Environmental Impacts of Reclaimed Asphalt Pavement (RAP)

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ABSTRACT

Florida, like many states in the US, has an interest in recycling reclaimed asphalt pavement (RAP). Two previous Hinkley Center projects, *Leaching Characteristics of Asphalt Road Waste* (1998) and *Risk Assessment of the Reuse and Disposal of Several Asphalt Waste Materials* (2013) have investigated the pollutants leached from RAP and concluded that RAP does not pose a significant threat to human health and the environment. However, concerns continue to be raised in some parts of Florida regarding potential environmental issues associated with RAP. Concomitantly, the concerns of reusing RAP have been raised in other states, prompting the National Asphalt Pavement Association (NAPA) to solicit a call to review work on this topic to identify and characterize the knowledge gaps remaining with RAP. The University of Florida team is currently working with NAPA to provide a more comprehensive and synthesized literature review on the potential environmental impacts of RAP to address these nation-wide RAP concerns. This proposal outlines research designed to examine several remaining issues pertaining to the use of RAP in Florida, which addresses Item 1 under Beneficial Use/Recycling on the 2020 Hinkley Center RFP. In addition to conducting and completing an extensive literature review with NAPA, the research team will focus on performing the laboratory tests required to address the identified knowledge gaps. First, the total and leachable contaminants in RAP, including heavy metals and polycyclic aromatic hydrocarbons (PAH), will be measured using state of the art technology and the data will be compared to current risk-based thresholds. Second, the potential toxicity of the RAP materials will be analyzed using receptor-based assays, which will provide preliminary data as to whether constituents of the materials have the affinity to act as (endocrine) disruptors. We believe a better understanding of both the potential direct exposure, leaching and toxicity concerns of RAP will provide a resource for future decision-making at the local, regional and state-wide level, helping guide decision makers to identify best management practices (BMPs) for use of RAP. Further, it will guide the next wave of studies aimed at understanding the overall environmental impact of RAP.

PRINCIPAL INVESTIGATORS

The investigators for the proposed research are John A. Bowden, an Assistant Professor in the Department of Veterinary Medicine at the University of Florida, and Timothy G. Townsend, a Professor in the Department of Environmental Engineering Sciences at the University of Florida.

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Dr. Bowden is a classically trained analytical chemist with over 15 years of experience in mass spectrometry, chromatography, method development, environmental chemistry, small molecule omics workflows, toxicity testing and data handling. He has experience with both targeted and untargeted mass spectrometric assays covering a wide range of analytes from anthropogenic pollutants to biomolecules. Dr. Townsend has more than two decades of research experience regarding RAP and other recycled aggregate product research involving physical and environmental characterization, beneficial use, actual road construction demonstrations, and permitting. He also has worked extensively with relevant industry partners (local governments, aggregate suppliers, concrete/asphalt batch plants, consultants) on both theoretical and applied understanding of RAP and other recycled aggregate behavior. Curriculum vitae for each PI are attached as a supplemental to this proposal.

INTRODUCTION AND BACKGROUND

Approximately 94% of the 2.7 million miles of paved road are surfaced with asphalt (NAPA, 2017). The regular repair and replacement of asphalt roadways results in the production of large amounts of milled asphalt road waste also known as reclaimed asphalt pavement (RAP). RAP is one of the most heavily recycled materials in the United States, with nearly 80 million tons being reused as an aggregate source and over 100 million tons stockpiled for future use in 2017 alone (NAPA, 2019). RAP has been successfully recycled back into new hot mix asphalt since 1970s, but in some cases not all of it can be recycled into new asphalt pavements. Reuse alternatives include using RAP as aggregate for unbound base materials, stabilized base materials, pothole/rut filler materials and roadway shoulder materials. Unused RAP has to be either stockpiled for future reuse or disposed in landfills. Recycling of RAP has both environmental and economic benefits; however, concerns have been raised for the potential leaching of pollutants from RAP during the RAP storage and reuse at both the state and national level.

In Florida, previous research sponsored by the Hinkley Center investigated the leaching of PAH and heavy metals from RAP using both batch and column tests (Townsend and Brantley, 1998). PAH concentrations examined in the previous work were found to be lower than the Florida groundwater cleanup target levels (GCTLs) at the time. Due to updated toxicology data and improvements in instrument capabilities, the GCTL values have been lowered for some PAH compounds. For example, the GCTL value for Benzo(a)pyrene was reduced from 4 µg/L to 0.05 µg/L. Thus, another Hinkley Center funded research project was conducted to re-examine potential PAH concerns with RAP leaching for the sake of regulatory clarification (Townsend et al., 2013). The PAH leaching results didn't deviate from the conclusions from the earlier Hinkley Center research, but the number of samples analyzed was not sufficient enough to make broad conclusions.

Other studies have also examined leaching pollutants from RAP materials over the years (Sadecki et al., 1996; Brandt and DeGroot 2001; Legret et al., 2005; Birgisdottir et al., 2007; Aydllek et al., 2017;

Mehta et al., 2017). Leaching issues have primarily focused on either heavy metals (e.g., lead, chromium, nickel, zinc) or PAHs. Though studies conducted to date have indicated that RAP does not overtly present a great risk to human health and the environment, a more complete and updated characterization of the amount and the type of chemicals that are in and can leach from RAP into the environment is needed. First, most previous studies only examine the leaching risks from RAP but ignore the direct exposure to humans. Though the issue of leaching has been the primary concern expressed in the literature, there are management practices where RAP would be likely in contact with humans when the material was used as a surface material for a road, driveway or parking lot. Thus, there is a need to measure the risk associated with direct exposure. Second, the data for PAH in RAP is limited. Among the hundreds of PAH, USEPA designated 16 as priority and thus non-USEPA priority PAH have been rarely investigated in RAP. Due to the updated availability of analytical methods, some emerging PAH have been identified, which have been shown to have considerably higher toxicity than that of the 16 priority PAH (Andersson and Achten, 2015). The risk associated with additional PAH warrant a re-evaluation of total and leachable PAH in RAP with an expansion of the PAH compound list.

The growing interest in recycling RAP and the concerns about potential environmental impacts of RAP have prompted numerous inquiries from state and national regulatory agencies regarding the stockpiling and various end uses or applications of RAP. In the fall of 2019, the University of Florida research team was awarded a National Asphalt Pavement Association (NAPA) proposal to synthesize and critically review existing literature regarding environmental impacts associated with stockpiling and various applications or end uses of RAP. The work is expected to be completed in 2020. While the NAPA work may answer many of the items addressed in Item 1 under Beneficial Use/Recycling on the 2020 Hinkley Center RFP, our ongoing work does not involve any laboratory testing. To help examine the remaining issues addressed above, we are proposing to evaluate direct exposure risks as well as leaching risks of heavy metals and PAH associated with RAP using state of the art analytical instrumentation. In addition, the selected RAP extracts will be preliminarily analyzed for toxicity with receptor-based assays.

MOTIVATION AND PROJECT JUSTIFICATION

The central motivation for the proposed research is to improve scientific understanding of the environmental impacts of RAP in order to promote the best possible strategies for use of RAP. We believe this is urgently needed for the following reasons:

- RAP is one of the most heavily recycled materials in the United States and the use of RAP provides significant economic and environmental advantages to road owning agencies. The continued use of RAP is critical to ensuring the cost-effective and environmentally responsible maintenance and improvement of the nation's roadway network
- The concerns about potential negative impacts of RAP to human health and the environment have been reported.
- States and agencies have prompt inquiries regarding the research about potential environmental impacts of RAP, but additional laboratory research is still needed to understand the environmental concerns associated with the use of RAP and the relevant toxicity.
- There is a lack of information on how to best manage RAP in Florida as a result of a lack of RAP emission data in Florida.

OBJECTIVES AND METHODOLOGY

The proposed research is to address the knowledge gaps of the environmental impacts of RAP. The total and leachable amount of pollutants in RAP will be measured, including various heavy metals and

PAH. In addition, potential toxicity will be conducted on the selected extracts (or fractions of extracts) using commercially-available receptor based assays. The results will expand the RAP emission data library and could be used to develop recommendations for best management practices (BMPs) for use of RAP in Florida. The proposed project will be completed over the course of two six-month periods (Phase I and Phase II) through the following specific tasks:

Phase I

Task 1. Measure the amount of total and leachable pollutants in RAP.

Representative RAP samples will be collected in Florida from discrete geographical locations (e.g., North/South FL) and based on other variables (e.g., direct road millings vs. facility stockpiles), as necessary and appropriate. The total and leachable heavy metal and PAH concentration will be measured for each sample. Proposed leaching tests include EPA 1311 method-Toxicity Characteristics Leaching Procedure (TCLP), EPA 1312 method –Synthetic Precipitation Leaching Procedure (SPLP), EPA 1313 method- Liquid-Solid Partitioning as a function of pH and EPA 1316 method- Liquid-Solid Partitioning as a function of Liquid-to-Solid ratio.

The PAH will be extracted using methods adapted from previous studies (Chen and Chen, 2011; Dong et al., 2012). The concentration of PAHs will be determined using a state-of-the-art analytical instrument (e.g., high resolution mass spectrometer), specifically, a Thermo Fisher Gas Chromatograph coupled to a Orbitrap Mass Spectrometer. For quantitation, we will employ mass-labeled PAH internal standards. The primary PAHs measured in the method include the 16 priority PAH as well as other six emerging PAH, 3 carcinogenic (anthanthrene-AN, 7H-benzo[c]fluorene-BcF, and dibenzo[a,l]pyrene-DlP: 3cPAHs) and 3 non-carcinogenic (dibenzo[a,e]pyrene-DeP, dibenzo[a,i]pyrene-DiP, and dibenzo[a,h]pyrene-DhP). It should be noted that the state of the art analytical instrumentation is capable of interrogating and identifying previously unknown, and yet unidentified PAHs, in the extracts. This aspect will potentially widen our current view of the PAH landscape associated with RAP and will lead to further studies/funding opportunities.

Phase II

Task 2. Conduct preliminary toxicity test with PAH extracts/fractions

Based on the determined concentrations of metals and PAH compounds in the solid sample and the leachate solution, RAP extracts (and or fractions of the extract) that cause either direct exposure risks or leaching risks will be selected for further toxicity testing using cell-based receptor assays. The receptor assays are based on human receptors and are linked to pathways that affect important physiological functions, including reproduction, development, metabolism, and immune response. Previous studies have demonstrated the ability of PAH to bind with cell receptors (White et al., 1999; Billiard et al., 2002), suggesting the cell receptor assays are useful for environmental assessment and monitoring for RAP materials. Two receptor will be selected for this study: estrogen and peroxisome proliferator-activated receptor-γ (PPAR- γ).

Task 3. Development of BMPs for use of RAP in Florida

Based on the findings from the laboratory results, BMPs will be developed to address the main environmental impacts and potential challenges of RAP reuse in Florida. The BMPs can be used for the purpose of educating government/regulatory officials, community members and other stakeholders. A final report will be developed to describe the results of the entire project. This report will document all findings in literature review and all laboratory results collected by the UF team.

A 12-month project is proposed with the following timeline.

	Phase I						Phase II					
Task/Milestone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Task 1. Measure the amount of total and leachable pollutants in RAP	X	X	X	X	X	X						
Task 2. Conduct preliminary toxicity test with PAH extracts/fractions							X	X	X	X	X	
Task 3. Develop BMPs for use of RAP in Florida									X	X	X	X
TAG Meeting			X			X*					X*	
Milestone 1: Developing the appropriate method for PAH analysis on the Orbitrap Mass Spectrometer		**X**										
Milestone 2: Collecting RAP samples around Florida and analyzing total and leachable PAH in the RAP samples					**X**							
Milestone 3: Developing the appropriate cell-based receptor assays for toxicity test of the PAH extracts/fractions							**X**					
Milestone 4: Conducting the toxicity test on the PAH extracts/fractions										**X**		
Milestone 5: Providing the BMPs of RAP in Florida												**X**

BENEFITS TO THE END-USER

The solid waste community, asphalt paving industry, and governing regulatory agencies in Florida will benefit from the knowledge generated regarding the environmental impacts of RAP. This research will allow the industry and the regulatory community to better assess the recycling of this material in an environmentally responsible manner. Developing BMPs will also serve the industry and regulatory agency by promoting responsible recycling and storage practices that minimize environmental risks.

DESCRIPTION OF PROJECT DELIVERABLES

Deliverables for the proposed work include quarterly progress reports to the Center, metrics, a draft and final technical reports, and any manuscripts or thesis chapters completed by students working on this project as part of their degree requirements. Additionally, a Technical Awareness Group (TAG) will be formed and two meetings will be held: one at the beginning of the project and a second one at the end. If Phase II of the project does not receive appropriation funding, the final TAG meeting will take place at the end of Phase I; otherwise, it will take place at the end of Phase II. All other deliverables required by the Center will be completed. Finally, a project website will be developed and maintained where project information such as the full proposal, TAG member information and quarterly reports will be published.

PLAN FOR INFORMATION COMMUNICATION

The results from this project will be compiled in Quarterly Reports and a Final Report that will be sent to TAG members and published in the project's website. Additionally, the data obtained here will be presented in manuscripts and thesis chapters completed by the students working on this project as part of their degree requirements.

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