SOME OBSERVATIONS ON ATMOSPHERIC DUST FALLOUT IN THE DENVER, COLORADO AREA OF UNITED STATES

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ABSTRACT

Dust fallout, as a contributor to the pollutants found on urban surfaces, has been discussed for years and many studies have been done to quantify it (Sartor and Boyd, 1972; Pitt and Amy, 1973; Pitt, 1979; Mustard *et. al.,* 1985; Schroder and Hedley, 1986; Schroder *et. al.,* 1987; Illinois State Water Survey, 2003). Despite these, there remains controversy as to how much of the total pollutants that are present on various urban surfaces come from atmospheric fallout. In the spring of 2003, the senior author had an opportunity to personally observe some of the accumulations of solids in roof gutters of a single-family house and the accumulation of sediment in a winterized swimming pool, both located in Denver, Colorado. This paper presents a summary of these findings and interpretations attributed to these observations in light of findings related to atmospheric dust fallout by other investigators.

CLEANING OUT ROOF GUTTERS

In May of 2003, clogged roof downspouts at one of the author's homes prompted the cleaning of roof gutters. These gutters were not cleaned for about 5- to 7-years. The grit and grime removed from the gutters serving approximately 700 square feet of the roof (horizontal projection) were collected in a plastic bag. These materials consisted of wet leaves, fine sediment and grit typically found on asphalt-composition roofs. Although these materials were not segregated and weighed separately, the following was observed:

1) Total weight of material was removed from the gutters serving 700 square feet (horizontal projection) of the roof was 30 to 40 lbs (13.6 to 18 kg).
2) Approximately 1/3 of the mass consisted of grit particles from the composition roof.
3) Approximately 1/3 of the mass consisted of wet leaves and water.
4) Approximately 1/3 of the mass consisted of very fine sediments.

Thus, over the 5- to 7-year period the gutter accumulated about 12 lbs (5.5 kg) of very fine sediment that would be classified as part of the Total Suspended Solids (TSS) found in stormwater runoff, or about 2 lbs (1 kg) of TSS per 100 square feet (9.3 m^2) of roof or 870 lbs/acre (977 kg/ha). This loading rate compares with a value of 700 lbs/acre (785 kg/ha) obtained from other studies of atmospheric dust accumulation completed in the Denver area (Mustard *et. al.,* 1985). *What is not known is the quantity of fine solids that were not trapped in the gutter during these years and were washed down onto lawns or onto streets and paved alleys that have a direct hydraulic connection to the streams in the Denver area.* Clearly, this example illustrates that roofs in the Denver area are significant sinks for atmospheric fallout and significant contributors of TSS found in stormwater runoff reaching our streams, especially if their downspouts discharge directly onto hydraulically connected paved surfaces, street gutters or storm sewers.

CLEANING OUT A SWIMMING POOL

On Memorial Day weekend, one of the authors observed the cleaning of a residential swimming pool. This presented an additional opportunity to document the effects of atmospheric dust fallout. Photograph 1 illustrates the difference in the pool bottom before and after cleanout. The area on the left side shows the bottom before it was vacuumed and the right side shows the results after vacuuming. The dark materials on left side of this photograph consist of the atmospheric dust fallout that was deposited on the pool's bottom since it was closed in September of 2002; namely, the amount that was deposited over a nine month period.

Photograph 2 shows a Ziploc™ bag filled with fine sediment that was washed off the vacuum's filter after 200 to 250 square feet of the bottom was cleaned. This sample does not contain all of the sediment that was on the filter; approximately 15% to 25% of the sediment was not captured and went down the drain during the filter washing process. These data indicate:

1. The total wet weight of the sample was 3 lbs (1.4 kg).
2. Assuming 50% water content and 20% bypass, the weight of the accumulated solids removed was around 1.5 lbs (0.7 kg), or 0.9 lbs (0.4 kg) of solids per 100 square feet (9.3 m^2) of surface area. Extrapolating this to a 12-month period, we get 1.2 lbs/100 square foot (5.6 kg/m^2) or 700 lbs/acre/year (785 kg/ha/y).
3. This material would be part of the TSS load in stormwater runoff when it was washed off impervious surfaces that have a direct hydraulic connection to the stormwater conveyance system.

Photograph 1. Difference between vacuumed pool bottom on the right and not vacuumed on the left, after nine months of dust fallout accumulation.

What is interesting to the authors is that these findings are similar to the findings reported by Beecham (2001) in Sydney, Australia. He reported that a load of 11 lbs (5 kg) of sediment is generated from a typical single-family residential roof on an average annual basis. Assuming an average roof area of 1,000 square feet (93 m^2) for Sydney, this rate corresponds to a unit-area loading of 1.1 lbs/100 square feet (4.7 $kg/100m^2$) of roof, as compared to the 1.2 lbs/100 square feet (5.2 $kg/100m^2$) of roof found by the authors from this single informal measurement in Denver.

A gradation test was performed of the pool sediments. This test roughly indicates what the distribution of particle sizes is within the atmospheric fallout in the Denver area. The results of the gradation test are shown in Figures 1 and 2. Approximately one-third of the sample can be classified as fine sand (larger than 74 microns) and two-thirds of the sample as silt and clay. Little more than 20-percent of the particles are clay-sized (2 microns or less). Studies have shown an inverse relationship between particle size and pollutant concentrations on street surfaces (Sartor and Boyd, 1972; Pitt and Amy, 1973; Pitt, 1979) and in bottom sediments in the South Platte River (Steele and Doerfer, 1983). Because of their small size, the clay- and silt-sized particles are difficult to remove from stormwater runoff using sedimentation processes.

Photograph 2. Wet solids collected from 200 to 250 square feet of pool's bottom.

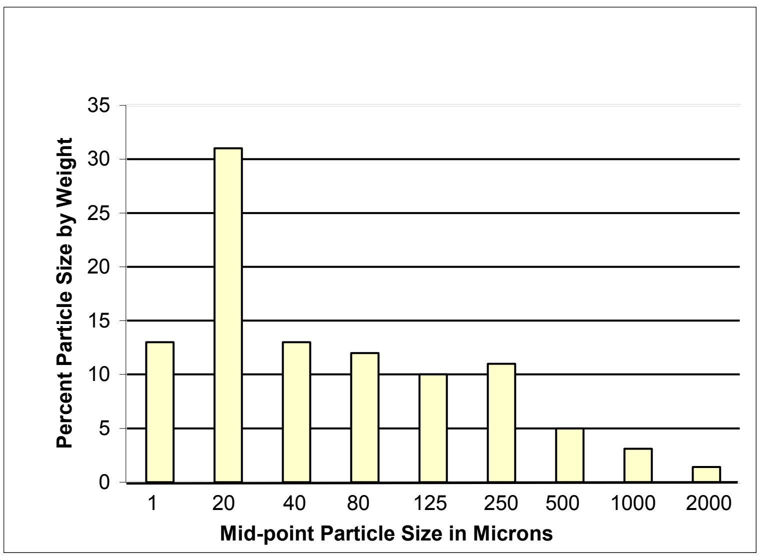
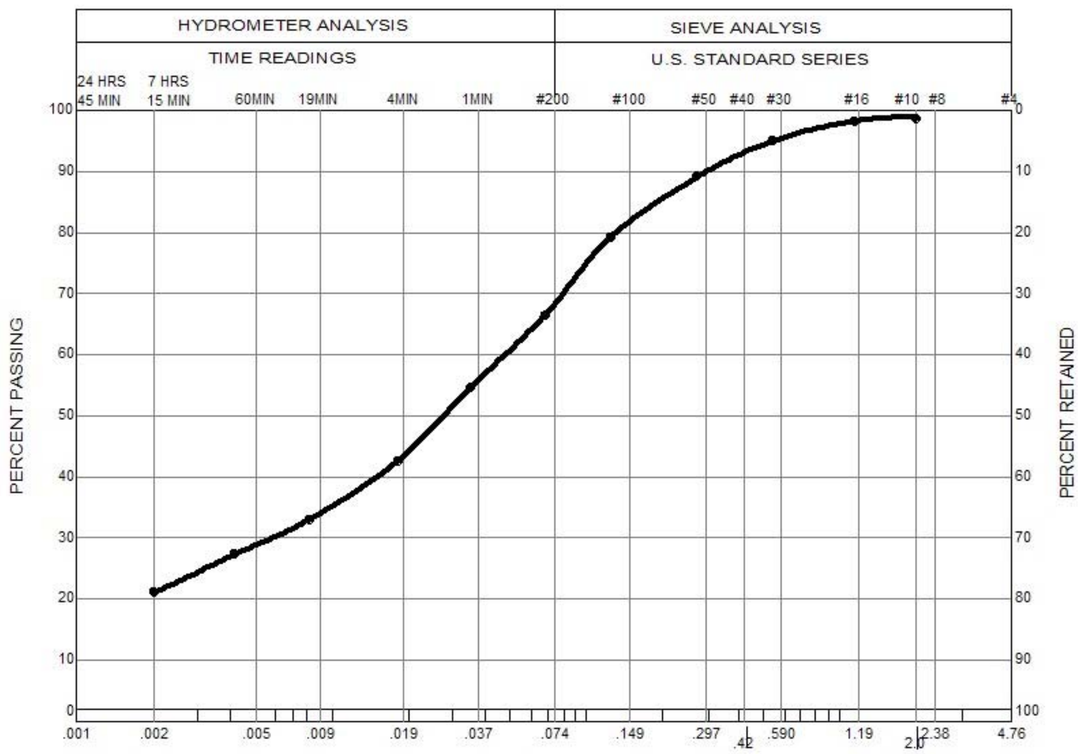


Figure 1. Distribution of particle mid-point sizes in the sample from bottom of a swimming pool.

WHAT DOES ALL THIS MEAN?

The two informal observations clearly imply that atmospheric fallout is a significant contributor of TSS found in stormwater runoff in the Denver. In addition, rooftops can be significant contributors of TSS and, potentially, of other pollutants in stormwater runoff.

Where do these solids come from? Air emissions from industry, commerce, fireplaces, diesel engines and other human activities are potential contributors. In addition, in a semi-arid climate such as Denver, wind picks up much dust and fine sediment from land surfaces within and adjacent to the urban area, including rangeland, farmland, streets, parking lots, construction sites, etc. Eventually these suspended materials settle to the ground. Unlike climates with more rainfall and humidity, the atmosphere in a semi-arid climate does not have as many opportunities to cleanse itself. In addition, native vegetated surfaces comprised of bunch grasses instead of turf grasses do not protect the soils from scour by wind, nor do they provide the trapping of dust particles that turf-forming grasses provide after particles settle to the ground.



Particle Size in Millimeters

Figure 2. Complete size distribution of particles in the sample from bottom of a swimming pool. Note that 70% of the particles are less than 80 micron in size and 80% are less than 125 micron in size (i.e., slow to settle and hard to remove from the water column).

It was found by more formal studies (Sartor and Boyd, 1972; Pitt, 1979; Mustard *et. al.,* 1985) that TSS initially builds up rapidly on impervious surfaces and then the buildup rate approaches an asymptotic equilibrium. This phenomenon of tapering off of the buildup rate can be attributed to wind resuspension and scour of deposited particles so that the buildup of sediment deposits do not continue at the same rate forever. In a swimming pool, all solids that fall out of the atmosphere cannot resuspend into the atmosphere. As a result, a swimming pool, a pond or a lake acts as a perfect sink for these solids.

The findings reported in this paper are not based on accurate scientific measurements. Nevertheless, they do provide a realistic assessment of what the atmospheric fallout of dust and other particles in the Denver area may be and how it affects stormwater runoff quality. It is recommended that these non-scientific initial data be better quantified through the use of more precise controlled measurements in existing sinks for atmospheric fallout (e.g., winterized swimming pools that have mesh type winter covers, lined ponds, etc.) in the Denver area. Unlike wet/dry samplers used by data collection agencies such as the Illinois Water Survey (2003), sinks like swimming pools provide large surface areas for the collection of these particles and can produce much more reliable data than wet/dry samplers used today because of their much larger surface area for trapping atmospheric fallout.

Nevertheless and despite this less-than-scientific methods employed, the data suggest that each 100 square feet (9.3 m^2) of impervious surface can yield as much a 1.0 to 1.2 lbs (0.45 to 0.55 kg) of solids on an annual average basis in stormwater runoff. What fraction of that range actually makes it into stormwater has yet to be determined. If, however, we assume that 100% of it makes it into stormwater runoff and an average of 30% of impervious surfaces have a direct hydraulic connection to the conveyance systems, each square mile (259 ha) of an average mixed-use urban development *can produce about 40 to 50 tons (18 to 23 metric tons) of TSS in stormwater runoff each year*. Considering that the Nationwide Urban Runoff Program data collected in the Denver area by USGS indicates an average TSS concentration for commercial and residential land uses in excess of 200 mg/L (EPA, 1983), the estimate using the unscientific samples collected informally by the authors in 2003 compare well to the annual stormwater TSS loads one calculates using the USGS and other data.

CONCLUSIONS

The observations made using simple atmospheric fallout dust capture techniques clearly show that:

1. Atmospheric fallout in the Denver area is a significant source of TSS and potentially of other pollutants found in stormwater runoff.
2. The fallout consists of very fine particles that are difficult to remove from the water column using dynamic and quiescent sedimentation facilities or devices.
3. It does not matter if the impervious surface is a street, a parking lot, sidewalk or a roof; they all accumulate this atmospheric fallout, which is then washed off by stormwater runoff.
4. The amount of this TSS that eventually arrives at the region's receiving waters depends on how the runoff from impervious surfaces is handled. The less of it that has a direct hydraulic connection to the conveyance system, the greater the chances for the turf lawns and landscaping to capture these particles before they reach the conveyance system.
5. The BMPs currently recommended in Volume 3 of the District's Urban Storm Drainage Criteria manual are well suited for the removal of these very fine solid particles from the water column before stormwater is discharged to the conveyance system or to the receiving waters.

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