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Microbial Degradation of Gasoline in Soil: Comparison by Soil Type

D A Turner [1], J. Pichtel [2], Y Rodenas, [3,2] J McKillip [3] and J V Goodpaster [1*]

[1]Department of Chemistry and Chemical Biology, Forensic and Investigative Sciences Program, Indiana University Purdue University Indianapolis (IUPUI), Indianapolis, USA
[2]Department of Natural Resources and Environmental Management, Ball State University, Muncie, USA
[3]Department of Biology, Ball State University, Muncie, USA

Abstract

'XULQJ WKH LQYHVWLJDWLRQ RI D VXVSLFLRXV ¿UH GHEULV LV RIWHQ FROOHF of ignitable liquids (e.g., gasoline). In cases where the debris is contaminated with soil, it is known that heterotrophic soil microorganisms can alter the chemical composition of the ignitable liquid residue over time. The effects of soil type and season upon this phenomenon are not known, however. Hence, soil collected from locations under WKUHH GLIIHUHQW XVHV UHVLGHQWLDO DJULFXOWXUDO EURZQ¿HOG ZHUH VSL PRQLWRUHG IRU GD\V 7KH VRLOV ZHUH DOVR FKHPLFDOO\ DQG ELRORJLFDOO\ VKRZHG WKDW UHVLGHQWLDO VRLO ZDV PRVW DFWLYH DQG EURZQ¿HOG VRLO OHD 7KH EURZQ¿HOG VRLO SRVVHVVHG UHODWLYHO\ KLJK PJ NJ FRQFHQWUDWLRQ activity. Predominant viable bacterial populations enumerated using real-time reverse transcriptase polymerase chain reaction (RT-PCR) included members of the Alcaligenes, Acinetobacter, Arthrobacter, Bacillus, Flavobacterium, and Pseudomonas genera. Principal Components Analysis (PCA) was found effective in elucidating trends of microbial degradation among the different soil types and seasons. The results of this study demonstrate the necessity of SURPSW DQDO\VLV RI IRUHQVLF HYLGHQFH IRU SURSHU LGHQWL¿FDWLRQ RI SRVV

Keywords: Soil chemistry; Bacteria; Microbial degradation; Ignitable liquids

Introduction

e number of incendiary res in the U.S. averages approximately 210,300 every year, which comprises about 13% of the total of all reported res, according to FEMA's Topical Fire Report Series[1]. On an annual basis, incendiary res claim 375 lives, injure over one thousand people, and cause approximately $1 billion in direct property damage [1]. In many cases, the arsonist uses an ignitable liquid to accelerate the re. Gasoline is the most commonly used ignitable liquid as it is readily accessible, inexpensive and ignites easily [2]. Gasoline and other ignitable liquids are classi ed according to the American Society of Testing and Materials (ASTM) guidelines by their boiling point range and chemical composition [3]. In practice, a forensic chemist will use various extraction methods coupled with gas chromatography/mass spectrometry (GC/MS) to determine if an Ignitable Liquid Residue (ILR) is present in a re debris sample. e ILR will then be classi ed according to ASTM guidelines [2,4].

Media rich in organic matter such as soil provides a rich source of carbon and typically contains substantial quantities of active bacterial biomass. Since ignitable liquids are composed of a range of hydrocarbons, they may be suitable as a carbon substrate by bacteria. Such transformations are problematic for re debris analysis as samples are o en stored for many weeks at room temperature before they are analyzed due to case backlog and lack of cold storage. As a result, selective loss of hydrocarbon species due to bacterial metabolism can occur, making the identi cation and classi cation of ignitable liquid residues di cult or even impossible. For example, ve speci c C_3 alkylbenzenes (3-ethyltoluene, 4-ethyltoluene, 1,3,5-trimethylbenzene, 2-ethyltoluene and 1,2,4-trimethylbenzene)must be identi ed in a sample in order to determine if residues of gasoline are present. Furthermore, because these compounds also occur in other materials, they must be present in relative amounts that are similar to that of a gasoline standard [3]. Among the serious consequences of microbial degradation are the selective losses of some of these compounds and/or changes in the ratios of these compounds in a gasoline sample.

Several factors a ect bacterial numbers and activities in soil including soil type and season. Chemical and physical characteristics of soils including pH, nitrogen level and phosphorus content will vary, as do soil physical properties (e.g., texture). In turn, varying populations of bacteria may impact the degree of microbial degradation observed in re debris samples containing soil.

Previous work has demonstrated that bacteria readily degrade normal alkanes (e.g. decane) and lesser substituted alkyl benzenes (e.g toluene, ethyl benzene, propyl benzene) while more highly substituted alkyl benzenes (e.g., 1,2,4-trimethylbenzene) and highly branched alkanes are more resistant to microbial attack [4-6]. While treatment of hydrocarbon-contaminated soils by bacteria is a well-known phenomenon in the environmental engineering community [7-17], microbial processes are not wellunderstood in forensic science. is phenomenon likely varieswith soil type and over di erent seasons as soil chemical properties, temperature and moisture status may impact heterotrophic bacteria.

e overall objectives of this study were to assess the degradation of a common ignitable liquid (i.e., 87 octane gasoline) in soil as ected by soil type. e focus of this paper will be upon the e ect of soil type, to include: (1) analysis of GC/MSdata from gasoline added to three di erent soils; (2) identi cation and quanti cation of bacterial populations present in the study soils; and (3) semi-quanti cation

*Corresponding author: JV Goodpaster, Department of Chemistry and Chemical Biology, Forensic and Investigative Sciences Program, Indiana University Purdue University Indianapolis (IUPUI), Indianapolis, USA; E-mail: jvgoodpa@iupui.edu

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of organic and inorganic compounds present in the study soils by Principal Component Analysis (PCA).

Materials and Methods

Soil chemical analyses

Soil material was obtained from an agricultural eld (Pella clay), a residential property (Miamian sandy clay), and a brown eld site contained high levels of phosphorous (P) and potassium (K) due to treatment with commercial fertilizers.

Levels of extractable Cd, Cr, Fe and Zn were all within range for non-contaminated soils (Table 1). However, extractable Pb levels in the brown eld soil measured 497 mg/kg. An upper limit for Pb content of a normal soil is approximately 70 mg/kg [27]. e levels of Pb in soils that are toxic to soil microorganisms and plants are a function of species, Pb concentration and soil factors (e.g., pH, fertility status, presence

Citation:

Conclusions

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