An Estimate of Coal Tar Sealant Wear Rates in Austin, TX

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Abstract

Parking lot sealant has been shown to be a major source of PAHs to the environment, yet yields predicted by a recent USGS/City of Austin study (0.2% per year), do not match wear rates as observed by looking at parking lots around Austin, Texas, nor with the industry recommended re-application rate of every 3-5 years. A photographic study was conducted using 10 coal tar sealed parking lots in Austin with age ranges from 0-5 years old to estimate amount of sealant on lots of different ages. Amount worn off over time was then calculated using average sealant wear and the ages of the sealant application. Although this approach is very conservative and likely underestimates total loads of sealant leaving parking lots, the results suggest that sealant wears off of parking lots at a predictive rate of at least 2.4% per year, with a mean annual loss from our study sites of 3.2%. These values provide a starting place for estimating best-case loading scenarios for PAHs from coal tar sealed parking lots.

Introduction

Collaborative studies by the City of Austin and the U. S. Geological Survey (USGS) have identified parking lot sealant, and particularly coal tar-based sealant, as a major and previously unrecognized source of polycyclic aromatic hydrocarbon (PAH) contamination (Mahler et al. 2005). Biological studies conducted by the City of Austin indicated that PAH levels in sediment contaminated with abraded coal tar sealant were toxic to aquatic life (Bryer et al. 2005, Great Lakes Environmental Center 2005).

Field observations reveal that coal tar sealant applied to parking lots abrades and leaves the lot over a period of years. The sealant wears unevenly with higher rates of loss in high traffic areas. This is easily observed in aerial photographs (Figure 1). Parking areas with little wear appear darker, and in worn drive areas the aggregate and aged asphalt binder underneath the sealant appears lighter. This is due to the black color of coal tar sealant, and its ability to remain black over long periods of time (Schoenberger 2001). Asphalt pavement itself oxidizes as it weathers and turns from black to grey (Lay 1999).

Figure 1. Worn Parking Lot in Austin, Texas.

When applied, the sealant with constituent PAHs forms a coating on the parking lot surface where it may remain for many years (Fig. 2). However, once the sealant wears and abrades, PAHs are introduced into the environment via stormwater runoff. These particles wash into the drainage system and eventually into stream and river sediments. Understanding the rate at which sealant-derived PAHs enter the environment will improve strategies for controlling PAHs accumulation in urban watersheds. Mahler et al. (2005) performed an artificial wash-off study that estimated the yield of PAH's entering the environment based on measured concentrations from known areas on different parking lot surfaces. This value can be extrapolated to an annual wear rate using various assumptions (44 rain events per year, 0.17 gallons of sealant per square yard applied per ASTM standard D3320), resulting in approximately 0.2% of PAHs in sealant applied leaving the lot per year. The Mahler et al. study was not designed for estimating annual loads from parking lot surfaces. It used a gentle spray of distilled water (approx. 1/10 of an inch, low rainfall energy) to attempt to wash abraded sealant off of parking lot surfaces, which may have been inadequate to represent natural rain events (high rainfall energy). Additionally, the study units were relatively small ($50 m^2$), the measurements not continuous and the method did not account for wind, tires or other modes of moving sealant around or off the lot.

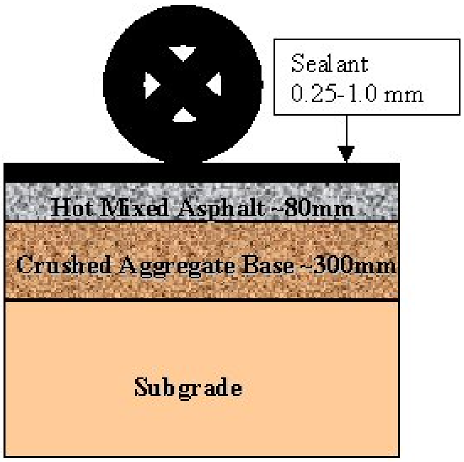

Figure 2. Generalized cross section of parking lot with sealant on asphalt.

Our study was designed to provide a more realistic estimate of sealant wear rates using visually apparent amounts of sealant on parking lots across a range of ages (0-5 years). Lots were sub-sampled by taking randomized, carefully standardized, digital pictures and using them to calculate the area of the picture covered by sealant. We assumed all parking lots start out completely (100%) covered by sealant and calculated the percent sealant lost. Our hypothesis was that sealant wears off lots on the scale of the industry warranties and recommended re-application rates of every 3-5 years (http://www.naturalhandyman.com/iip/infdrivewaysealer/infdrivewaysealer.shtm , http://mspave.com/index-3.html), after approximately half the sealant is worn away (5-10% per year). This would be much faster than the 0.2% per year estimated yields from the Mahler et al. (2005) study. In addition to time, we hypothesized that traffic volume would also play an important part in abrading sealant off of parking lots.

Methods

Site selection
Ten parking lots in the Austin area were selected based on knowledge of the date they were sealed with coal tar sealant and their age distribution over a five-year study period (the industry recommended maximum re-application period). The lots had been sealed by various contractors with various coal-tar based sealant preparations. All of the lots selected were commercial in nature, serving strip malls, high-turnover restaurants or large churches.

Sampling plan
Each lot was divided into two areas, a parking space area and a drive isle area. An *a priori* 200-photo sample limit was used because of time and staff constraints. Using an area-weighted calculation, the 200 data points were distributed among the 10 parking lots, using a minimum of 3 and a maximum of 20 per area type (park and drive). Maps were generated with an excess (50) of randomly placed points that staff used to locate the correct location of each photo site. Beginning with the lowest point number on the map, staff would take the requisite number of photos per lot. If a location was unavailable because of a parked car or other obstruction or unsuitable due to obvious repair, paint or oil spots, another random photo location was used. Once the stipulated number of photos was taken in both drive and park areas, the data collection was complete for that parking lot.

Table 1. Parking lot reference numbers, age of sealant application, parking lot areas by use and number of photos taken per lot by area type. Age of sealant, park area and drive areas are averaged at the bottom and number of photos for park and drive areas are totaled.

Parking lot Number	Age of sealant (years)	Park Area (sq. ft.)	Drive area (sq. ft.)	# Park photos	# Drive photos
1	0.5	7015	9214	3	3
2	0.9	38599	32045	5	4
3	1.0	56975	83915	8	11
4	2.0	167504	174021	21	19
5	2.0	13224	31346	3	4
6	2.2	62688	94110	8	13
7	3.7	43731	61445	6	8
8	4.1	107717	141242	14	20
9	4.1	42319	44320	6	6
10	5.4	84452	105377	6	7
Average/Totals	**2.6**	**59509**	**74136**	**80**	**95**

Photography
A Nikon D50 digital SLR camera was mounted on a tripod positioned with the back of the camera 1.46 cm from the ground with the focal length of the lens set at 32 mm, giving a sampling frame of 1.05 by 0.69 meters (0.725 sq meters). For a consistent exposure, a 13.8 by 10 cm piece of 18% grey card (Kodak) was placed in the center of the frame and the camera was set to "Program" mode with the on board light meter set to "spot" mode so that the grey card would have the same density in all images regardless of the ambient light level. All photos were 3008 x 2000 pixels, or 1.5 megabytes. For even, flat lighting the camera and subject where shaded by a large piece of non-reflective black mat board. All photos were taken from August 22 to September 21, 2006 and between 9:00 am and 2:00pm.

Image analysis
Images were cropped and converted to grayscale tiff format and then analyzed with Scion Image (a repackaged version of NIH Image available at www.scioncorp.com) using the "density slicing" function. Density slicing was used to identify the coal tar sealant in photographs of parking lot surfaces (Figure 3). Scion Image was configured to select all pixels darker than the grey card (lower left hand corner in each photo). Results (% sealant) were exported to spreadsheet and statistical software for further analysis.

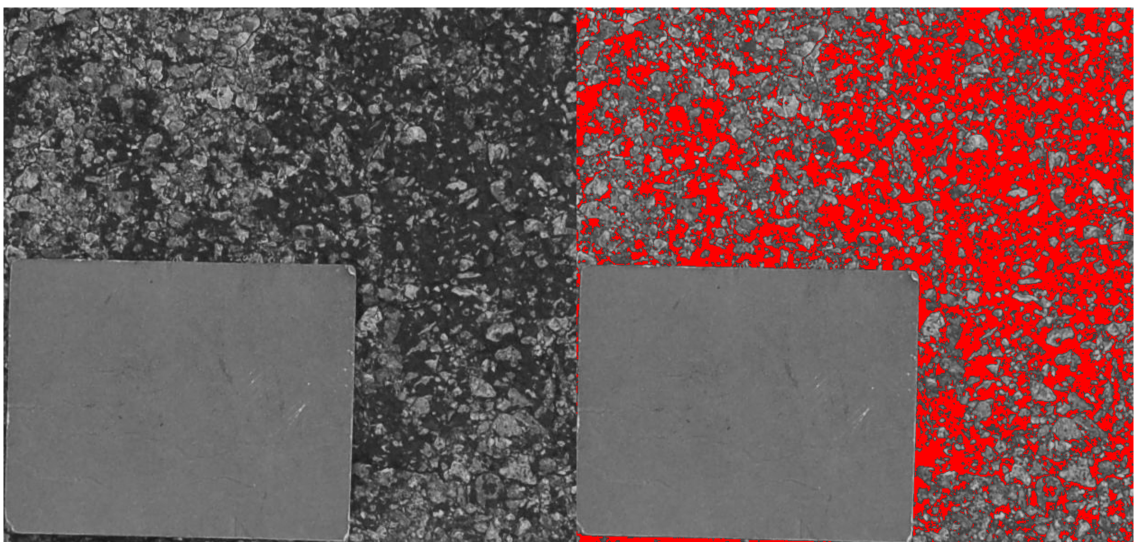

Figure 3. Example of density slicing technique of separating sealant from unsealed asphalt. The photo on the left shows a black and white image where black=sealant, while the photo on the right shows the separation of sealant from background, using false red color.

A two-point linear calibration line was generated using reference photographs from unsealed parking lots (0% coverage of sealant) and newly sealed parking lots (100% coverage). The calibrations line was used to standardize all test lots to the same relative distribution of percent cover. A series of quartiles at approximately 25, 50 and 75% covered by sealant were selected in the field by three observers, verified by a graphics expert, and placed along the calibrations line as a quality assurance check.

Estimation of traffic volume on parking lots
Traffic volume was hypothesized to be an important variable in sealant wear. The amount of times a parking lot was driven across was estimated according to the Institute of Transportation Engineers Trip Generation Report Handbook which gives mathematical formulas for determining the number of trips a business will generate based on size and type. We chose the broadest categories, describing shopping centers as one unit rather than by summing the individual businesses. This was the most practical way to approach this because the older lots have undergone tenant turnover during the study period. To calculate

the unit exposure to traffic, the total number of vehicle trips since the parking lot was sealed (daily estimate of trips x number of days since sealed) was divided by the area of the parking lot. This normalized traffic volume per unit area so that all lots were directly comparable.

Results and Discussion

We analyzed 175 data points to calculate the amount of sealant coverage on the 10 study parking lots. When all of these data (both drive and park areas) are plotted against age of parking lot sealant it demonstrates that there is a wide range of sealant coverage on lots of all ages (Figure 4). The geometric mean of sealant loss per year for all lots (average sealant loss per lot/age of each lot) was 3.2% with a standard deviation of 1.3%. The variability observed in sealant wear within study lots was examined more closely by plotting the maximum and minimum % coverage of sealant remaining on study lots as a function of age (Figure 5). This results in a wedge shaped distribution where minimum sealant wear on lots does not change over time (essentially no slope) but maximum sealant coverage does change over time with a slope of approximately 6.3% sealant wear per year.

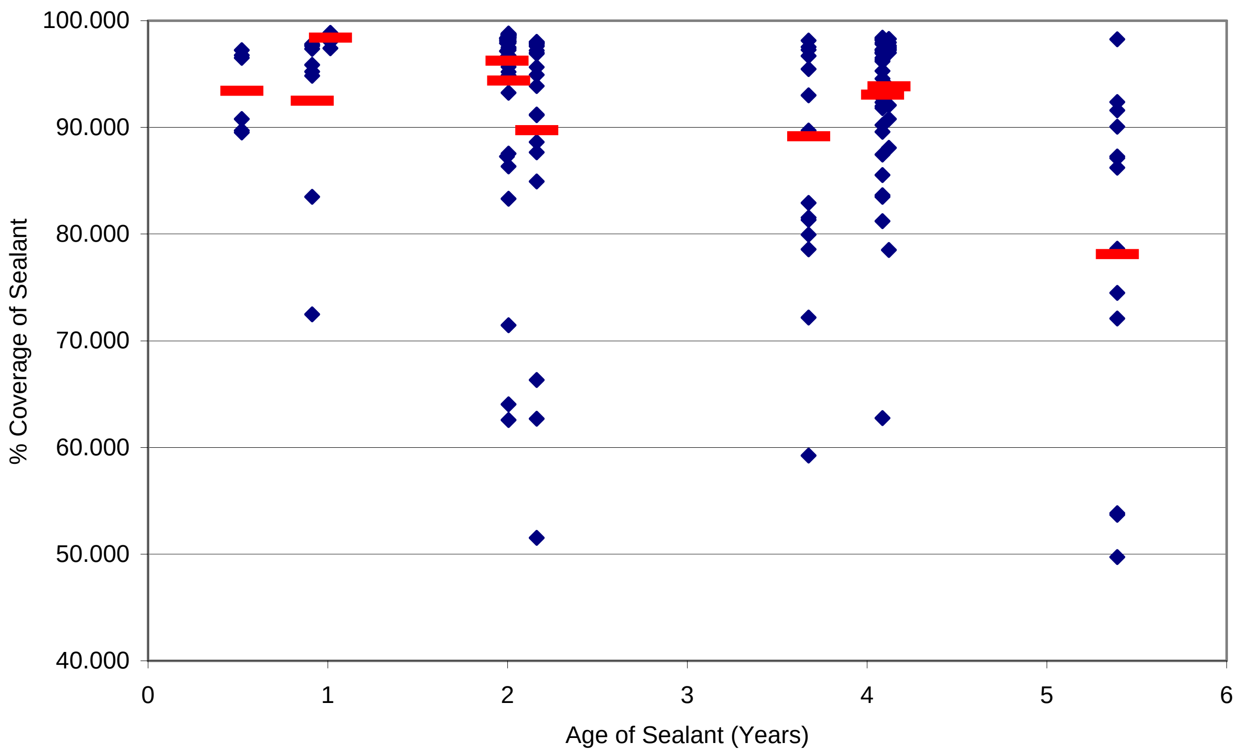

Figure 4. Percent sealant remaining on 10 study parking lots as a function of age in years. The vertical lines of data points (diamonds) represent all data from each of the study lots. The lateral red bar represents the average amount of sealant on each lot at the time the photographs were taken.

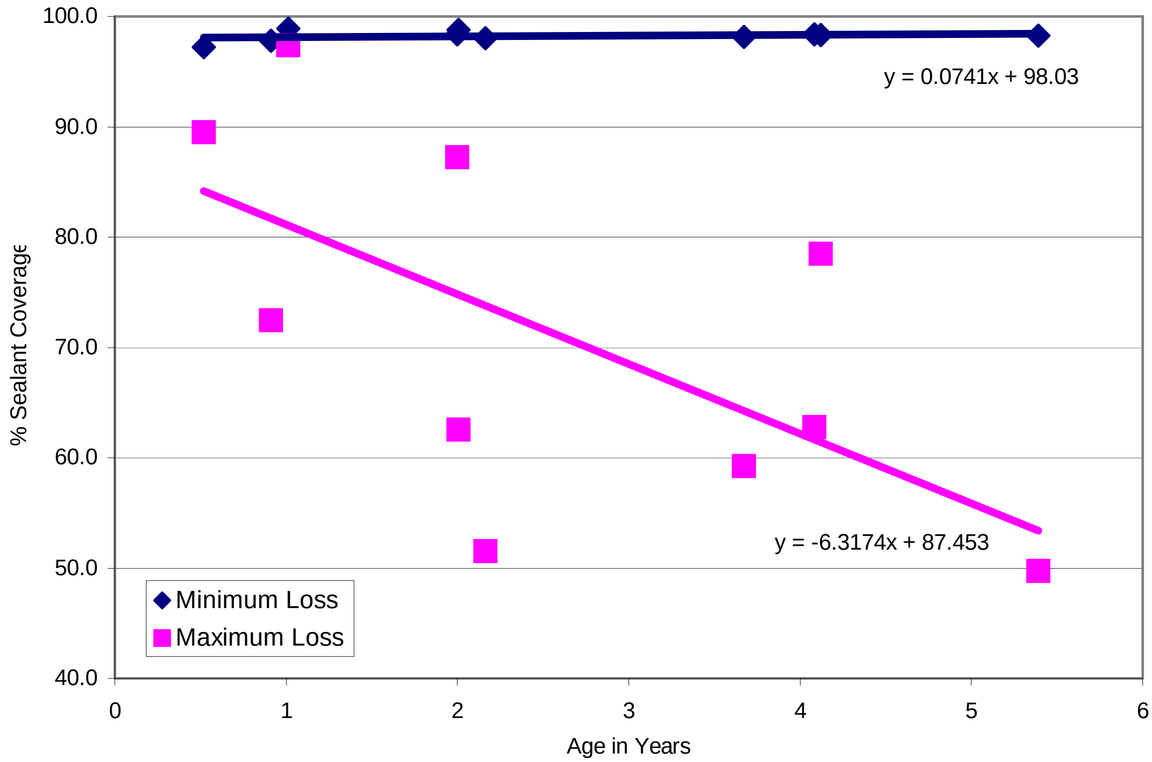

Figure 5. The observed minimal (blue) and maximal (pink) sealant wear as a function of age in years.

Drive areas of parking lots had more wear than parking areas, as would be expected (Wilcoxen Matched Pair Test, Statsoft, $p<0.05$). The average coverage of sealant on drive areas for all 10 lots was 88% while parking areas averaged 95%. Wear as a function of vehicle trips on a parking lot was explored using estimated daily trips on each lot multiplied times the number of days since the lot was sealed and divided by lot area. This value did not contribute significantly to wear patterns documented (no significant correlation) and although drive areas were more closely related to traffic volume than park areas (Figure 6), our hypothesis that traffic volume would be a primary predictor of wear rates must be rejected at this time. Intuitively, it is clear that traffic volume on parking lots should help explain wear rates. However, due to high variability in wear patterns or due to an inaccurate method of estimating traffic volume, this relationship could not be quantified.

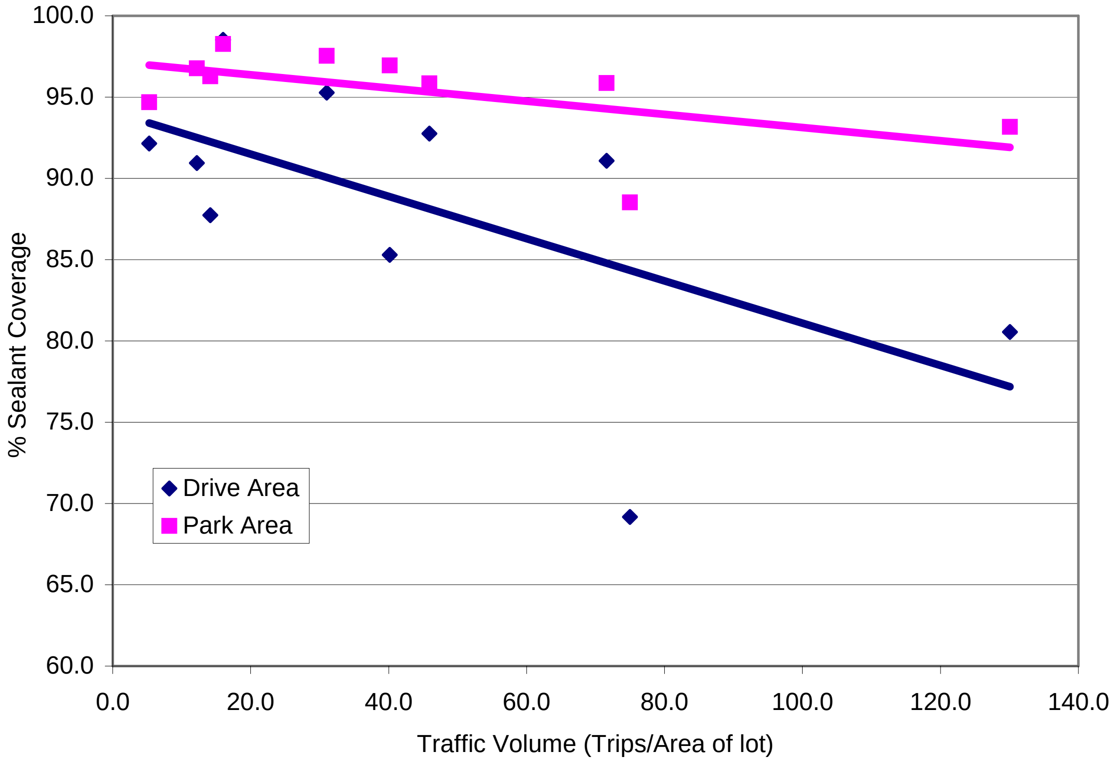

Figure 6. Sealant remaining in drive areas and park areas as a function of traffic volume.

Total percent sealant loss (both park and drive areas) was significantly explained ($p=0.03$, $R^2=0.46$) by time, with an annual loss rate (slope) of 2.4% per year (Figure 7). This relationship predicts that a three-year-old lot would have 7.2% sealant loss and a five-year-old lot, 12% loss. This relationship is probably not accurate in the first few months after a sealant application, as the slope here does not intercept the Y-axis at zero, nor beyond the 5-year range of these data. The oldest study lot, at 5.3 years old had an average sealant loss of 22%, seven percent higher than the regression model would predict. This could be an outlier, or it could be that after a certain amount of time, loss rates increase. More parking lots in the 5-year range would be needed to explore this further. The mean annual sealant loss of 3.2% was higher than the rate predicted by the regression model, but relatively close in scale. Depending on the application, both of these values could be useful in discussing load estimates of PAHs from coal tar sealed parking lots.

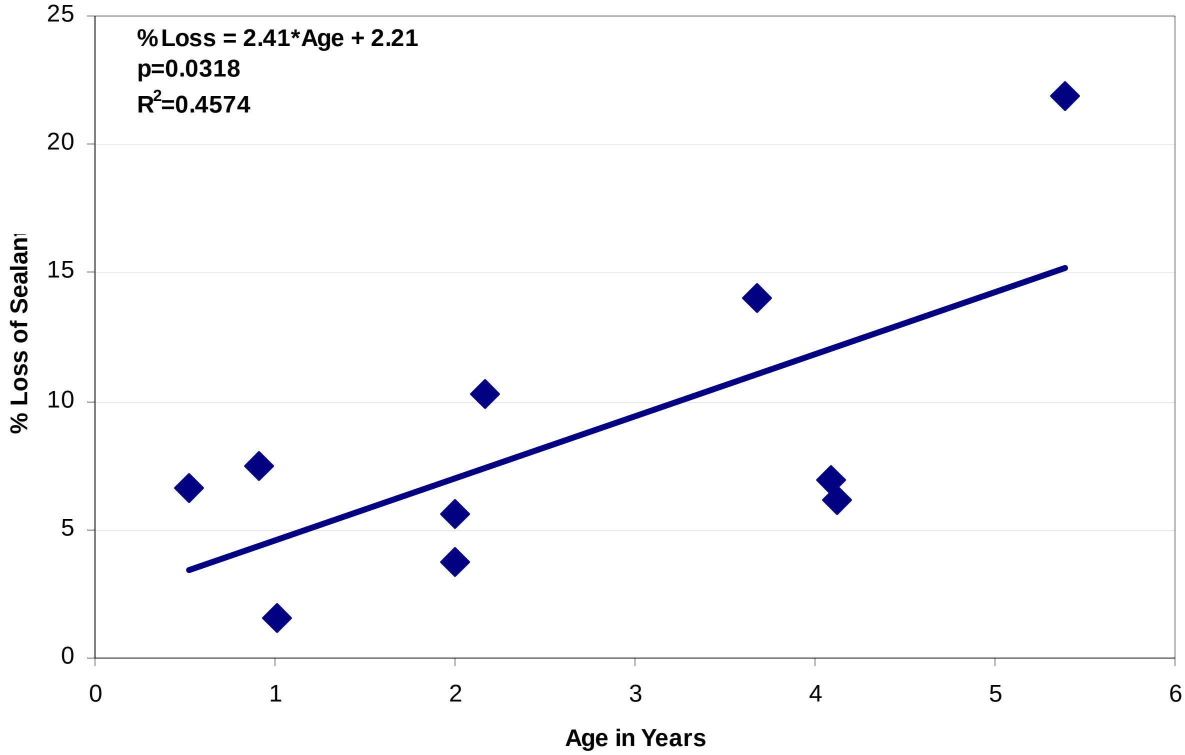

Figure 7. Linear relationship between sealant loss and age of sealant.

Conclusions

Perhaps the most important constraint on this study was the fact that our methods only detected sealant loss when underlying aggregate in asphalt parking lots was exposed, thereby providing visual evidence that no sealant was present. In reality, a relatively large percentage of the sealant applied to the asphalt must be worn off the parking lot before aggregate begins being exposed. If the average newly sealed commercial parking lot has two coats in park areas and three coats in drive areas (industry standard - http://mspave.com/index-3.html, http://www.neyra.com/jenapp.htm, http://www.starseal.com/starseal.htm), resulting in over a millimeter of sealant, most of that would need to be gone before aggregate broke through. Exactly how much is worn before aggregate shows, or how to correct for this error, has not been explored at this time and will require further study. Regardless, the resulting sealant loss estimates can be assumed to represent the absolute minimum losses that are occurring on sealed parking lots in the Austin area, which has very minimal freeze/thaw cycling and no plowing.

The annual wear rate of 2.4% can be used to calculate some useful load estimates, such as 1.3 grams of PAHs worn off every square meter of coal tar sealed parking lots per year (assuming 1.47 kg sealant applied per square meter times a concentration of 36,000 ppm). If quantitative estimates of sealed parking areas in a drainage area can be made, this may the most appropriate method for calculating watershed annual loads from sealant. For example, in Mahler et al., all sealed parking lots in the suburban Williamson Creek watershed in Austin were identified, resulting in about 2% of total area, or 1.5 square kilometers. This would result in 1950 kg of PAHs per year leaving parking lots in the Williamson Creek watershed alone. Since watershed delivery is not perfectly efficient, much of this load may be deterred before it gets to the receiving water. However, these quantities of PAHs are probably contributing significantly to long term PAH increases in Austin's receiving waters (Van Metre and Mahler 2005).

The results of the photographic method suggest that the amount of sealant leaving parking lots is much higher than the extrapolated annual yields from Mahler et al. (2005). This value for the Austin area (using 44 rain events per year) would be less than 0.2% per year, where photographic method estimates a rate of 2.4% per year, or over 10 times higher. The mean annual loss of all lots was 3.2%, higher than the predictive (regression) rate. As previously stated, both of these estimates are probably far below total actual loads, but much closer to the scale of the industry recommended reapplication rate of every 3-5 years and closer to what is intuitively observed on sealed parking lots around Austin.

In our study lots, parking areas represented 45% of total area and drive areas 55%. One aspect of the sealant process that was clearly documented was that almost all apparent wear occurs in drive areas, and that in those areas, the wear rate is closer to 3.5% per year (vs. 2.4% per year for the whole lot). These areas are what drive the re-application of sealant every 3-5 years, since they look so visibly worn. A parking lot does not have to have a majority of sealant worn off before it will appear very worn, due to the striking contrast between the totally black park areas and the worn drive areas. Drive areas appeared very worn, and contrasted with the park areas, after as little as 10% of the aggregate was showing through the sealant. Obviously this is a subjective and aesthetic variable, but does indicate that sealant is probably re-applied based on drive area wear, but includes areas of the lot that have minimal wear, and that comprehensive overall wear rates should include contributions from various coatings of sealant. Our conservatively low estimates of wear in the parking area do not take into account multiple layers. Nor do they take into account northern sealant stressors like snowplows and salt. In order to address these variables, a continuous perimeter-controlled study of pollutant load from stormwater run-off of parking lots should be performed capturing all materials leaving the surfaces. This study should include sufficient replicates and control of age and traffic variables as well as representative coating methods, materials, and layering.

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