used Oil Along the Mexico-US Border*. Austin, Texas : LBJ School of public Affairs .

Eaton, D. (2007). *Managing Used Oil Along the Mexico-U.S. Border. Policy Research Project Number 158. Policy Research Project on Cross-Border Environmental Management*. Lyndon B Johnson School of Public Affairs Policy Research.

Eaton, D. (2007). Managing Used Oil Along the Mexico-U.S. Border. Policy Research Project Number 158. Policy Research Project on Cross-Border Environmental Management. *Lyndon B. Johnson of Public Affairs . The University of Texas at Austin*.

Ellis, J. B., & Chatfield, P. R. (2006). Diffuse oil pollution in the UK. *Urban Water Journal* , 3(3): 165-173.

EPA . (1993). *Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons*. USEPA.

EPA & SEMARNAT. (2011, May). *Border 2012: U.S. - Mexico Environmental Program* . Unated States of American.

EPA & SEMARNAT. (2014, March 16). Border Environmental Program. *Border 2020* .

EPA & SEMARNAT. (1983 йил 14-August). Treaties and other International Acts Series. *La Paz Agreement* . Unated States of America and Mexico.

EPA. (1992). 40 CFR Ch. I (7-1-07 Edition). *Code of federal Regulations (CFR) title 40, part 261, subpart A, rule 261.1*.

EPA. (1992). 40 CFR Part 260, 261, 266, 271 and 279. *Resource Conservation and Recovery Act* .

EPA. (1994). *Collecting Used Oil for Recycling/Reuse: Tips for Consumers Who Change Their Own Motor Oil and Used Filters*. Washington, D.C.: U.S. EPA.

EPA. (2013). *Integrated Risk Information System (IRIS), the Health Effects Assessment Summary Tables (HEAST), the Risk Assessment Information System RAIS and other sources*. Tennessee: RAIS and other sources. The University of Tennessee.

FAO. (2006). *Guidelines for Soil Description*. Roma, Italia: FAO.

FAO. (2001). *Lecture Notes on the Major Soils of the World*. Roma, Italia: FAO.

Figuerola, A., De la Mora, A., Corral, A., & López, S. (2010). *Used Motor Oil Management in the Ciudad Juarez*. The University of Texas at Austin, Lyndon B. Johnson School of Public Affairs. Austin, Texas : LBJ school of public affairs.

Fitzsimmons, D. (2005, September 26). *Improving Markets for Waste Oil*. Retrieved from <http://www.oecd.org/dataoecd/14/9/35438706.pdf>

Flowers, A., McBerty, F., & Reamer, R. (1925). Deterioration and Reclamation of Used Automobile Crank-Case Oil. *Industrial and Engineering Chemistry*, Vol. 17 No. 5.

Franklin Associated. (1984). *Composition and Management of Used Oil Generates in the United States*. Washington D.C.: U.S. EPA.

Granados-Olivas, A., Brown, C., Greenlee, J., Creel, B., Hawley, J., Kennedy, J., et al. (2006). Geographic Information Systems at the Paso del Norte Region. The Academic Accomplishments and Challenges for a Transboundary Water Resources Gis Cooperation. *Geographic Information System at The Paso Del Norte Region*, 1-12.

GRI/PERF. (2000). *Environmentally acceptable endpoints for hydrocarbon-contaminated soil. Final Project Report*. Prepared by ThermoRetec Consulting Corporation. Gas Research Institute (Contract No. 5094-250-2863) and Petroleum Environmental Research Forum (Project No. 94-06, Research Area 1).

Grimmer, G., Dettbarn, G., Brune, H., Deutsch-Wenzel, R., & Misfeld, J. (1982). Quantification of the Carcinogenic Effect of Polycyclic Aromatic Hydrocarbons in Used Engine Oil by Topical Application onto the Skin of Mice. *Int Arch Occup Environ Health*.

Hanner, P., Schiavon, M., Druell, V., & Linchtouse, E. (2008). Phytotoxicity of ancient gaswork soils. Effect of polycyclic aromatic hydrocarbons (PAHs) on plant germination. *Organic Geochemistry*, 963-969.

Hawley, J., Kennedy, J., Granados-Olivas, A., & Ortiz, M. (2009). *Hydrogeologic Framework of the Binational Western Hueco Bolson-Paso Del Norte Area, Texas, New Mexico, And Chihuahua: Overview and Progress Report on Digital-Model Development*. New Mexico : New Mexico Water Resource Research Institute.

Henner, P., Schiavon, M., Druelle, V., & Lichtouse, E. (1999). Phytotoxicity of ancient gaswork soils. Effect of polycyclic aromatic hydrocarbons (PAHs) on plant germination. *Organic Geochemistry*, 30: 963-969.

Hoffman, E. J., Mills, G. L., Latimer, J. S., & Quinn, J. G. (1984). Urban runoff as a source of polycyclic aromatic hydrocarbons to coastal waters. *Environmental Science and Technology*, 18(8): 580-587.

Hurd, B., Brown, C., Greenlee, J., Granados, A., & Hendrie, M. (2006). Assessing Water Resource Vulnerability for Arid Watersheds: gis-based research in the Paso del Norte region. *New Mexico Journal of Science*, Vol. 44.

INEGI. (2005). *Conteo de Poblacion y Vivienda*. Ciudad Juarez: INEGI.

INEGI. (2010). *Información nacional, por entidad federativa y municipios*. Retrieved from México en cifras: <http://www3.inegi.org.mx/sistemas/mexicocifras/default.aspx?src=487&e=8>

Jiang, Y.-F., Wang, X.-T., Wang, F., Jia, Y., Wu, M.-H., Sheng, G.-Y., et al. (2009). Levels, composition profiles and sources of polycyclic aromatic hydrocarbons in urban soil of Shanghai, China. *Chemosphere* , 1112-1118.

Joner, E., Corgié, S., Amellal, N., & Leyval, C. (2002). Nutritional constraints to degradation of polycyclic aromatic hydrocarbons in a simulated rhizosphere. *Soil Biol. Biochem* , 34(6): 859-864 .

Joy, T., & VanCantfort, C. (1999). *User Guide for Risk Assessment of Petroleum Releases*. Virginia: West Virginia Division of Environmental Protection Office of Environmental Remediation.

Juhaz, A., & Naidu, R. (2000). Bioremediation of high molecular weight polycyclic aromatic hydrocarbons: a review of the microbial degradation of benzo(a)pyrene. *Int. Biodeterioration & Biodegradation* , 45: 57-88.

Katan, L. L. (1996). *Migration from Food Contact Materials*. New York: Blackie academic & professional.

Latimer, J. S., Hoffman, E. J., Hoffman, G., Fashing, J. L., & Quinn, J. G. (1990). Sources of petroleum hydrocarbons in urban runoff. *Water, Air and Soil Pollution* , 52(1-2): 1-21.

Latimer, J., Hoffman, E., Hoffman, G., Fasching, J., & Quinn, J. (1990). Sources of Petroleum Hydrocarbons in Urban Runoff. *Water, Air and Soil Pollution* , 1-21.

Lee, E., Wilson, C., Lara-Valencia, F., De la Parra, C., Van Schoik, R., Patron-Soberano, K., et al. (2013). *The State of the Border Report. A Comprehensive Analysis of the U.S.-Mexico Border. Border Research Partnership*. Wilson Center, Mexico Institute. El Colegio de la Frontera. ASU North America Center for Transborder Studies. Arizona State University.

Lijinsky, W. (1991). The formation and occurrence of polynuclear aromatic hydrocarbons associated with food. *Mutation Research* , 259: 251-261.

Linz, D., & Nakles, D. (1997). *Environmentally Acceptable Endpoints in Soil - Risk-Based Approach to Contaminated Site Management Based on Availability of Chemicals in soil*, [Gas research Institute Contract No 5094-250-2863]. Annapolis, MD: American Academy of Environmental Engineers.

Lundstedt, S. (2003). *Analysis of PAHs and their transformation products in contaminated soils and remedial processes* . Suecia: Umea Universidad, Department of Chemistry.

Mauro, D. M., DeClercq, P. J., Siegener, R., & Coleman, A. (2006). Survey of the distribution and sources of PAHs in urban surface soils. *Land Contamination & Reclamation* , 1-9.

Mazur, L., Milanes, C., Randles, K., & Salocks, C. (2006). *Characterization of Used Oil in StormWate Runoff in California*. California : California Environmental Protection Agency.

Miyamoto, S. (2012). *Salinization of Irrigated Urban Soils: A Case Study of El Paso, Tx*. Texas: Texas Water Resource Institute.

Nganje, T. N., Edet, A. E., & Ekwere, S. J. (2007). Distribution of PAHs in Surface Soils from Petroleum Handling Facilities in Calabar. *Environ Monit Assess* , 1-8.

Office of the United States Trade Representative. (1994, January 1). *North American Free Trade Agreement (NAFTA)*. Retrieved from <http://www.ustr.gov/trade-agreements/free-trade-agreements/north-american-free-trade-agreement-nafta>

Pankow, J., Storey, J., & Yamasaki, H. (1993). Effects of relative humidity on gas/particle partitioning of semivolatile organic compounds to urban particulate matter. *Environ Sci Technol* , 27(10): 2220-2226.

PROFEPA. (1993). *NORMA OFICIAL MEXICANA NOM-052-ECOL-93*. Diario Oficial de la Federación.

PROFEPA. (2003). *NORMA OFICIAL MEXICANA NOM-087-SEMARNAT-SSA1-2002*. Diario Oficial de la Federación.

Pruell, R., & Quinn, J. (1988). Accumulation of Polycyclic Aromatic Hydrocarbons in Crankcase Oil . *Environmental Pollution* .

Reeves, W., McDonald, T., Bordelon, N., George, S., & Donnelly, K. (2001). Impacts of aging on in vivo and in vitro measurements of soil-bound polycyclic aromatic hydrocarbon availability. *Environ Sci. Technol.* , 35: 1637-1643.

Rincon, C., & Emerson, P. (2000). Binationally Managing Air Quality in the U.S.-Mexico Borderlands: A Case Study. *Borderlines* , Vol. 8 No. 1.

SEGOB. (2003, October 8). *Diario Oficial, Ley General para la Prevencion y Gestion Integral de los Residuos* . Mexico .

SEMARNAT. (2014). *Direccion General de Gestion Integral de Materiales y Actividades Riesgosas*. Retrieved from SNIARN:
http://dgeiawf.semarnat.gob.mx:8080/ibi_apps/WFServlet?IBIF_ex=D3_RESIDUOP01_20&IBIC_user=dgeia_mce&IBIC_pass=dgeia_mce

Sowards, S., Alvarado, K., Arrieta, D., & Barde, J. (2012). *Across Borders and Environments: Communication and Environmental Justice in International Contexts. Proceedings of the Eleventh Biennial Conference on Communication and the Environment (COCE)*. The University of Texas at El Paso.

TCEQ Border Initiative. (2014). *TCEQ Border Affairs 12th edition Waste Management*. TCEQ.

Texas Commisison on Environmental Quality. (2003). *An Environmental Guide for Texas Automotive Repair Shop*. Austin, Texas: TCEQ.

Texas Groundwater Protection Committee. (2013). *Report to the 83rd Legislature* . Austin, Texas : Texas Commission on Environmental Quality.

Thair, N. M., Jeen, L. B., Rahim, H. M., Ariffin, M., Suratman, S., & Abas, M. R. (2008). Polycyclic Aromatic Hydrocarbons in Urban Soils of Kemaman . *The Malaysian Journal of Analytical Sciences* Vol. 12 , 1-8.

Totten, G., Westbrook, S., & Shah, R. (2003). *Fules and Lubricants Handbook: Technology, Properties, Performance, and testing*. West Conshohocken, Pennsylvania: ASMT Manual Serie: MNL37WCD.

- U.S Census Bureau. (2010). *State and county QuickFacts*. Retrieved from American FactFinder: <http://quickfacts.census.gov/qfd/states/48/4824000.html>
- U.S. Department of Energy. (2005). *Used Oil Re-refining Study to Address Energy Policy Act of 2005 Section 1838*. Washington.
- U.S. Department Of Agriculture. (1971). *Soil Survey. El Paso County Texas*. El Paso, Texas: El Paso County, Texas.
- Volkerine, F., & Breure, A. (2003). *Biodegradation and general aspects of bioavailability*. p 81-96 In: P.E.T. Douben (ed.) *PAHs: An ecotoxicological perspective*. New York: John Wiley and Sons Ltd.
- Wang, G., Zhang, Q., Ma, P., Rowden, J., Mielke, H., Gonzales, C., et al. (2008). Sources and Distribution of Polycyclic Aromatic Hydrocarbons in Urban Soils: Case Studies of Detroit and New Orleans. *Soil & Sediment Contamination* .
- Western Sustainability and Pollution Prevention Network. (2014). *EPA Region 9*. EPA.
- Wick, A., & Daniels, W. (2011). *Remediation of PAH-contaminated Soils and Sediments: A Literature Review*. Blacksburg: Department of Crop and soil. Environmental Sciences.
- Yang, Y., Woodward, L., Li, Q., & Wang, J. (2014). Concentrations, Source and Risk Assessment of Polycyclic Aromatic Hydrocarbons in Soils from Midway Atoll, North Pacific Ocean. *PLoS ONE* 9(1): e86441. doi:10.1371/journal.pone.0086441 .
- Yu, G., Zhang, Z., Yang, G., Zheng, W., Xu, L., & Cai, Z. (2014). Polycyclic aromatic hydrocarbons in urban soils of Hangzhou: status, distribution, sources and potential risk. *Environ Monit Assess* .
- Zhang, Y., & Wang, J. (2011). Distribution and source of polycyclic aromatic hydrocarbons (PAHs) in the surface soil along main transportation routes in Jiaxing City, China. *Environ Monit Assess* , 535-543.
- Zietsman, J. (2009). *Emissions Implications and Control Strategies for Old Imported Light Duty Vehicles*. College Station : Texas A&M Transportation Institute.

CURRICULUM VITA

Alma Leticia Figueroa Jimenez enrolled in the Universidad Autonoma de Guadalajara, Jalisco in 1970 and earned her Bachelor' Degree in Biology in 1974. She joined the school of Agricultural and Forest Science at the Universidad Autonoma de Chihuahua and received her Master's Degree in Agricultural Productivity Science in May, 2007.

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