Office of Science
Research Project Summary
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The Contribution of Dust Particles from St. Lawrence Cement to Outdoor Dust in the Surrounding Waterfront-South Community in Camden, New Jersey

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Abstract

In response to community concerns about dusty conditions in the Waterfront South area of Camden, NJ, and specific concerns that the nearby St. Lawrence/Holcim facility was a major contributor to these conditions, a study was undertaken to examine the contribution of that facility to dust deposition in the Waterfront South area. A composite sample of material was collected from the exposed piles at the facility and outdoor dust deposition and surface wipe samples were collected at multiple locations during two periods for a total of 52 days within a distance of 800 m of the facility as well as at a control location 2 km from the facility. Dust mass was examined as a function of distance from the facility, and the source material from the facility was compared to the community dust samples on the basis of elemental concentration (particularly calcium) and elemental ratios. In addition, a chemical mass-balance model was created that attempted to account for the elemental signature of the source material from the facility against the background of elemental occurrence in urban dust. Also, facility-wide deposition modeling was conducted using operations data supplied by the facility. Several independent lines of evidence point to a contribution from the facility of 2-13% with a most likely contribution in the range of 2-8% of the total dust material in the community at a distance of up to about 0.5 km. Unusual wind conditions could increase this contribution in the short-term. Both stack and fugitive emissions contribute to the facility's overall dust emissions. However, fugitive emissions appear to be the larger source. This study was specifically focused on identifying the extant to which the St. Lawrence/Holcim facility contributed to the dust deposition in Waterfront South. It did not attempt to identify other contribution to the dust deposition. However, from other studies in the scientific literature in other locations, it appears that soil, and automotive use and wear (including tire wear) are major sources of urban dust.

Introduction

The residents of the Waterfront-South community in Camden, New Jersey, have, over time, expressed concerns about the perceived dustiness of their outdoor environment. They cited anecdotal evidence that the nearby St. Lawrence/Holcim facility is a major contributor to that condition. The St. Lawrence/Holcim facility processes steel production slag into recycled raw material for cement manufacture by grinding. In order to address residents' concerns and to determine the extent to which on-site material contributes to the overall outdoor dust burden in this community, the Environmental and Occupational Health Science Institute (EOHSI) of Rutgers/UMDNJ undertook a study, in collaboration with the New Jersey Department of Environmental Protection (NJDEP) with the goal of determining the specific contribution of stored recycled material dust in Waterfront-South.

Methods

Community dust sample collection

Since small particles (<10μm) can be transported long distances in air, settled dust in the residential area relatively close to the facility will largely consist of "coarse" particles with a diameter of 10-2,000 μm. Based on particulate transport modeling and meteorological data, it was estimated that particles in this size range would deposit within 800 m of the facility. Given prevailing wind direction, this distance indicates the potential for impact on the Waterfront-South community. Two types of outdoor dust samples were collected. Wipe samples were collected from 15 separate outdoor surfaces including a control location (Gloucester City Park, located 2.2 km from the facility). Dry deposition samples were collected onto filters using a wind/rain protected passive sampler. For the deposition samples, secure sampling locations were identified within

Waterfront-South area and at the control location. Deposition sample collection at these locations was conducted over 31 days in two periods, 7/5-26 and 8/17-9/17/2007). The number of deposition sampling locations varied from 10-12 between the two periods.

Source dust collection

Three samples were collected at a height of ~2 m at different locations from the pile of raw material within the plant. These samples were composited. Given site access limitations, sampling was conducted on a single day.

Table 1. Enrichment factors and Ca/Fe ratios for the deposited dust, surface dust, and source material samples

Element	Source Material	Deposited Dust				Surface Dust			
		Sampling Sites (< 0.66 km)		Background (> 2.0 km)		Sampling Sites (< 0.5 km)		Background (> 2.0 km)	
	Mean	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Al	1.02	0.86	0.67 – 1.37	0.84	0.75 – 0.94	1.62	0.43 – 7.97	1.21	0.69 – 1.72
Ba	5.10	7.24	4.27 – 10.5	5.56	4.63 – 6.48	28.0	1.43 – 143	4.02	3.48 – 4.57
Ca	36.4	9.23	7.07 – 12.2	8.02	7.18 – 8.86	5.76	0.95 – 21.2	1.18	0.09 – 2.26
Co	0.17	2.71	1.00 – 6.32	2.73	2.57 – 2.89	4.76	2.35 – 25.3	2.37	1.83 – 2.91
Cr	1.47	12.3	3.21 – 62.9	7.19	6.74 – 7.63	13.5	4.29 – 56.6	11.6	8.82 – 14.3
Cu	4.63	26.5	12.0 – 41.4	29.6	23.6 – 35.5	27.3	4.79 – 62.0	26.2	14.7 – 37.6
Fe	0.68	3.86	2.02 – 9.09	3.43	3.07 – 3.78	8.30	1.66 – 29.5	4.94	2.88 – 7.00
Ga	4.43	4.22	2.28 – 7.43	4.62	3.86 – 5.38	29.1	2.08 – 145	4.96	3.82 – 6.09
Li	3.35	3.77	2.45 – 6.05	3.94	3.80 – 4.08	5.15	1.16 – 16.0	3.98	2.42 – 5.53
Mg	3.06	3.64	2.49 – 6.01	4.78	4.44 – 5.11	2.96	1.46 – 6.45	1.68	1.37 – 1.98
Mn	4.04	4.20	3.11 – 7.57	3.58	2.99 – 4.17	2.97	0.67 – 4.34	2.09	1.51 – 2.67
Ni	0.34	7.48	3.28 – 18.8	6.93	6.35 – 7.52	6.33	1.27 – 17.8	6.09	4.60 – 7.59
Pb	3.31	224	101 – 375	144	111 – 176	538	67.8 – 2,860	143	114 – 173
Rb	0.15	0.90	0.57 – 1.37	1.42	1.39 – 1.46	1.03	0.28 – 2.21	1.38	0.80 – 1.95
Si	0.00	0.00	NA	0.00	NA	0.00	NA	0.00	NA
Sr	6.87	2.80	2.10 – 3.70	2.30	1.83 – 2.77	1.68	0.27 – 3.79	0.87	0.84 – 0.90
Ti	1.00	1.00	NA	1.00	NA	1.00	NA	1.00	NA
V	0.34	2.66	1.63 – 4.29	5.74	4.97 – 6.51	3.37	1.10 – 9.43	4.70	3.85 – 5.54
Zn	9.25	287	135 – 733	421	377 – 465	1145	22.1 – 13,935	91.4	56.7 – 126
Ca/Fe	38.7	2.00	0.89 – 3.00	1.70	1.70 – 1.70	0.58	0.10 – 1.89	0.44	0.32 – 0.57

Sample analysis

The mass of collected dust was determined and samples were analyzed for elemental content by inductively coupled mass spectrometry (ICPMS). Morphological analysis of selected samples was conducted by light microscopy.

Data analysis

Several approaches were investigated for providing information about the contribution of the facility to the outdoor dust.

Dust mass vs. distance - The relationship between distance from the facility and total dust mass in outdoor samples was determined based on the simple mass of total dust collected.

Concentration vs. distance - Since calcium (Ca) is the most abundant element in the source dust, the concentration of Ca in the outside dust was examined as a function of distance from the facility.

Elemental ratio - Since iron (Fe) is ubiquitous at relatively high concentration in soil dust, but not in the source material, the concentration vs. distance relationship for Ca was also examined relative to the Fe concentration in the outdoor dust samples.

Enrichment factor (EF) - This approach calculates the relative abundance of an individual element in a dust sample (i.e., the outdoor dust) compared to the abundance of that element in a crustal material that is assumed to represent the source of ubiquitous background dust. Both the sample concentration and the reference concentration of the element in question are normalized to a reference element that has a low abundance in the sample material. An EF>5 is generally considered to indicate a local source. In this case, titanium (Ti) was selected as the reference element.

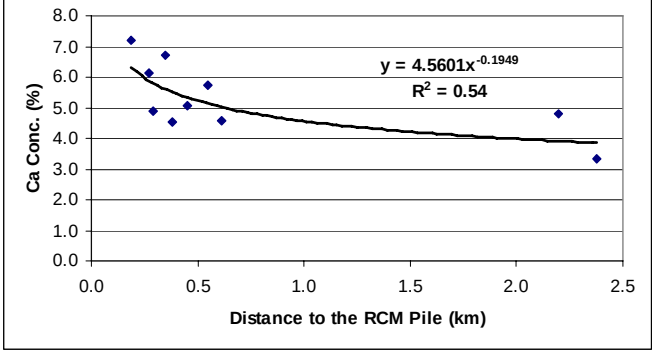
Chemical mass-balance model - This approach used the USEPA Chemical Mass Balance (CMB) model to simultaneously estimate the contribution of various urban background sources (crustal rock, marine aerosol and anthropogenic sources such automobile exhaust, stationary combustion,) and the concrete/cement source material to an integrated linear sum of 19 elements in the outdoor dust samples. The percent contribution of the concrete/cement source material is estimated by dividing the contribution of the source material by the contribution from the total modeled sources.

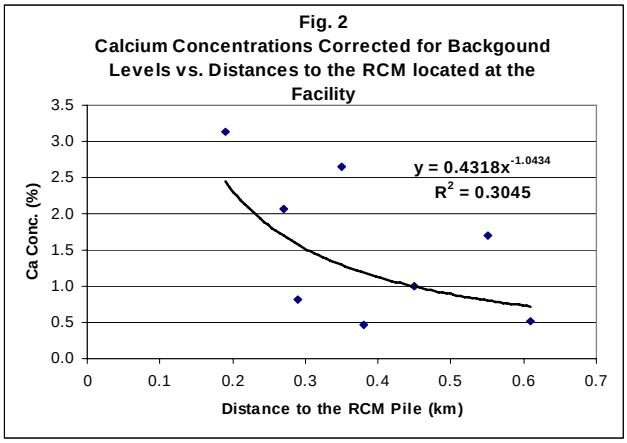
Deposition modeling based on facility - wide emissions data using the USEPA ISCST3 model - Using emissions data supplied by the facility for permitting purposes, the deposition flux at various distances from the facility was estimated for total suspended particulates (TSP) based on modeled air concentration and settling velocity.

Results

Dust mass vs. distance – For the deposition samples, the mass of dust generally decreased with distances from the facility (r_s = -0.7697; p = 0.0069), suggesting an impact of the dust emitted from the Cement Facility to outdoor dust. No such relationship, however, was observed for the surface wipe samples. This likely reflects the fact that surface wipe samples were subject to rain and wind whereas the deposition samples were specifically protected from these factors. Therefore, the analysis focused on the deposition sample results rather than the surface wipe results.

Fig. 1
Calcium Concentrations vs. Distances to the RCM located at the Facility



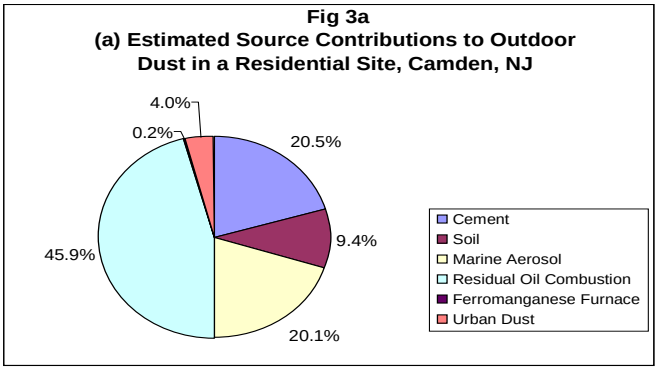


Calcium (Ca) concentration vs. distance - Ca was, by far, the most abundant element in the source material accounting for 30% of the material. Ca, along with Fe, was also one of the most abundant elements in the dust samples. Only Ca showed a significant negative relationship with distance from the source material. That is, Ca concentration in the dust decreased with increasing distance from the site. This provides evidence that Ca is a marker for dust deposition from the facility. Figure 1 shows the Ca concentration in the dust as a function of distance from the facility piles. Figure 2 shows the same data minus the Ca concentration in the background samples. The data presented in Fig. 2 can provide an estimate of the contribution of the source material to the overall dust in the Because of the distance of the background locations from the facility and their orientation away from the average downwind direction relative to the facility, the concentration of Ca in the background samples is unlikely to be significantly influenced by the facility. Therefore, the Ca in the dust deposited in the background locations represents the Ca that is ubiquitous in the area. The measured Ca concentration in the dust in Waterfront South, corrected for background Ca was modeled to estimate the Ca concentration in the dust as a function of distance from the facility. This estimate was then divided by the concentration of Ca in the source material from the facility to give an estimate of the contribution of the facility to the dust in Waterfront South as a function of the distance from the facility. Using this approach, the facility is estimated to contribute between 2 and 8% of the dust deposited in Waterfront South.

Elemental ratio - For the deposition samples the Ca/Fe ratio displayed a similar pattern of decrease with distance from the source material as did the simple Ca concentration. However, a significant relationship with distance was not seen for the dust wipe samples. This may reflect the solubility of Ca in rain water compared to Fe on these unprotected surfaces.

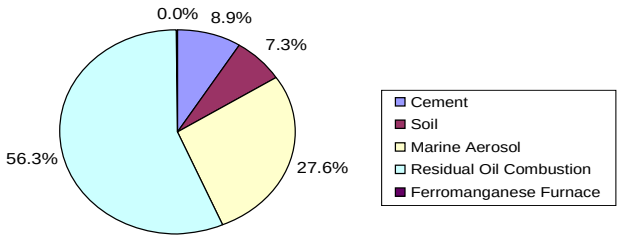
Enrichment factor (EF) - The enrichment factor for Ca, of 9.2 and 5.8 for deposition samples and wipe samples respectively, indicated a local source of Ca in the dust. The Ca enrichment factor decreased with distance from the source material. Table 1 presents the enrichment factor and Ca/Fe data. Interestingly, lead (Pb) and zinc (Zn), while not enriched in the source material, were highly enriched in the dust. This indicated local sources for these metals. A metals treating facility and iron workshop were located close to the cement facility and are likely sources for elevated enrichment factors for these metals.

Chemical mass-balance model - The CMB model predicted that within the sampling area, cement accounted for 4.9-21.8% of the dust material. The contribution decreased with distance from the site. Figures 3a, b show the model predictions for the various source contributions to the dust in the Waterfront-South community at the deposition sampling site closest to the cement facility (Fig. 3a) and at the control location (Fig. 3b). Since, as shown in Fig. 1 and Table 1, the control location does not appear to be impacted by the source material, the model prediction that 8.9% of the dust at the control location was contributed by cement probably represents the background contribution of cement to urban dust in this area of New Jersey. Therefore, based on this model, the maximum contribution from the cement facility to the dust in Waterfront-South at the closest sampling location is 20.5%-8.9% = 11.6%. This agrees reasonably well with the estimate of 8% derived from the percent Ca in the dust as a function of distance from the facility.



Deposition modeling based on facility-wide emissions data using the USEPA ISCST3 model - The modeling exercise for the entire facility using data supplied by the facility for permitting purposes predicted that the facility would contribute 34%, 24% and 18% at distances of 200, 500 and 800 m from the facility. These values are larger than those based on the measurements in this study. However, this is to be expected as the emissions data supplied for permitting purposes reflect worst-case (and not current) operating scenarios including full time, 7 days/week operations. When these factors are taken into account, these predictions are in reasonable agreements with those based on Ca concentration and chemical mass balance. Analysis of the various sources of particulate emission from the facility suggests that the stacks contribute less than half of the overall facility dust emission. Fugitive emissions from a variety of possible sources associated with the facility appear to account for the majority of the emissions.

Fig. 3b
(b) Estimated Source Contributions to Outdoor Dust in the Background site, Gloucester City, NJ



Uncertainties

There are several significant sources of uncertainty in this study. One source of uncertainty involves the placement of the deposition samplers. It was necessary to find secure locations for the samplers so that samples could be collected undisturbed for several weeks at a time. Because such locations were not easily obtained, the samples were located in a general downwind direction from the facility, but they were not located on a straight line relative to the facility and to each other. Thus, some deposition samples may have been more influenced by the downwind movement of particles from the facility than others. Another significant uncertainty is that local wind direction data were not available for the specific samples period. Thus, although the samples were located in the prevailing downwind direction from the facility, they may not have been downwind of the facility at all times. A third uncertainty is specific to the CMB model. No data were available to model the specific sources of urban dust in Waterfront South. Instead data from a study in Portland, Oregon were used to provide a generic model of sources of urban dust. These data have been used by EPA in its use of the CMB model when local, specific source information is unavailable. These uncertainties likely contributed to the range of estimates of the contribution of the St. Lawrence/Holcim facility to Waterfront South dust deposition. However, the consistency in the results obtained by the several different approaches used in this study suggests that the overall affect of these uncertainties is not large. These uncertainties are discussed in greater detail in the peer-review comments and responses to those comments (see) http://www.state.nj.us/dep/dsr/cement-study/.

Conclusions

Taking the several independent lines of evidence together, the findings of this study suggest that the St. Lawrence/Holcim facility accounts for about 2-13% of the total dust material at a distance of up to about 0.5 km from the exposed piles of material. At greater distances from the facility the contribution of the source material is smaller. Therefore, this range overestimates for the range for much of the community. Considering the approaches individually, it appears that the measurement and modeling of Ca concentration in the dust with distance from the facility is the most direct approach and requires the fewest assumptions. That approach suggests that the contribution of the facility to the dust in Waterfront South is likely to be in the lower end of that range (i.e., 2-8%). It is possible that on rare occasions, particularly high winds could mobilize larger amounts of particles from these piles.

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RESEARCH PROJECT SUMMARY

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