

The Houston Aerosol Can Recycling Evaluation

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The Steel Recycling Institute (SRI) is an industry association dedicated to promoting and sustaining steel can recycling. Supported by six domestic and two Canadian steel companies and the American Iron and Steel Institute (AISI), SRI has fostered the nationwide growth of steel can recycling. Through its seven regional recycling managers, SRI offers assistance to communities and recyclers to ensure that steel can recycling is implemented in their programs.

For the past four years, SRI's efforts have focused on building the steel can recycling infrastructure. Initially concentrating on steel food and beverage cans, SRI has achieved a 1992 steel can recycling rate of 40.9%.

In the last two years, the recycling focus has broadened to encompass steel general purpose cans, which include paint and aerosol cans. These containers comprise more than 10% of the total steel can population. When they are recycled, more materials are diverted from the landfill and additional steel scrap is made available to the steel industry.

SRI recommends that residential empty paint and aerosol cans be recycled along with food and beverage cans in curbside and voluntary drop-off programs. SRI also recommends that aggregate quantities of full or partially full paint and aerosol cans be processed appropriately so that the scrap steel can be recovered. The seven re-

gional managers have been meeting with local recycling officials, curbside operators and recycling processors throughout the United States to secure their participation in this new and highly positive initiative. Many questions were asked and answers given before commitments were obtained. Progress was slow at first because there were few peer referrals available. This has changed over the last year as more and more communities enhance their recycling programs by adding empty paint and aerosol cans to the mix.

Amid the earliest of these initiatives was the Houston, Texas curbside recycling program, which unexpectedly required an aerosol can recycling evaluation. This article provides an overview of the Texas steel aerosol can recycling program final report submitted to the Texas Water Commission (TWC). The report was approved by the TWC on December 21, 1992. The issues, findings and conclusions of the report strongly support the advocacy of recycling empty steel aerosol cans together with steel food, beverage and empty paint cans.

THE HOUSTON AEROSOL CAN RECYCLING EVALUATION

Early in January 1991, the Steel Recycling Institute (SRI) and the city of Houston reached an agreement to begin accepting empty steel aerosol cans as part of the city's curbside recycling program. Collection would begin in April 1991. The motivation for including aerosol cans

was threefold:

1. Prevent them from being landfilled, thus saving landfill space and achieving a cost avoidance.

2. Reduce the cost and increase the effectiveness of household hazardous waste collection and disposal by eliminating empty containers from unnecessary and inappropriate inclusion.

3. Increase the flow of steel can scrap to the steel industry for recycling.

The implementation of the program was postponed after questions were raised as to whether or not the empty aerosol cans should be treated as a hazardous waste under Texas Water Commission (TWC) and Texas Administrative Code (TAC) regulations.

An operations plan was prepared by SRI and approved by the TWC and the City of Houston. It was to evaluate a sample of steel aerosol cans collected on each Tuesday through the city's

curbside recycling program over a period of six weeks. The purpose of the evaluation was to demonstrate the desirability of recycling steel aerosol cans in a curbside recycling program as well as to validate the absence of potential safety issues involved in collection and processing.

The operations plan provided an initial public education program to advise residents of the preparation instructions for recycling empty steel aerosol cans. The city would collect aerosol cans along with the other recyclables and

take them to the municipality's Post Oak Intermediate Processing Facility. Aerosol cans collected on Tuesdays were separated from the other



steel cans for evaluation. Those aerosol cans collected for recycling on Mondays, Thursdays and Fridays were routinely processed with other steel food and beverage cans and shipped to a local scrap dealer for sale to the steel industry.

The evaluation process provided that the aerosol cans be numbered, coded by product type, weighed and emptied. Through a series of measurements, three residual levels were determined: the product residual, the propellant residual and the combined residual. The collection and evaluation began on August 4, 1992 and concluded on September 8, 1992.

PARTICIPANTS

The curbside aerosol can evaluation was conducted by Dr. Kenneth Vos, Vice President of Palmer of Houston. Dr. Vos spent 19 years as a chemist with S.C. Johnson Wax, for which he was Director of Research and Development. He served on the Board of Directors of the Chemical Specialties Manufacturers Association and served as the Vice Chair for their Aerosol Division. Dr. Vos has served on the Scientific Affairs Committee of the Cosmetic, Toiletries and Fragrance Association. He also holds several patents in the aerosol industry.

The statistical analysis of the evaluation data was conducted by Dr. Joe Ensor, a partner in Empirical Science, a consulting firm in Houston. Dr. Ensor received his B.S. and M.S. in Mathematics from Arkansas State University and his Ph.D. in Statistics from Texas A&M University in 1989. He has served as a Visiting Teaching Professor at Rice University as well as the University of Houston. Most recently, he served as an Assistant Epidemiologist, Department of Patient Studies at the University of Texas M. D. Anderson Cancer Center in Houston.

EVALUATION AND ANALYSIS

A total of 1,722 aerosol cans were evaluated from cans collected on Tuesdays. During this period, as many as 5,000 additional aerosol cans were routinely collected on Mondays, Thursdays and Fridays. They were not evaluated, but, as mentioned above, were shipped with other steel food and bev-

erage cans to a local scrap dealer.

The table below is the evaluation and analysis of residual amounts in the aerosol cans collected on Tuesdays. They are shown by product code (right).

The mean combined residual of product and propellant is 2.69%, well below the 3% established by the 40 Code of Federal Regulations, §261.7(b)(1)(iii)(A).

The credibility of the 2.69% is firmly established by the statistical procedure of the "standard error." The "standard error" provides a level of confidence that if the total population of curbside aerosol cans could have been tested at once, the results would be similar. Using two "standard errors," it is statistically established that the level of confidence is 97.75% that if all curbside aerosol cans could have been tested at once, the true mean combined residual would not be more than 2.95%.

When reviewing the standard deviation of 5.49%, it is observed that the data points are fairly spread out, suggesting that an examination of the median might provide a better estimate of the data than the mean. The median combined residual, or center point of the data, is 1.18%. This means that half of the data has a mean combined residual below 1.18%, while the other half is greater. The significance of this is amplified when the top 2% and 5% of the combined residuals are trimmed or isolated from the sample. Trimming the top 2% and 5% removes those cans that are not representative of the empty can population and would be considered statistical anomalies. The trimmed data reinforces that very

100 INSECT SPRAYS

- 101 Space insecticides
- 102 Residual insecticides (personal and surface repellents, moth proofers, etc.)

200 PAINTS AND VARNISHES

- 201 Paints, primers and varnishes
- 202 Other related products (strippers, graffiti removers, snow and other decorative products)

300 HOUSEHOLD PRODUCTS

- 301 Room deodorants and disinfectants
- 302 Cleaners (glass, oven, rug, fabric, wall and tile, etc.)
- 303 Laundry products (starch, fabric finish, prewash, etc.)
- 304 Waxes and polishes
- 305 Other household products (shoe polishes, dyes, leather dressings, fuels, drain openers, anti-stats, caulking and sealing compounds)

400 PERSONAL PRODUCTS

- 401 Shaving lather
- 402 Hair sprays
- 403 Other hair products
- 404 Medicinals and pharmaceuticals (vaporizers, fungicides, burn treatments, antiseptics, contraceptives, etc.)
- 405 Colognes, perfume, etc. and aftershave
- 405 Personal deodorants, antiperspirants, powders and deodorant colognes
- 406 Other personal products (suntan preparations, lotions, breath fresheners)

500 ANIMAL PRODUCTS

- 501 Veterinarian and pet products (shampoos, insecticides, repellents, etc.)

600 AUTOMOTIVE, INDUSTRIAL AND MISC. HOUSEHOLD LUBES

- 601 Refrigerants
- 602 Windshield and lock spray de-icers
- 603 Cleaners (auto upholstery, leather, vinyl, tire etc.)
- 604 Lubricant degreasers
- 605 Lubricants and silicones (penetrating oils, demisterizers, rust proofing)
- 606 Spray undercoating
- 607 Tire inflator and sealants
- 608 Carburetor and choke cleaners
- 609 Brake cleaners
- 610 Engine starting fluid
- 611 Other automotive and industrial products (adhesives, etc.)

700 FOOD PRODUCTS

- 701 All types (including pan sprays)

800 MISCELLANEOUS

- 801 Other products not listed above

PRODUCT CAN CODE*	TOTAL NUMBER OF CANS COLLECTED	MEAN COMBINED RESIDUAL—PERCENT**	MEDIAN COMBINED RESIDUAL—PERCENT**
100	252	2.48%	1.18%
200	161	4.56%	2.06%
300	642	2.52%	1.28%
400	297	3.59%	1.57%
500	6	2.79%	.77%
600	268	1.20%	0.00%
700	72	3.09%	2.02%
800	24	1.21%	.85%
TOTALS	1,722	2.69%	1.18%

*See list, above right, for product types by CSMA can code.

**Includes product and propellant residuals.

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few cans appear as full or partially full, while the normal condition is empty or nearly empty. It is a truly rare occasion that a full or partially full can appear in the collection, and such cans were demonstrated as being safely processed without incident within the mix of all steel cans. See

Figure 5.

When the results on the mean, median and standard deviation are examined with the top 2% and 5% trimmed, the extent to which they are affected by a few, non-representative cans with high combined residual levels becomes clear. The median re-

mains largely unchanged, but the mean changes noticeably. This suggests that the sample contains a very few cans with an unusually large amount of residual which is not characteristic of the vast majority of cans.

Two other important points should be considered beyond just the statistical data presented. The first is the fact that the collection and evaluation of the aerosol cans began within two weeks of the distribution of the public education information, providing consumers little time to be seen in the week to week mean combined residuals. Secondly, during the last three weeks, a marked and consistent reduction in the mean can be seen. In other words, it would appear that residents began to respond to the instructions requiring the aerosol cans to be empty. Even without further reduction, the typical aerosol can is virtually empty.

The city of Houston collected the commingled curbside recyclables from the individual residences and brought them to the Post Oak Inter-

FIGURE 1

Aerosol Can Data Collection Log

Inspection Date: 8/4/92
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Aerosol Can Code	Net Product Weight (oz.)	Gross Can Weight (oz.)	Intermediate Weight (oz.)	Final Weight (oz.)	Residual Weight (oz.)
304	1402	1029	1029	99	
301	1802	1472	1442	140	
301	1202	1302	1292	4	
301	1202	992	972	95	
304	702	658	652	62	
301	1202	678	668	63	
305	1602	992	982	94	
301	1502	1202	1162	111	
301	1202	1282	1282	100	
302	1002	952	952	92	
302	21.2502	1522	1482	137	
304	12.502	932	932	90	
301	1602	672	672	64	
301	1202	972	9102	93	
305	1102	1102	1082	103	
302	702	712	702	65	
303					
301					
303					
302					
301					
302					
305					
304					
304					



FIGURE 2

8/25 Aerosol Excel by code

Houston Aerosol Residuals - Week Of August 25, 1992

		Net		Gross		Propellant			Intermediate		Product			Final		Combined			Residual	
Can	Can	Product		Can		Residual			Can		Residual			Can		Residual			By Can	
Code	Number	Weight		Weight		Weight			Weight		Weight			Weight		Weight			Code	
		Grams	Ounces	Grams	Ounces	Grams	Ounces	%	Grams	Ounces	Grams	Ounces	%	Grams	Ounces	Grams	Ounces	%		
						(E-J)	(F-K)	(E-J)/C			(J-O)	(K-P)	(J-O)/C			(E-O)	(F-P)	(E-O)/C		
101	187	170	6	66	2.33	1.00	0.04	0.59%	65	2.29	1.00	0.04	0.59%	64	2.26	2	0.07	1.18%		
101	188	170	6	80	2.82	11.00	0.39	6.47%	69	2.43	1.00	0.04	0.59%	68	2.40	12	0.42	7.05%		
101	189	170	6	74	2.61	0.00	0.00	0.00%	74	2.61	1.00	0.04	0.59%	73	2.57	1	0.04	0.59%		
101	192	170	6	209	7.37	2.00	0.07	1.18%	207	7.30	1.00	0.04	0.59%	206	7.27	3	0.11	1.76%		
101	193	170	6	69	2.43	0.00	0.00	0.00%	69	2.43	2.00	0.07	1.18%	67	2.36	2	0.07	1.18%		
101	198	340	12	108	3.81	8.00	0.28	2.35%	100	3.53	1.00	0.04	0.29%	99	3.49	9	0.32	2.65%		
101	111	624	22	115	4.06	8.00	0.28	1.28%	107	3.77	0.00	0.00	0.00%	107	3.77	8	0.28	1.28%		
101	170	454	16	112	3.95	0.00	0.00	0.00%	112	3.95	11.00	0.39	2.43%	101	3.56	11	0.39	2.43%		
101	178	454	16	110	3.88	3.00	0.11	0.66%	107	3.77	1.00	0.04	0.22%	106	3.74	4	0.14	0.88%		
101	182	142	5	74	2.61	4.00	0.14	2.82%	70	2.47	2.00	0.07	1.41%	68	2.40	6	0.21	4.23%		
101	183	142	5	76	2.68	7.00	0.25	4.94%	69	2.43	1.00	0.04	0.71%	68	2.40	8	0.28	5.64%		
101	184	142	5	70	2.47	2.00	0.07	1.41%	68	2.40	0.00	0.00	0.00%	68	2.40	2	0.07	1.41%		
101	185	142	5	73	2.57	1.00	0.04	0.71%	72	2.54	16.00	0.56	11.29%	56	1.98	17	0.60	11.99%		
101	190	170	6	58	2.05	0.00	0.00	0.00%	58	2.05	2.00	0.07	1.18%	56	1.98	2	0.07	1.18%		
101	191	170	6	58	2.05	0.00	0.00	0.00%	58	2.05	2.00	0.07	1.18%	56	1.98	2	0.07	1.18%		
101	194	170	6	59	2.08	0.00	0.00	0.00%	59	2.08	2.00	0.07	1.18%	57	2.01	2	0.07	1.18%		
101	195	170	6	61	2.15	1.00	0.04	0.59%	60	2.12	4.00	0.14	2.35%	56	1.98	5	0.18	2.94%		
101	196	170	6	60	2.12	1.00	0.04	0.59%	59	2.08	1.00	0.04	0.59%	58	2.05	2	0.07	1.18%		
101	197	170	6	62	2.19	1.00	0.04	0.59%	61	2.15	1.00	0.04	0.59%	60	2.12	2	0.07	1.18%		
101	199	170	6	58	2.05	0.00	0.00	0.00%	58	2.05	2.00	0.07	1.18%	56	1.98	2	0.07	1.18%		
101	200	170	6	56	1.98	0.00	0.00	0.00%	56	1.98	2.00	0.07	1.18%	54	1.90	2	0.07	1.18%		
101	201	326	12	81	2.86	0.00	0.00	0.00%	81	2.86	13.00	0.46	3.99%	68	2.40	13	0.46	3.99%	2.61%	
102	113	425	15	298	10.51	5.00	0.18	1.18%	293	10.34	183.00	6.46	43.03%	110	3.88	188	6.63	44.21%		
102	114	425	15	121	4.27	3.00	0.11	0.71%	118	4.16	7.00	0.25	1.65%	111	3.92	10	0.35	2.35%		
102	115	425	15	140	4.94	7.00	0.25	1.65%	133	4.69	0.00	0.00	0.00%	133	4.69	7	0.25	1.65%		
102	116	454	16	123	4.34	7.00	0.25	1.54%	116	4.09	4.00	0.14	0.88%	112	3.95	11	0.39	2.43%		

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mediate Processing Facility (IPF). Among the recyclables collected were steel food and beverage cans as well as the emptied aerosol cans.

After unloading at the IPF, the steel and aluminum cans were run through a conveyor system with a magnetic head pulley at one end. The magnet pulled off all the steel cans and dropped them into bins under the conveyor. After they were magnetically separated, several employees removed the aerosol cans from the other steel cans collected on Tuesdays. The aerosol cans were placed into separate bins for transport to Palmer of Houston for evaluation. All aerosol cans collected, regardless of condition, were sent for evaluation.

The aerosol cans collected and separated from the other steel cans on Tuesdays were transported to Palmer of Houston by city personnel. The cans then underwent a seven step process to determine the residual levels. This process is outlined as follows:

1. Each can was individually numbered.
2. The net product weight as printed on the can was recorded.
3. The aerosol can was weighed to determine a gross weight of the can and its contents.
4. A small hole was punctured in the dome of the can to allow any remaining propellant to escape.
5. The can was weighed again to determine an intermediate weight.
6. The top of the can was removed and the contents emptied.
7. The can was weighed again to determine the final weight.

A sample data collection sheet is shown as Figure 1. Data were entered into a spreadsheet program in order to calculate the following information. A sample data spreadsheet is shown as Figure 2.

Propellant Residual Weight was determined by subtracting the intermediate weight from the gross weight.

Product Residual Weight was determined by subtracting the final can weight from the intermediate can weight.

Combined Residual Weight was determined by subtracting the final can weight from the gross weight and dividing this difference by the net product weight as printed on the can.

This process was continued for the six week evaluation on a week to week basis. At the conclusion of each weekly

FIGURE 3 Percent Combined Residual

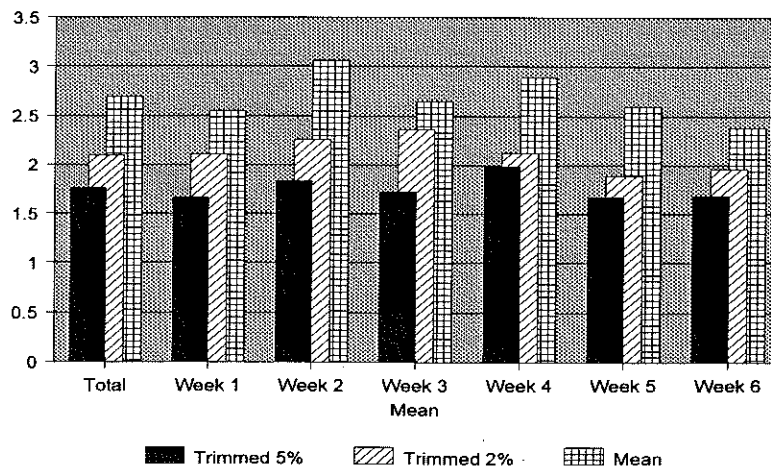
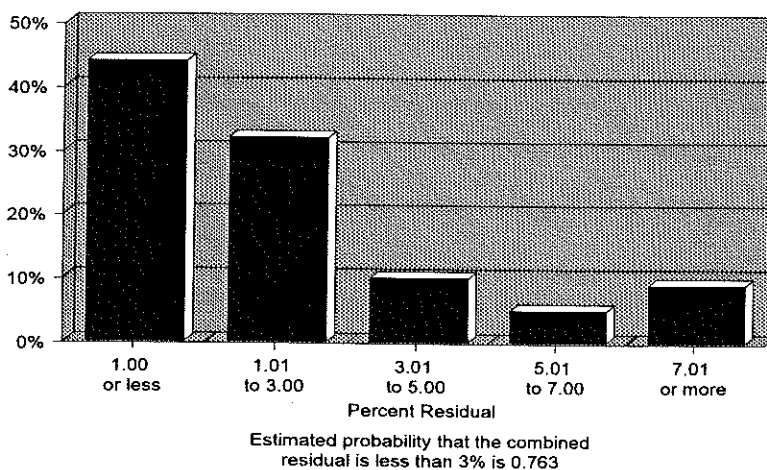


FIGURE 5: COMBINED RESIDUAL

MEAN	2.69%	MEDIAN	1.18%	STD.DEV.	5.49%
TRIMMED 2%	2.10%	TRIMMED 2%	1.18%	TRIMMED 2%	2.71%
TRIMMED 5%	1.76%	TRIMMED 5%	1.13%	TRIMMED 5%	1.99%

FIGURE 4

Percent Combined Residual
Mean = 2.69, Median = 1.2



evaluation, the data were entered into the spreadsheet computer program. After the results of the sixth week were entered, the total compilation of data was presented to Dr. Ensor for statistical evaluation. His statistical analysis and discussion appear in the sidebar. The percent combined residual mean is presented graphically as Figure 3, demonstrating the 2.69 percent mean. The percent combined residual percentage is also presented

graphically (Figure 4), showing that about 78% of all aerosol cans collected and evaluated were very empty, with 3% or less residual.

As noted earlier, in addition to the evaluation of the 1,722 cans collected on Tuesdays, as many as 5,000 aerosol cans were collected on Mondays, Thursdays and Fridays along with other steel food and beverage cans and were sent without incident to a local scrap dealer for processing and shipment to the steel industry.

TRIMMED ANALYSIS OF COMBINED RESIDUAL

If you are of a mathematical bent, here's how the analysis of the data works. Trimming the top 2% or 5% (see Figure 3) of the percentage of combined residual has an enormous effect on the mean (the arithmetic mean or average of a population is simply the sum of the measurements divided by the number of

measurements). To illustrate the large amount of skewness in the data, compare the standard deviation of the raw data and the top 2% trimmed data. The standard deviation is reduced by 50% (5.49 vs. 2.71). If one compares the median of the different methods, one sees almost no change even between the raw data and the top 5% trimmed data. Since the mean is greatly affected by extremely

large (or small) observations and the median is not, the median is preferred in locating the center of skewed distributions (i.e., distributions that are asymmetric and tail off rapidly to the right or left). This mandates using the median to measure the center of the distribution of percentage of combined residual because the median measures the point in the data in which exactly half of the ranked data lies below and half

above. The estimated mean of the percentage of combined residual is 2.69%. This estimate plus twice the standard error,

$$2.69 + 2 \frac{5.49}{\sqrt{1722}} = 2.95$$

does not exceed the 3% level.

When the standard deviation of a statistic is estimated from the data, the result is called the standard error of the statistic. One realizes that 2.69% is only a point estimate of the true mean percentage of combined residual; that is, it is only an unbiased estimate of the true mean percentage of combined residual.

Large sample theory of statistics tells us that the probability that the true mean is actually more than two standard errors above the point estimate is only 0.025. Hence, there is only a very small chance that the true mean residual is 3% or more.

TRIMMED ANALYSIS OF COMBINED RESIDUAL

	TOTAL	WEEK1	WEEK2	WEEK3	WEEK4	WEEK5	WEEK6
MEAN	2.69	2.55	3.06	2.65	2.89	2.60	2.38
TRIMMED 2%	2.10	2.11	2.26	2.36	2.13	1.89	1.96
TRIMMED 5%	1.76	1.66	1.83	1.72	1.99	1.67	1.68
MEDIAN	1.18	1.18	1.18	1.18	1.47	1.16	1.13
TRIMMED 2%	1.18	1.13	1.18	1.16	1.44	1.10	1.12
TRIMMED 5%	1.13	1.10	1.12	1.12	1.44	1.06	1.04
ST. DEV.	5.49	4.32	5.98	4.09	6.46	5.62	5.26
TRIMMED 2%	2.71	2.89	2.96	3.30	2.15	2.46	2.60
TRIMMED 5%	1.99	1.66	2.10	2.16	1.85	1.92	2.00

CONCLUSIONS

The mean combined residual falls well below the 3% specified by 40 CFR §261.7(b)(1)(iii)(A). It has been shown that if all curbside aerosol cans could have been taken for evaluation at once, there would be a 97.75% confidence that the true mean would also fall below 3%.

Additional statistical evaluation shows that the data are closely distributed around a median combined residual of 1.18% and have a mean of 2.69% with only a few cans over 3%. It has been demonstrated that collection and processing has occurred without incident fulfilling the objectives of the operations plan. Thus, it was recommended to the TWC and subsequently approved that steel aerosol cans be recycled.

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