United States
Environmental Protection
Agency

Air and Energy Engineering
Research Laboratory
Research Triangle Park NC 27711

Research and Development

EPA/600/S7-85/008 May 1985

EPA

Project Summary

Performance Evaluation of an Improved Street Sweeper

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Dust emissions from paved streets can be controlled by street cleaning, but the commonly used broom and vacuum street sweepers are ineffective in removing small particles from the street surface, and they disperse the dust into the air during sweeping. A.P.T. improved a commercial vacuum sweeper under a previous EPA contract, and in limited testing showed that the Improved Street Sweeper (ISS) cleans the street better and disperses less dust.

In this study, an extensive evaluation of the ISS was carried out in Bellevue, WA, and in San Diego, CA. The cleaning performance of the ISS was compared with that of broom sweepers and a vacuum sweeper. The ISS cleaned streets better than the other sweepers. Typically, the broom sweepers removed 20% of the street solids, the vacuum sweeper, 70%, and the ISS, 80%. Additionally, the ISS was the only sweeper tested that gave a constant, low level of residual street solids that was independent of the initial amount of street solids.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Dust on urban streets can cause air pollution because of redispersion of the dust and water pollution from rain water runoff. One way to minimize these pollution problems is to clean the streets regularly. The existing types of street sweepers have been primarily designed to remove trash and the larger solids. They have low to moderate efficiency for removing fine dust from streets. In addition, most street sweepers disperse some of the street dust into the air during sweeping.

Under a previous U.S. EPA contract, A.P.T. evaluated the problems with present sweepers and modified a vacuum sweeper by adding partial hoods to the gutter brooms, and venting an air stream through a spray scrubber.

This improved street sweeper (ISS) was subjected to a limited testing program in San Diego and Los Angeles during the previous contract. Results clearly indicated that the ISS could eliminate the the dust plume during sweeping and give a cleaner street. However, additional research work was needed to refine the design and to demonstrate its capability.

Under this contract, extensive tests were conducted to determine the improved street cleaning performance and the effectiveness for reducing fugitive particle emissions from the ISS.

Objectives

The ISS and conventional street sweepers were tested in operation under identical conditions in the City of Bellevue, Washington, and in San Diego, California. The objectives for this study were:

1. Compare the street cleaning abilities of the following street sweepers:
   a. A.P.T. ISS.
   b. Tymco Model 600 regenerative air sweeper.
   c. Mobil broom sweeper.

d. FMC broom sweeper.
2. Compare the dust dispersions of the ISS and Tymco sweepers.
3. Determine particle emissions from the ISS.
4. Evaluate the effects of street cleaning on water runoff. This portion of work was performed in cooperation with the City of Bellevue, which studied the effect of street sweeping on urban water runoff quality (under contract with the Municipal Environmental Research Laboratory of the U.S. EPA). The results were reported by the City of Bellevue and are not included in this report.

Street Sweeper Descriptions

Street sweepers can be categorized into two major groups according to the mechanism that they use to pick up solids from the street. These two groups are broom sweepers and vacuum sweepers. The ISS is a vacuum sweeper with equipment added by A.P.T. for performance improvement. Brief descriptions of the four sweepers evaluated in this study are presented below.

Mobil and FMC Sweepers

Both the Mobil and the FMC sweepers are four-wheeled broom sweepers with similar features. They use rotating gutter brooms to move the dirt from the area near the curb to the area under the sweeper. From there, the dirt is swept onto a squeegee-type dirt elevator by a large, cylindrical, pickup broom that rotates about a horizontal shaft at the rear of the sweeper. The dirt elevator lifts the dirt into a collection hopper.

Tymco Sweeper

The Tymco model 600 sweeper is a vacuum sweeper which uses a regenerative air system to recirculate the air from vacuuming the street dirt. A gutter broom moves the street dirt from the curb toward the center of the sweeper. A blower forces air through a slot in the pickup head which rides on and seals against the street surface. The slot directs a high-velocity blast at the street surface, loosening the dirt. The dirt is then vacuumed up and is carried to a hopper through a vacuum hose. In the hopper, paper and leaves are removed from the air stream by a screen, and large particles are removed by a centrifugal separator. The air then enters the blower to complete the cycle.

A.P.T. Improved Street Sweeper

The ISS is the above Tymco sweeper with modifications to maximize the collection of fine particles. The modifications include:

1. Installing a partial hood around each gutter broom and venting the hood to the hopper.
2. Increasing the vacuum in the pickup head by venting about 1000 cfm (28,317 L/min) of air out of the regenerative air system.
3. Installing a scrubber to clean the vent air. The scrubber was originally a charged spray scrubber. It was changed in this study to a low pressure drop venturi scrubber because the spray scrubber was too small and had substantial water drop loss on the walls. In addition, the charged spray scrubber system was too complicated and its efficiency differed little from a regular spray scrubber because electrostatic augmentation only improves collection efficiency for particles smaller than 3 μmA diameter and there were not many particles smaller than 3 μmA diameter in the vent air stream.

Test Methods

Four sweeper performance parameters were measured in this study: the ability of a street sweeper to remove solids from a street surface, the relative dust dispersions of the ISS and the Tymco sweepers, and the mass rate and size-distribution of the ISS scrubber emissions. The measurement methods are summarized below.

Street Solids Removal

The ability of a street sweeper to remove solids from a street was determined by measuring the amount of street solids on the street before and after sweeping. Each test was performed on a test section of street that was from 160 to 320 m (0.1 to 0.2 mile) long. The width of each test section was from the street centerline to the curb, on only one side of the street. Each test involved only one sweeper, making one sweeping pass next to the curb.

Each street dust sample was taken by vacuuming 5 to 60 randomly selected 13.3 cm wide strips. Two types of samples were taken: half-of-street strips from the curb to the street centerline, and strips of the sweeping lane. The half-of-street samples were taken to express sweeper performance in terms of commonly used street sweeping practice; which is sweep the street by passing the sweeper once on one side of the street near the curb. Sweeper performance based on half-of-street samples may be penalized because part of the sampled area is not swept. The sweeping lane samples were taken to accurately determine the ability of a sweeper to remove the solids from its path.

The street dust sampler consisted of a triangular vacuum pickup head, two vacuum cleaners in parallel, and a cascade impactor sampling system. During sampling, the pickup head contacted the street and the leading edge was elevated manually 0.3 cm above the street surface to permit an adequate air flow and to collect the large solids. The dirt was collected in each vacuum cleaner canister, and the vacuum cleaner air was filtered by a pair of cloth filters in each canister. The canister sample was later sized by sieve analysis.

The particles smaller than 15 μmA diameter were sized with a cascade impactor sampling train. A sample probe was inserted into the vacuum hose of the vacuum cleaner, and an air sample was withdrawn isokinetically. The sample passed through a precutter to remove the particles larger than 15 to 20 μmA diameter and then through a University of Washington Mark III cascade impactor for size fractionation.

Dust Dispersion

The mass concentration of the dust dispersed by the Tymco and the ISS was determined with two glass-fiber filters mounted on the top of the pickup head at its leading edge. Since the total volume of the dust-laden air is not known, the measurement results are only an indication on the relative amount of dust dispersed by the Tymco sweeper and ISS.

ISS Scrubber Emission

The mass emission rate and the particle size distribution of the ISS scrubber exhaust were determined by sampling the scrubber outlet with a cascade impactor.

Results

Test Areas and Sweepers

In Bellevue, sweepers were tested at two areas: SE 30th St. (in a light-industrial area) and Surrey Downs (a residential neighborhood). The ISS, Tymco, and Mobil sweepers were tested at both areas.

In San Diego, tests were made at two areas: Mission Blvd. (in a commercial-residential-recreational area) and Morena Blvd. (in a commercial area). At Mission Blvd., the ISS, Tymco, Mobil, and FMC sweepers were tested. At Morena Blvd., the ISS, Tymco, and FMC sweepers were tested.

Distribution of Street Solids

Comparison of the initial half-of-street and sweeping lane samples revealed that 70 to 100% of the street solids were within the sweeping lane. The mass median diameters of the street solids were found to vary from 200 to 500 μm.

This distribution of street dust agrees with the measurement results reported by the city of Bellevue. The city of Bellevue measured the distribution of street solids on 110th Avenue SE. They found that: 45 to 55% of the solids were within 0.51 m of the curb, 75 to 80% were within 1.2 m of the curb, and 85 to 95% were within 2.4 m of the curb.

Street Sweeper Cleaning Performance

The street cleaning performance of a street sweeper cannot be expressed in terms of removal efficiency because the efficiency depends on the amount of solids on the street, the size distribution of the solids, and the street surface characteristics. Instead, the sweeper performance was evaluated based on plots of residual versus initial solids on the street. The effect of particle size on sweeper performance was determined from plots for various particle size ranges. To eliminate the effects of street surface characteristics on sweeper performance, each graph is for only one test site.

Figure 1 shows typical results for half-of-street samples of total street solids. Depending on initial street dust loading, the broom sweepers removed 0 to 40% of the solids, the Tymco, 30 to 55%, and the ISS, 30 to 60%. Therefore, based on half-of-street results, the Tymco was only slightly less effective than the ISS, but each was more effective than the broom sweeper.

Figure 2 shows typical results for sweeping lane samples of total street solids. It reveals larger differences in performance between the sweepers than the half-of-street graphs, because the solids of the unswept area were not included in the residuals. The broom sweepers removed about 5.0 to 45% of the solids and their sweeper curves usually have slopes of about 1. The Tymco removed about 50 to 75% of the solids, and its performance curve slopes are about 0.25. The ISS removed 50 to 85% of the solids and its curves have slopes of zero. This indicates that the ISS gave a constant residual level that was independent of the amount of initial street solids.

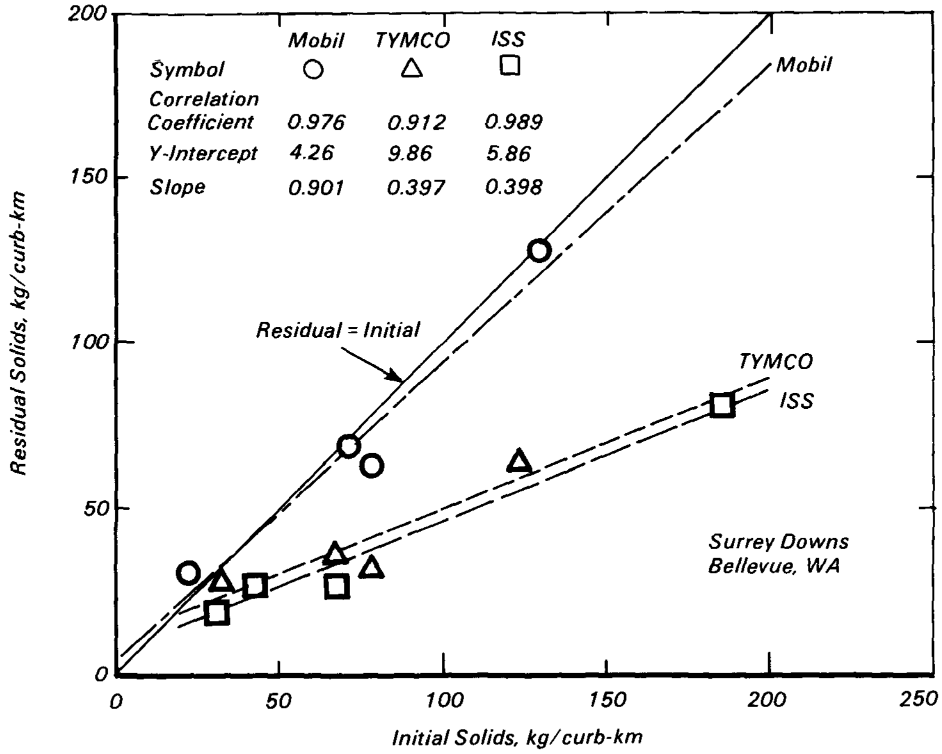

Figure 1. Total solids performance at Surrey Downs from half-of-street samples.

Results from sieve analysis showed that the broom sweepers were only effective in removing large particles (larger than 2,000 μm diameter). They were not effective in removing particles smaller than 125 μm diameter. In some cases, there were more small particles on the street after sweeping than before sweeping!

The performance difference between the Tymco and the ISS was not great for particles larger than 500 μm diameter. In half of the test site, the Tymco performed as well as the ISS. For solids with a diameter smaller than 500 μm, the Tymco did not pick up as much solids as the ISS (Figure 3). The curves of the Tymco have slopes from 0.2 to 0.5. The ISS has the best performance curves, with slopes of about zero.

Relative Dust Dispersed by Tymco and ISS

The mass concentrations of dust measured at the pickup head of the ISS and the Tymco were scattered. Therefore, it cannot be concluded that the ISS dispersed less dust during sweeping. However, based on visual observations, the ISS did have a smaller dust plume.

ISS Scrubber Emissions

The mass median diameter of the particles in the ISS scrubber exhaust was about 2 μmA, and 94% of the emissions were smaller than 10 μmA. The mass emission rate of the ISS scrubber is plotted against initial solids on the street which were smaller than 10 μmA in Figure 4. Depending on the amount of initial dust on the street, the emissions varied from 0.005 to 0.4 kg/curb-km, which corresponds to 2 to 40% of the initial street solids which were smaller than 10 μmA diameter. The average was about 10%.

The venturi scrubber was limited to a maximum pressure drop of 15 cm W.C. because of limitations of the existing fan on the sweeper. The scrubber emission could be lowered if this fan were replaced with a higher pressure drop fan.

Conclusions

The ISS was evaluated along with other conventional sweepers in Bellevue, Washington, and in San Diego, California. The results show that the ISS removes more street solids than the same sweeper without the improvements (and also better than broom sweepers). Typically, a broom sweeper removes 20% of the street solids, the Tymco sweeper, 70%, and the ISS, 80%. Additionally, the ISS was the only sweeper tested that gave a constant, low level of residual street solids that was independent of the initial amount of solids on the street. However, the residual level does depend on the street surface characteristics.

Based on visual observations, the ISS dispersed less dust during sweeping. However, the data from measurements of the dust concentration at the pickup head of the Tymco and the ISS were too scattered to allow statistical verification.

Recommendations

This evaluation shows that the ISS cleans streets better than conventional sweepers especially in the fine particle range. Its effects on ambient air quality have not been measured. To complete the evaluation of the ISS, the emission factors of the ISS and conventional sweepers need to be measured. This could be accomplished by sampling ambient air upwind and downwind of streets during and between sweepings. A fugitive emissions measurement program would reveal the contribution of fine particles into the air from street sweeping and how much this dust loading would be reduced using the design principles developed by A.P.T.

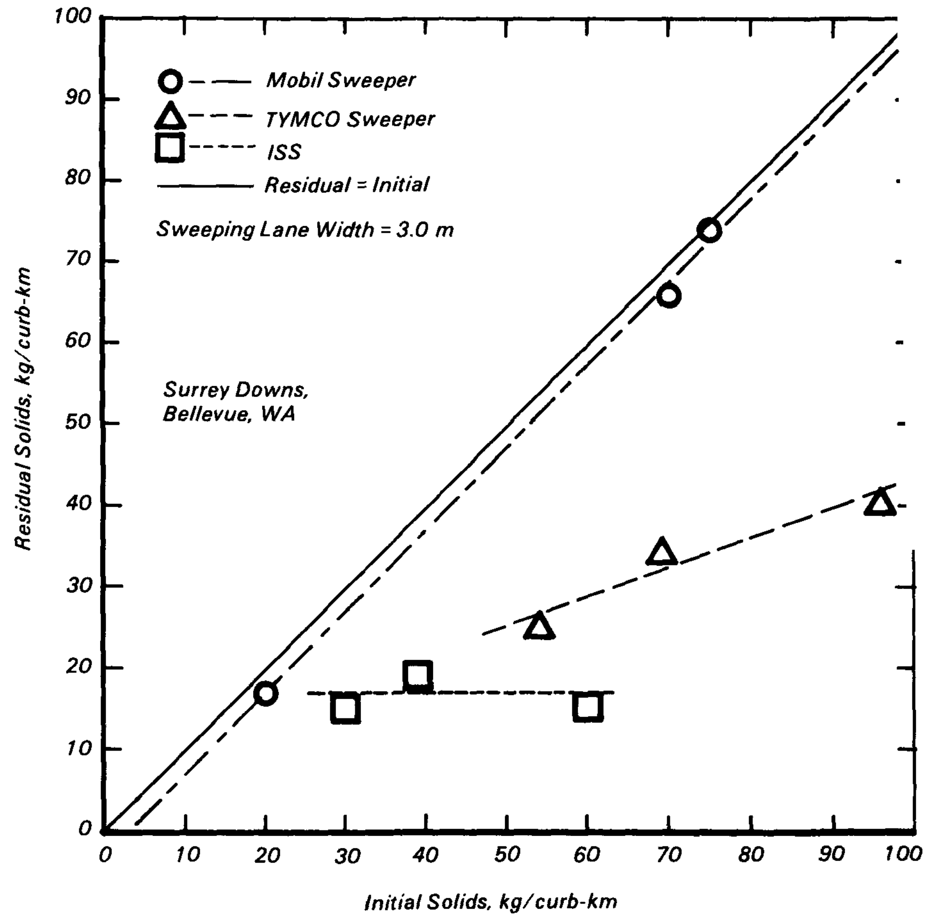

Figure 2. Total solids performance at Surrey Downs from sweeping lane samples.

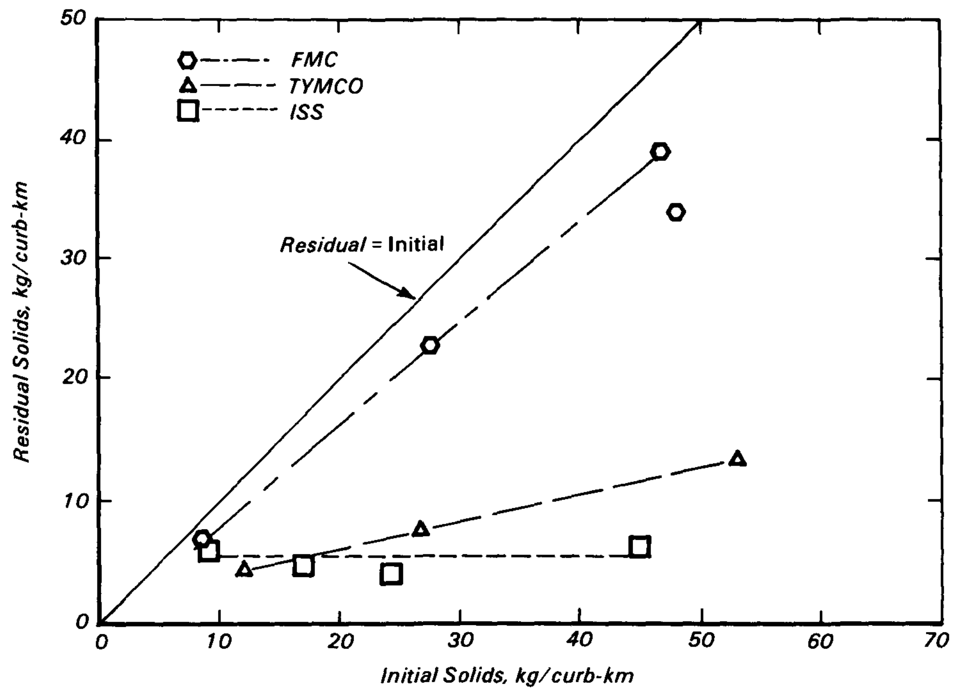

Figure 3. Performance on 63 to 500 μm sweeping lane samples at Morena Blvd.

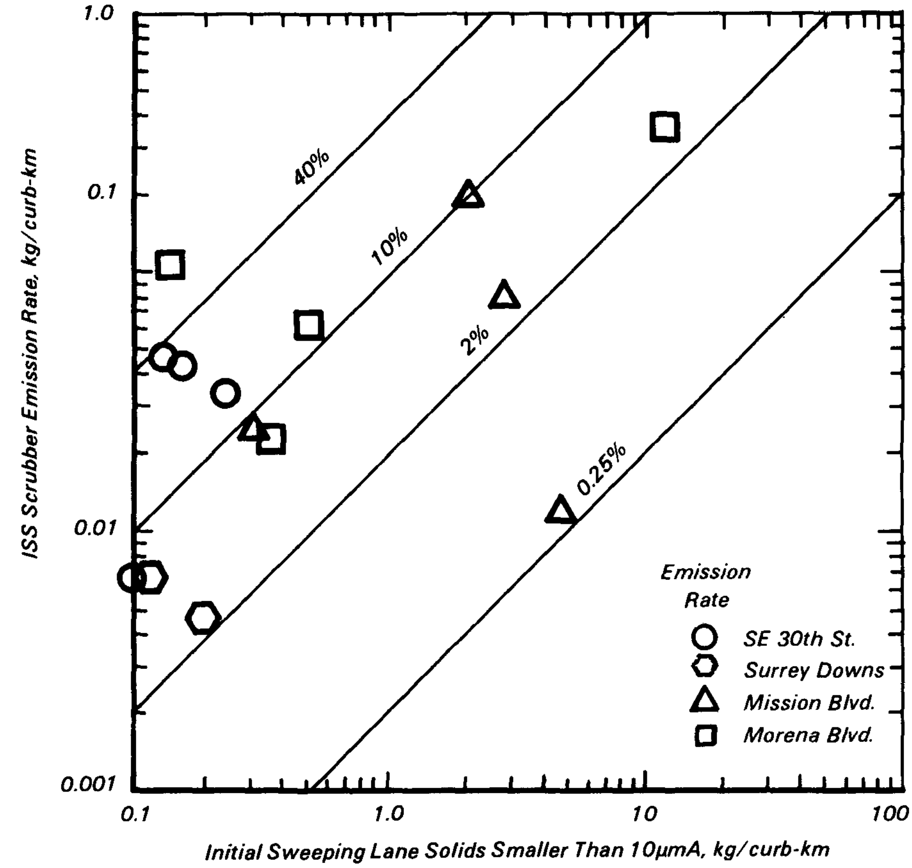

Figure 4. *ISS scrubber emissions.*

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The complete report, entitled "Performance Evaluation of an Improved Street Sweeper," (Order No. PB 85-169 845/AS; Cost: $20.50, subject to change) will be available only from:
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