New Jersey Department of Environmental Protection
Science Advisory Board

FINAL REPORT

Review of
SITE REMEDIATION & WASTE MANAGEMENT
SHORT TERM ISSUE:
Recycled Asphalt Pavement (RAP) commonly known as asphalt millings.

Prepared for:

Commissioner Catherine R. McCabe
and
NJDEP Division of Science and Research

Prepared by:
SAB Workgroup*† [1]

Approved by:

NJDEP Science Advisory Board
Judith Weis, Ph.D. (Chairperson)
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Robert J. Lippencott, Ph.D. *†
Tavit Najarian, Sc.D.
Nancy C. Rothman, Ph.D.*
Mark G. Robson, Ph.D.
David A. Vaccari, Ph.D., P.E.

March 26, 2019

[1] Clifford P Weisel, Ph.D., Rutgers Environmental and Occupational Health Sciences Institute (Non-SAB member)
*Workgroup Member; † Workgroup Chair.

NJDEP Science Advisory Board

Review of

SITE REMEDIATION & WASTE MANAGEMENT

SHORT TERM ISSUE:

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March 26, 2019

NOTICE

SITE REMEDIATION & WASTE MANAGEMENT

SHORT TERM ISSUE:

Recycled Asphalt Pavement (RAP) commonly known as asphalt millings.

NJDEP Charge Questions and Issue Statement

How can potential human health and environmental exposures to asphalt millings be minimized in order to better utilize/recycle this material? What causes exposure? Does reuse of RAP cause leachate? How much RAP can be used with new asphalt? Why are we using residential-type 'standards' for use of this product?

Background:

• RAP is generated in large quantities in the State due to repaving of roads and demolition activities.

• Due to the presence of PAHs, a known carcinogen, recycling of RAP has many restrictions.

• Hot-mix Asphalt used for surface paving contains the same PAHs but its use does not have restrictions as it is a product.

• Recycling options are very limited, which has generated illegal piles of RAP all over the

State, especially at the Quarries with adjacent asphalt manufacturing Plant.

INFORMATION NEEDED:

a. What possible restrictions should there be for its reuse in New Jersey?

b. Need scientific data based on research and studies to determine exposure pathways and potential adverse impact of milled asphalt on human health and the environment.

c. Need recommended reuses of RAP.

d. Need BMPs for RAP Management.

SITE REMEDIATION & WASTE MANAGEMENT

SHORT TERM ISSUE:

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SAB Response

Introduction

The SAB has prepared this response to the above short term issue regarding RAP in accordance with the related charge questions and stated information needs as noted above. Discussion and background information has been included where necessary to provide context and to clarify some of the questions.

Based on the background information provided above, it seems evident that an increased rate of RAP reuse is desirable if such reuse can be accomplished in a manner that is protective of human health and safety and the environment. The primary reuse of RAP is in road construction where RAP is incorporated into the new roadway bituminous concrete admix. However, this reuse option alone is unsustainable since only approximately 20% to 30% of the RAP generated from typical road and pavement projects is consumed back into pavement construction (Williams et al., 2018).

Some of the current restrictions on storage, management or reuse of RAP are imposed due to the presence of contaminants of concern (COCs) that are principally composed of polycyclic aromatic hydrocarbons (PAHs) and to a lesser extent, various metals. The PAHs in RAP derive mostly from the asphalt content in the RAP that is added as the (petroleum based) binder in the pavement manufacturing process, although some small amount may be from vehicle exhaust and fuel (Mehta, et al., 2017). RAP, like new asphalt pavement, contains approximately 3% to 7% asphalt with the remainder primarily being quarry materials that compose the load bearing portion of the original bituminous concrete material (FHWA, 2016). However, weathering of asphalt pavement RAP causes hardening of the asphalt (FHWA, 2016) and loss of lower molecular weight PAHs over time. The metals present in RAP due to exposure of roadway paved surfaces to vehicular use such as tire and break wear, metals in petroleum, as well as naturally occurring metals found in the quarried geologic materials (Mehta, et al., 2017). Other restrictions on RAP reuse appear to be due to engineering performance concerns for roadway construction and load-bearing concerns under structures. For example, RAP is prohibited for use in subbase for certain roadway projects under the current (2007) NJDOT specifications.

New Jersey Regulatory Framework

The management and reuse of RAP from road construction and demolition projects is regulated primarily by the New Jersey's Solid Waste and Recycling Regulations (NJAC 7:26 and 26A) and guidance, including the NJDEP Division of Solid and Hazardous Waste's (DSHW's) March 2013 *Recycled Asphalt Pavement And Asphalt Millings (Rap) Reuse Guidance* (DSHW RAP Guidance). According to this guidance, it is the policy of the NJDEP to encourage and promote the use of recycled asphalt pavement (RAP), including asphalt millings excavated from public highways and roads. RAP may be recycled without the Department's prior approval, pursuant to existing regulations at N.J.A.C. 7:26A-1.4(a)1, for recycling directly into hot mix asphalt pavement and in cases where it is reused directly for road construction when used in "Transportation Allowed Uses" in accordance with applicable NJDOT 2007 Standard Specification for Road and Bridge Construction. The NJDOT regulations identify RAP as "reclaimed asphalt pavement" and provide specifications and limits for the amount of RAP that may be incorporated in pavement products used for certain paving applications (NJDOT 2007 Standard Specifications for Road and Bridge Construction per N.J.A.C.16:44A). The NJDEP Site Remediation Program (SRP) also imposes additional requirements and restrictions on the use of RAP for fill at remediation sites through guidance documents, including the NJDEP SRP's April 2015 *Fill Material Guidance for SRP Sites* (SRP Fill Guidance). However, RAP is apparently not specifically defined in any of New Jersey's regulations, and the definitions and requirements for RAP in these guidance documents is somewhat inconsistent. A robust discussion of the technical basis and background in support of the current specific requirements and policies is not included in the regulations or guidance, and is not readily available. However, a recent report of a RAP study conducted in 2017 by Rowan University (in conjunction with Columbia University and Stoney Brook University) for the NJDOT (Mehta, et al., 2017) provides some detailed technical background and a summary of research related to RAP, along with a report of laboratory studies of RAP from three locations in New Jersey conducted by the authors. The report appears to serve as the technical basis for a New Jersey law approved in January 2018 that provides for expanded options for reuse of RAP (N.J.S.A. 13:1E-99.28a; see Attachment 1). However, the regulations and guidance noted above have not been updated to reflect the new law at this time.

As a preliminary matter, the definition of RAP is clarified for the purpose of this review. Although, the issue statement implies RAP is equal to asphalt millings, RAP is understood to include more than only asphalt millings. Although not defined in New Jersey's regulations, RAP is defined in the DSHW RAP Guidance as follows:

> ***Recycled Asphalt Pavement (RAP):*** *Recycled asphalt pavement (RAP) shall mean asphalt millings (the material produced from the milling of roads before repaving) and pieces of asphaltic roadway pavement removed from the roadway surface or subbase, or from other asphalt-paved surfaces such as parking lots. RAP does not include other Class B recyclable materials that contain recycled asphalt.*

The above definition of RAP is adopted by the SAB for the purpose of this review and represents the SAB's intended definition in the following discussion and responses to the charge questions.

While the above definition suffices for this review, some fundamental concepts should be noted.

First, as RAP is derived from asphalt pavement, a basic understanding of the pavement manufacturing and construction process is important for understanding the general nature of RAP and how/why the composition may vary. In general, asphalt pavement is manufactured by mixing aggregate (e.g., sand and gravel, dense graded aggregate [DGA]) with a petroleum-based binder (asphalt). This is commonly performed in a heated process resulting in a "hot mix" pavement product. Other types of pavement products manufactured with less heat or unheated include "warm mix" and "cold mix", respectively. The aggregate is typically produced from processing of quarried rock to specified grading and size specifications. Pavement is constructed in an upward sequence that generally includes a subbase gravel layer beneath a base course of asphalt pavement covered by a top or wearing course, which is the upper-most exposed pavement surface. The top course typically includes coarse to medium sand sized aggregate, while base courses and subbase layers are usually constructed with larger size aggregate (e.g., ¾-inch, 1-inch, etc.). Additional information, specifications and references related to asphalt pavement manufacturing and construction can be found in the United States Department of Transportation (USDOT) Federal Highway Administration's (FHWA's) *User Guidelines for Waste and Byproduct Materials in Pavement Construction* (Pub. No. FHWA-RD-97-148, last updated 03/08/2016; a.k.a. "FHWA, 2016").

Second, the reference to "asphalt millings" in the above definition generally refers to the removal of the top wearing course pavement layer. Often, this process is performed using specialized equipment that can recycle asphalt millings on the paving project site within the paving equipment. However, the admix designs for pavement projects and amounts of RAP reuse vary. Regardless, excess RAP is typically generated as a result of paving projects.

Third, the form of RAP is another overarching issue not completely covered by the definition above. RAP may be comprised of asphalt millings only, or as "pre-processed" or 'post-processed" demolished asphalt pavement. Processing of RAP commonly includes crushing and sizing of RAP using screens that sieve crushed RAP to meet desired gradations – typically ¾-inch or less. Processed RAP can also be "bound" (i.e., by combining with additional asphalt binder) or "unbound" (i.e., no additional asphalt binder). Unprocessed RAP is generally considered "unbound", and can include large slabs, and cobble-sized pieces of demolished pavement.

Fourth, RAP comprised primarily of asphalt millings is expected to exhibit a higher internal surface area and perhaps a high potential to mobilize by leaching or movement of particulates in storm water or by movement of particulates, for example, via erosion due to the high amounts of smaller particle sizes. In contrast, unprocessed RAP from sources other than milling of pavement generally contains a range of sizing that would likely exhibit lower surface area and less percentage of fine particles as compared to asphalt millings. The general description of grain size and surface area for processed RAP derived from demolished pavement would fall somewhere between that of milled asphalt and unprocessed RAP. This is based on a general assumption that crushing and sizing of pavement results in larger sized granular RAP due to granular subbase and base courses that include larger size aggregate as compared to top course millings.

Responses to Specific Questions

The order of the charge questions provided in the Issue Statement were reorganized and in some cases questions were revised for clarification and to more efficiently address the issues, and are restated with responses below.

What causes exposure?

PAHs are the predominant COC present in RAP due to the asphalt binder used in pavement manufacturing. RAP may also contain other COCs such as lead and other heavy metals, which are generally associated with RAP as a result of vehicular use (fuel exhaust, tire and break wear, and natural occurring metals in the quarry stone) (Meta, 2017). Studies conducted to assess leaching of COCs from RAP have focused primarily on PAHs and to a lesser degree on metals (e.g., arsenic, lead, chromium, etc.). The specific metals of concern vary among the studies and the presence and concentrations of metals are generally variable among studies (Townsend, 1998; Winter, 2006; Meta, 2017). The variability in the presence of individual metals and their respective concentrations is likely related to sources of RAP and of the aggregate that was used in the manufacturing of the original pavement from which the RAP derives. In limited circumstances, RAP can also potentially contain other COCs; for example, RAP sourced from paved areas where process chemicals or waste may have been stored or handled. But contamination of RAP with COCs other than PAHs and metals from conditions specific to a particular facility or area at a facility would be due to localized and somewhat limited conditions that are beyond the scope of this review. We will assume for this review that most of the RAP being managed in the overall circulation of material in New Jersey is from common roadway and parking area sources. For the purposes of this review, PAHs and metals are the principal COCs associated with RAP from these types of common pavement areas (i.e., roadway areas, driveways, parking lots, etc.) that are understood to represent the bulk of the volume of RAP in New Jersey.

Based on the chemical fate and transport properties of PAHs and the form of metals generally associated with RAP (i.e., relatively extremely low water solubility; high organic carbon partition coefficient [Koc] for PAHs), the potential leachability of PAHs and metals from asphalt pavement and RAP under a typical range of common environmental conditions is relatively low.

The routes of exposure to the COCs typically present in asphalt pavement are limited in properly installed and maintained paved surfaces due to the binding properties of the bituminous pavement manufacturing and installation process. However, RAP can break down to unconsolidated, soil-like particles similar in sizes to gravel, sand, silt, etc. The process of asphalt pavement demolition and weathering results in RAP containing large chunks to fine particles. However, weathering and use have similar aging effects on virgin asphalt pavement.

Milling of asphalt road surfaces creates a RAP graded from a medium sand to dust-sized particles that can be subject to erosion by wind and water when exposed to the surface outdoor conditions. Asphalt pavement that is removed during demolition activities tend to break apart creating a larger range of sizes of RAP from thick slabs to fine particles similar to asphalt millings. However, the large-sized RAP can continue to break apart and weather with time and if disturbed, representing increased amount of fine-sized particles over time. While there may be some potential for leaching of COCs from RAP into adjacent soils and/or migration of dissolved COCs from RAP to ground water, the potential physical migration of fine particles from RAP containing COCs appears to represent additional exposure pathways. The general lack of PAHs and metals as COCs in ground water throughout New Jersey is indicative of the relative low leaching potential of these substances from properly installed asphalt pavement (R.Lippencott personal experience from numerous NJDEP SRP investigations). Therefore, it is no coincidence that the NJDEP allows the use of asphalt pavement as a capping contaminated material (e.g., soil, historic fill material, alternative fill including RAP, etc.) as an option for remediation at contaminated sites (SRP Fill Guidance).

Migration pathways and exposure routes for COCs in RAP are practically limited to those associated with COCs bound to particulates (e.g., dust in air and related inhalation, incidental ingestion, particulates in runoff and sediment deposition) and COCs that may leach and become dissolved in water. However, the potential for exposure via aqueous environments (i.e., groundwater and surface water) from leaching of COCs from RAP is considered very low due to the low solubility of the COCs in RAP and the likelihood that the more leachable COCs will have already leached out of most RAP material due to weathering.

The incorporation of RAP with virgin asphalt or as subbase under pavement for creating new pavement, roadways, and parking lots or as a base for pavement that are properly sealed is not likely to result in particulate COC exposure beyond what virgin asphalt pavement would, as the latter weathers and potentially produces particles that can become mobilized.

There is also a potential market for unbound RAP use for non-residential driveways, parking areas, storage yards, temporary roads, or possibly residential driveways and parks. These methods of unbound RAP reuse can lead to some exposure to RAP-related COCs if the material becomes worn, although exposure to RAP-related COCs would be lessened where RAP is subject to less mechanical stress from no or low vehicular traffic under some of these exposure scenarios. RAP use as a substitute for gravel on unpaved roads (e.g., for dust suppression) presents a potential source of airborne particulate matter containing COC from RAP that can potentially lead to inhalation exposure and potentially incidental ingestion. For example, particulate matter from RAP could get onto the hands of particular children playing outside or after being tracked into a home near locations where RAP material is located exposed at the surface resulting in potential for incidental ingestion. While these conceptual scenarios are plausible for use of RAP in certain circumstances (e.g., residential areas), based on this review, there appears to be a lack of evaluation through scientific studies and/or research. In addition, these exposure scenarios are not necessarily different from similar exposures from common pavement used in roadways and driveways, especially those that are old and worn.

In general, binding or surface sealing of the RAP should be considered for some of these reuse scenarios, for example residential or parks used often by children for playing. Unbound RAP used on roads would potentially be subject to additional mechanical abrasion and increased potential for airborne mobilization as wind-blown dust with increased vehicular traffic. Under these conditions, the RAP particle size would likely decrease with time, leading to increasing amounts of RAP available to become airborne and increasing the potential for incidental ingestion. Thus, use of RAP on unpaved roads should be limited to rural roads with limited traffic and away from population centers and schools. If used on temporary unpaved roads for construction or commercial sites the locations should be sufficiently away from residential settings to not impact the air quality in surrounding areas.

The concerns for contamination of drinking water supplies from the use of RAP is premised on the leaching of COC into rainwater, surface or ground water that subsequently flows into an aquifer or reservoir leading to elevated levels in drinking water and ingestion exposure. This is more likely related to metals contamination of RAP than PAH due to the low solubility of the latter chemicals in water. Leaching is more likely to occur when the RAP is not sealed or completely mixed with virgin asphalt, such as when added as fill or to replace gravel in unpaved roads since a much greater surface area of the RAP material would contact the water. These considerations should be incorporated for temporary roadways (such as for construction sites) as well as permanent roads, though in estimating the potential exposure it should be recognized that dilution of leachate contaminants will occur prior to the water reaching an aquifer.

It is not clear that the uncertainties regarding COCs and their relative concentrations in RAP are fully or adequately addressed in some of the references reviewed by the SAB. Mehta et al. (2017) notes differences in RAP samples obtained from various locations and suggests sampling of RAP to inform site-specific decisions under some conditions (e.g., pH<4). However, a more robust conceptual discussion of RAP sources and ranges of the inherent PAH concentrations expected in RAP should be explored to facilitate developing technically based options for site-specific conditions. For example, RAP derived from some pavement demolition projects may be characterized as containing very low concentrations of PAHs and no metals. In this case, a surface reuse option based on compliance averaging (e.g., spatially-weighted averaging in upper 2-feet) may be protective and considered comparable to soils or pavement.

Why are we using residential-type 'standards' for use of this product?

As a clarification, residential standards are not applied to RAP in a consistent manner across state programs. For example, the NJDEP SRP Guidance requires a deed notice for certain uses of RAP in paving projects at remediation sites. However, the NJDOT allows essentially the same reuse of RAP in bound and unbound forms for pavement projects without requiring a deed notice. (A deed notice is an institutional control used by the NJDEP SRP to identify and document the presence of COCs above soil remediation standards at remediation sites.) The SAB understands the reference to “residential-type standards” to mean the NJDEP’s residential direct contact soil remediation standards (RDCSRS; see New Jersey Administrative Code [NJAC

7:26D]). While the RDCSRS are "soil" standards, they are ostensibly applied to non-soil materials like RAP, due to the similarity of soil and RAP regarding the routes of exposure. Although it is not soil, RAP can break down to become soil-like with respect to exposure mechanisms, as described elsewhere in this document. The NRDCSRS are established based on evaluation of three primary routes of exposure – inhalation, ingestion and dermal absorption. In terms of the exposure mechanisms assumed for calculation of the RDCSRS, there is essentially no difference between soil and RAP containing similar COCs (e.g., PAHs and metals).

Potential exposure routes via aqueous pathways are addressed below since they are not necessarily limited to residential scenarios.

It should be noted that the reference to RAP as "product" in the charge question was not considered by the SAB in this response, since the term has no bearing on a technical/scientific evaluation of RAP, or on any technically feasible management options that can are proven to be protective of human health and safety, and the environment.

Does reuse of RAP result in leaching of COCs?

The original question (Does reuse of RAP cause leachate?) was restated for clarification because the term "leachate" can have more than one meaning and carry with it connotations of dark viscous liquid typically associated with landfills.

Also, the answer to this questions is conditional based on the type of RAP reuse being considered. For example, there is practically no concern about leaching of COCs when RAP is properly recycled in asphalt pavement and road/pavement construction. While there is some limited potential for leaching when unbound RAP is used or stored with surface exposure or in unprotected piles. Thus, the focus of this discussion is on the latter scenarios (i.e., RAP reuse/storage other than reuse in pavement construction).

Studies conducted in Minnesota and Denmark (see ref. in Mehta et al., 2017) evaluated leachate from RAP and conclude RAP generally does not cause leachate. However, the studies appear similar to other studies that evaluate potential for leaching of COCs from RAP, and do not necessarily address potential for to contribute to landfill leachate.

The potential for reuse of RAP to result in leaching of COCs depends on several factors related to the type of reuse and site conditions where reuse is to take place. However, based on the research reviewed, and fate and transport characteristics of the RAP and related COCs, the potential for RAP to leach PAHs and metals is relatively low.

The charge question asks about leachate but it does not necessarily raise the issue of particulates and suspended solids that may harbor undissolved concentrations of COCs. The term "leachate" includes substances that may be dissolved in water that comes into contact with RAP, but does not include suspended solids. While migration of particulates and suspended solids are not a common concern in ground water, their migration to surface water bodies may be a legitimate concern under some circumstances (e.g., direct contact with surface water, potential for significant mass transfer of RAP to sediment bed via erosion and discrete conveyance, etc.). However, the use of dissolved COC concentrations reported in published leachate studies for generalized evaluation of impacts the surface water is not advisable for several reasons; primarily because the test methods for evaluation of leachate are designed for assessment of dissolved substances not migration of particulates. Also, surface water quality criteria are intended for in-stream, ambient surface water quality assessment. Thus, a simple direct comparison of test leachate concentrations without consideration of other assimilative factors is likely to result in impact estimates that are erroneously conservative and unnecessarily restrictive.

To provide context, comparisons between new asphalt pavement or pavement surface seal coatings and RAP may be informative. Surface seal coating of RAP with asphalt or tar binders is currently recommended (i.e., effectively required) in the SRP RAP Guidance for certain uses. However, some studies indicate that PAH concentrations in runoff from coated surfaces are higher than non-coated pavement surfaces. This is likely related to the higher concentrations of PAHs in seal coat products as compared to asphalt pavement (Williams, et al. 2018). Other studies have reported a decrease of COC concentrations in leachate extracts over relatively short time frames (Townsend, 1998). This is ostensibly due to several factors including early loss of more soluble PAH compounds that are present at higher concentrations in fresh asphalt pavement as asphalt products weather or cure. This is especially important when considering RAP since RAP is generally composed of older asphalt that has been subject to extensive weathering prior to reuse. Thus, the potential for PAH leaching from RAP may be lower than for new asphalt pavement or asphalt surface seal coatings, while surface seal coatings may provide some decrease in particulates migration. Although, Processing of RAP (milling or crushing) will tend to increase surface area and increase the percentage of finer particle sizes, which could counter effects of weathering and represent a potential for an increase in leaching of COCs. Differences in pre-processed vs. post-processed RAP is also a consideration that may impact potential leaching or particulates migration.

How can potential human health and environmental exposures to asphalt millings be minimized in order to better utilize/recycle this material?

Theoretically, casual exposure to RAP is not a major concern due to the relatively low leachability of the COCs and relatively low exposure. In many respects RAP is comparable to asphalt pavement, especially with so many crumbling streets and paved areas that appear ubiquitous especially in urban areas. Also consider the square miles of paved roadways and other surfaces in NJ vs. the relatively small areas of RAP.

Hypothetically, development of generalized scenarios that may conceptually model conditions that are similar to those at actual known sites may be helpful to evaluate and establish guidelines. However, extreme, unrealistic hypothetical scenarios should be avoided for use to establish general guidelines.

Practically, it seems the growing RAP piles are mostly at the quarries and asphalt pavement manufacturing plants. Although, RAP is sometimes used as a cheap gravel, DGA, or as a pavement alternative for construction of surfaces. Use in quarry reclamation, especially where asphalt pavement is produced and where RAP is already handled seems to be a reasonable option to consider for reuse of RAP under certain site conditions. Quarry reclamation often requires extremely large amounts of fill. Use of RAP in quarry reclamation may be feasible where it could be considered protective of human health (e.g., direct contact exposures such as inhalation and incidental ingestion) and provided protection of water resources can be demonstrated, e.g., via geological and hydrogeological conditions, monitoring of ground water at sentinel compliance points, storm water runoff controls, etc.

How much RAP can be used with new asphalt?

We assume the question is referring to new asphalt pavement products (e.g., hot mix asphalt, roadway base course and wearing surface pavement, etc.). The amount of RAP that can be incorporated into new asphalt pavement products varies due to several factors that are both technical and regulatory. For example, the NJ Department of Transportation regulates asphalt manufacturing specifications for roadway pavement products that indicate addition of 10% to 50% of RAP in various raw material fractions for different types of asphalt pavement. For example, the NJDOT specifications prescribe that dense graded aggregate (DGA) used for hot mix asphalt (HMA) can contain up to 50% RAP. It should be noted that the total amount of RAP in HMA product would be less than 50%. In addition, actual amounts of RAP reuse may also vary to achieve necessary product quality.

According to the 2018 *Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2017,* an annual survey report prepared for the U.S. Federal Highway Administration, annual reuse of RAP New Jersey's (19%) lags behind several other states. For example, annual RAP reuse rates for a number of states are around 25%, and generally exceed 30% in Florida and Michigan. The survey report includes additional respondent survey information that suggests the biggest impediment to RAP reuse is related to "specification limits".

Obviously, these types of restrictions on the amount of RAP that may be used for road pavement manufacturing can negatively impact the overall reuse rates.

Possible restrictions for RAP reuse in New Jersey

- Controls consistent with Mehta et al. 2017
- Use of RAP as fill or for unpaved surfaces in environmentally sensitive areas (e.g., surface water bodies, wetlands, etc.)
- Significant mass transfer of RAP via erosion to environmentally sensitive areas
- Special storm water drainage system BMPs to protect RAP migration into and through catch basins and collection systems adjacent to where RAP may be reused
- Minimize surface exposures in residential and recreational areas

The existing regulations, guidance and policies appear to provide significant restrictions that minimize environmental exposure of RAP in general and by default likely achieve most of the restrictions listed above. However, some of the existing restrictions may be contributing to the overall state-wide increase of unused RAP. A review of the existing regulatory and guidance requirements may be warranted to evaluate addition of options or revisions that incorporate flexibility and use of site-specific data to facilitate appropriate protection of human health and safety and the environment while achieving RAP sustainability goals.

The SAB's consideration of possible restrictions on reuse of RAP is limited to concerns related to exposure of COCs. Potential restrictions to be considered for concerns regarding geotechnical and manufacturing specifications for use of materials that incorporate RAP are beyond the scope of this review.

Scientific research and studies to support evaluation of exposure pathways and potential adverse impacts of RAP on human health and the environment.

There are numerous studies that report research about leaching of PAH and other COC's from RAP. The summaries of prior studies provided in the literature do not appear to include the kinds of details that are necessary to answer some of the charge questions. For example, recent study completed for the NJDOT (Mehta et al., 2017) does not include a complete discussion of laboratory analytical quantitation limits, and does not include the actual leachate concentrations or water quality standards in some of the literature summary discussion. It is not clear whether these details are not available in the literature cited or if they were simply not included in the report as a matter of style.

The NJDEP should consider conducting a literature review that includes evaluating existing literature using some previous established guidelines or criteria for usability and comparability with current NJDEP methods and procedures and water quality values. Studies may be accepted or rejected based on these criteria. However, such criteria should be flexible and should not be so stringent as to render valuable research information unusable. Some research resources are provided in the References Section below.

More research is needed in the following areas:

- Effects of aging and weathering on COC leaching from RAP.
- Transport and exposure pathway mechanisms for migration of RAP-related COCs bound to particulates via storm water to surface water, airborne dust particulates, and potential for related human and ecological exposure. Evaluation of both inhalation and incidental ingestion routes should be considered for different uses.
- Sustainability, public health and safety, and environmental protection of RAP management practices in pavement manufacturing, road construction.
- Risk analysis and economic evaluation of letting the RAP stockpiles remain on site, use RAP as a component of engineered fill (e.g., in quarry reclamation), transport and disposal of RAP in landfills, and/or used in several of the ways suggested above to

determine the safest sustainable and economical approach to deal with increasing production of this material.

See additional comments under "BMPs" and "Questions for Further Research" below.

Need recommended reuses of RAP.

The SAB recommends evaluation of the following potential areas for reuse of capped (i.e., covered with pavement, concrete, gravel or soil) or uncapped forms of RAP. Note that the reuse of bound forms of RAP (e.g., in HMA) and unbound RAP currently approved for reuse in road and pavement construction is considered to be acceptable.

Capped RAP Reuse

- Review current restriction in pavement specifications.

- The increased reuse of RAP in asphalt pavement manufacturing for roadway and parking lot construction and maintenance is a conceptually straightforward means of reusing RAP. The idea that virtually all RAP derives from roadway/parking lot construction and development/redevelopment seems to point at reuse within those same use categories. The regulations, guidance and the industry have advanced reuse of RAP as a whole. However, existing specifications that prohibit use of any RAP should be reviewed and unnecessary restrictions should be eliminated. For example, the prohibition on use of any RAP in subbase noted in the NJDOT road construction specifications as indicated in the DHSW RAP Guidance may be antiquated based on recent research. A study by Montepara et al., (2012) indicates that subbase aggregate containing up to 50% RAP performs similar to roads constructed with conventional 100% virgin subbase stone, as required in the NJDOT road construction specifications. The USDOT FHWA (2016) indicates successful RAP reuse in granular subbase by several states. This represents a potential opportunity to review the NJDOT specifications (circa 2007) and consider some flexibility for use of RAP in subbase for certain roadways or paving projects. For example, local streets or cars-only roadways and parking lots. The NJDEP should consider reviewing current DOT pavement specifications and other regulations and guidance related to RAP to address potentially antiquated limitations on manufacturing and reuse that may unnecessarily restrict more efficient RAP reuse in pavement in New Jersey. As an example, the NJDEP RAP Guidance prohibits use of RAP as roadway subbase in projects that must meet NJDOT specifications that were last updated in 2007. It is not clear that the 2007 specification limits are supported by current technology.

- The USDOT FHWA identifies the following uses for RAP as granular fill (FHWA, 2016):

  > Granular base or subbase material in virtually all pavement types, including paved and unpaved roadways, parking areas, bicycle paths, gravel road rehabilitation, shoulders, residential driveways, trench backfill, engineered fill, pipe bedding, and culvert backfill.[2]

- Other options to consider for reuse of RAP include:
  - Landfill daily cover
  - Areas with low potential for particulates migration to surface water
  - Areas with low potential for impacts to ground water
  - Alternative fill or alternative for gravel surfaces for non-residential areas

Site-specific conditions should be considered to evaluate options (e.g., depth to ground water; presence of soils, clay or rock layers that may serve to mitigate potential impacts to ground water; for uncapped RAP, distance from residential and environmentally sensitive areas). There appear to exist regulatory impediments to implementing some of the reuse options noted above in various overlapping programs (e.g., NJDEP SRP and DSHW), including expanded uses as alternative fill, engineered fill, backfill, that would need to be addressed if some of these uses are determined to be technically feasible and protective.

BMPs for RAP Management.

Fundamentals to consider for development of best management practices (BMPs) for management of RAP to mitigate potential exposure to COCs:[3]

- Prevention or reduction of migration of RAP particulates to surface water bodies (e.g., stormwater conveyances, storm drains)
  - Prevention from entering storm drains
  - Use of storm drains that trap solids and particles
  - Distance from Surface water bodies, flood hazard areas, wetlands
  - Reliance on riparian areas, which generally provide a natural particulate filtering function adjacent to water bodies
  - Reduction of runoff
  - Runoff evaluation or monitoring
  - Staged pile stabilization and monitoring (e.g., storm water BMPs)

[2] Placement of RAP in contact with groundwater is identified as an unresolved issue for these uses. Some of the uses may be unbound and/or uncapped.

[3] The primary COCs associated with RAP are PAH and Metals; however, other chemical substances may be identified for evaluation, if warranted based on the RAP source or site-specific knowledge indicating the potential for the presence of other chemical substances in RAP on a site-specific basis.

- Maintenance dewatering of RAP pile pore water to mitigate potential migration to ground water or surface water seeps.

- Prevention or reduction of migration of RAP particulates in air (e.g., dust)
  - Addition of binder
  - Surface cover (e.g., pavement, coating, soil cap)
  - Distance from residential areas, parks, playgrounds

- RAP Piles and Engineered/Alternative Fill

The long-term staging of RAP piles and reuse of RAP as a fill admix represent unique circumstances that do not appear to be directly or completely addressed by existing studies (e.g., potential exposures to human and environmental receptors from particulates migration due to surface runoff and airborne dust).

Applying established methods for evaluating potential human health and environmental exposure from existing asphalt piles, including:

- potential for leaching dissolved COCs and migration to ground water
- potential dissolved and particulate-bound COC migration to surface water bodies
- potential direct contact exposure pathways (e.g., inhalation and incidental ingestion)

Batch leachability tests like TCLP and/or SPLP should be adequate for evaluating the potential for migration of dissolved COCs from RAP to surrounding environmental media (e.g., soil, ground water, surface water, sediment). Column studies may also be appropriate for more advanced evaluation where determined to be necessary or appropriate.[4] However, batch and column study test results should be interpreted in context within the context of generalized or site-specific environmental conditions (e.g., soils and geology, hydrogeology, ambient geochemistry) and assessment of potential migration pathways. Also, paired sample analysis for total recoverable COCs may be conducted with batch tests to facilitate batch test data interpretation. The USEPA's "divide by 20" rule may be considered as a substitute for batch tests when appropriate total recoverable data are available.

Where batch tests indicate some potential for migration of dissolved COCs to groundwater, review of local hydrogeological conditions may be warranted to assess protectiveness of local ground water resources. This may include sampling and analysis of any perched water or pore-water existing within the RAP and/or sampling and analysis of soils or ground water beneath the RAP for COCs and geochemical characterization (e.g., pH, redox, etc.) using standard sampling and analytical procedures.

[4] See Kosson et al., 2017 for examples of USEPA leach and column study test methods and procedures.

Questions for Further Review and Research

What are the regulatory and technical limitations to RAP reuse from manufacturers' perspective?

Do other states have issues with RAP reuse, increased RAP piles and RAP reuse sustainability?

How are the FHWA and other states recycling RAP and addressing environmental impact concerns?

Consideration of competing sustainability objectives:

- Increasing RAP piles; landfill space;
- Resource and Energy Conservation associated with asphalt production and trap rock mining; use of clean fill soils vs. non-soil alternative fill at SRP Sites.
    - Reduced manufacturing-related environmental impacts
    - Reduced virgin materials – aggregate material, e.g., trap rock mining; petroleum resources and refining)
- Environmental Risks – Surface water (localized)
- Human Health Risks – Drinking water; air quality (localized); incidental ingestion.

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