A Comparison of Los Alamos County and Pajarito Plateau Urban Storm Water Monitoring Studies

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Introduction

Since 2009, Los Alamos National Laboratory (LANL) has periodically conducted surface water monitoring on the Pajarito Plateau and Los Alamos County (LAC) to study storm water runoff from developed urban landscapes. Monitoring efforts have included urban neighborhood areas in LAC, LANL developed areas, and historical townsite areas where past LANL operations took place (Figure 1). These studies help establish the background chemistry of storm water runoff as a result of normal urban activities and help identify potential impacts of current and historical LANL and LAC activities.

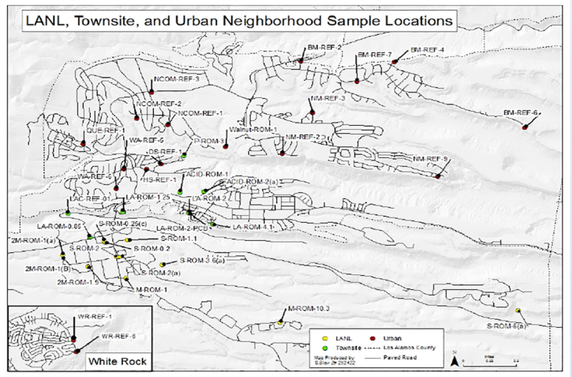

Figure 1. Locations of urban neighborhood, LANL, and townsite storm water samplers

Where do the constituents come from?

Urban environments generally contain high amounts of aluminum, copper, lead, zinc, and polychlorinated biphenyls (PCBs) from cars, industrial activities, and decay of buildings and other infrastructure components. Construction of houses and infrastructure in Los Alamos began as early as 1945 in the Western Area and later at the Denver Steels. Construction materials were less regulated during this period, and many houses have started to weather and decay, releasing contaminants in the process. Each time it rains, these contaminants are incorporated in storm water and enter the water cycle.

- **Aluminum** is associated with sediments entrained in storm water in most urban environments. Mineral-bound aluminum in the sediment load is generally insoluble, and aluminum is not expected to be detected at high levels in storm water runoff.
- **Copper** is a component of brake pads and is released each time a vehicle slows or stops. Copper is also found in copper wiring, motors, flashing, and plumbing components.
- **Lead** is most commonly found in paint pigments, tire wear, and motor oil.
- **Zinc** is used in paint, automobile tires, and other construction materials.
- **PCBs** were developed in the 1930s and were banned from production in the U.S. in 1979. Sources of PCBs include electrical equipment, oil-based paint, caulking, and many other items historically used in construction.

Methods

Urban storm water studies were grouped into three types of sampling locations: on LANL property, at the LAC townsite, and in urban neighborhood locations within LAC. Townsite monitoring was performed on the developed area around the central business district. Urban neighborhood monitoring was conducted in Western Area, North Mesa, Barranca Mesa, North Community, Quemazon, and White Rock. Urban storm water monitoring at LANL was conducted at developed areas within buildings, parking lots, and roads.

Figure 2. ISCO sampler at a LANL location

During the summer and fall monitoring seasons (May to November) from 2009 to 2016, storm water was collected using Global water samplers and ISCO samplers (Figure 2). A total of 37 samplers were deployed: 11 samplers at LANL locations, 9 at townsite locations, and 18 at urban locations. The samplers were triggered during storm events, samples were collected, and the samples were sent to an analytical laboratory.

How does LANL, Townsite, and Urban storm water differ?

Mean levels of constituents detected in LANL, townsite, and urban storm water generally differed among the three location groups. Figure 3A-F shows comparison box plots of levels of select constituents at the three locations. Tables 2A-2C all show mean as well as median, maximum, minimum, and standard deviation of levels of select constituents.

To test the difference among the locations, an ANOVA statistical evaluation of filtered aluminum, copper, detected and nondetected lead, zinc, hardness, and total PCBs was conducted. Results showed that some sample populations were statistically different, while others were not. Copper, zinc, and hardness were proven to be statically different populations. Aluminum, lead, and PCBs were not statistically different across the sample populations (Table 3A).

A two-sample t-test assuming unequal variance further showed that only copper had statistically different means across all three sample populations. Hardness had a statically different mean only when the urban and townsite populations were compared. Zinc had statically different means when both urban and LANL and townsite and urban populations were compared. Comparisons of LANL and townsite and urban for zinc, hardness, and PCBs did not show statically different means (Tables 3B-3E).

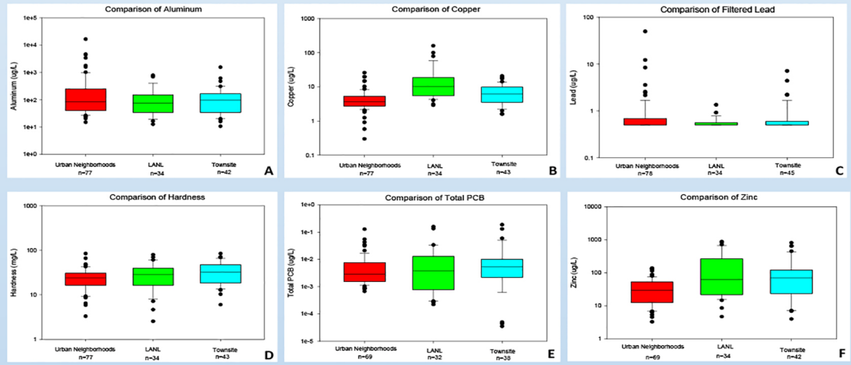

Figure 3A-3F. Comparison of box plots of constituents found at the three study locations. The median is represented by the line across each box.

A	LANL Aluminum (ug/L)	LANL Copper (ug/L)	LANL Total PCB (ug/L)	LANL Lead (ug/L)	LANL Hardness (mg/L)	LANL Zinc (ug/L)
Number of Samples	34	34	32	34	34	34
Mean	140	21	0.017	0.6	32	200
Median	75	160	0.0038	0.5	29	63
Max	790	200	0.16	0.9	80	880
Min	13	2.9	0.0022	0.5	2.5	8.6
Standard Deviation	190	33	0.036	0.1	22	270

B	Townsite Aluminum (ug/L)	Townsite Copper (ug/L)	Townsite Total PCB (ug/L)	Townsite Lead (ug/L)	Townsite Hardness (mg/L)	Townsite Zinc (ug/L)
Number of Samples	42	43	38	45	43	42
Mean	200	7	0.02	0.8	35	100
Median	90	6	0.005	0.5	32	50
Max	2000	20	0.2	7	85	800
Min	10	0.3	0.00004	0.5	6.0	3
Standard Deviation	300	5	0.04	1	20	200

C	Urban Aluminum (ug/L)	Urban Copper (ug/L)	Urban Total PCB (ug/L)	Urban Lead (ug/L)	Urban Hardness (mg/L)	Urban Zinc (ug/L)
Number of Samples	77	77	69	78	77	69
Mean	600	5	0.0086	2	25	30
Median	80	4	0.0029	0.5	24	20
Max	20000	30	0.13	50	85	100
Min	10	0.6	0.001	0.5	3.3	3
Standard Deviation	2000	4	0.018	6	13	30

Tables 2A-2C. Mean, median, maximum, minimum, and standard deviation of constituents across all three locations

ANOVA Test	Al	Copper	Hardness	Lead	Total PCB	Zinc
F	1.47	12.2	4.62	0.86	1.50	10.2
F crit	3.06	3.06	3.06	3.06	3.06	3.06
Statistical Variance?	No	Yes	Yes	No	No	Yes

T-Test	LANL and Townsite: Copper	LANL and Urban: Copper	Townsite and Urban: Copper
t Stat	2.38	2.76	2.30
T Critical two-tail	2.03	2.03	1.99
Statistically Different Mean?	Yes	Yes	Yes B

T-Test	LANL and Townsite: Hardness	LANL and Urban: Hardness	Townsite and Urban: Hardness
t Stat	-0.869	1.75	3.16
T Critical two-tail	1.99	2.02	2.00
Statistically Different Mean?	No	No	Yes C

T-Test	LANL and Townsite: Total PCB	LANL and Urban: Total PCB	Townsite and Urban: Total PCB
t Stat	0.049	1.22	1.37
T Critical two-tail	2.00	2.02	2.01
Statistically Different Mean?	No	No	No D

T-Test	LANL and Townsite: Zinc	LANL and Urban: Zinc	Townsite and Urban: Zinc
t Stat	1.26	3.33	3.00
T Critical two-tail	2.00	2.03	2.01
Statistically Different Mean?	No	Yes	Yes E

Table 3A-3E. Results of statistical analysis of LANL, townsite, and urban populations

Acute Aquatic Life Criteria and Toxicity Unit

Acute aquatic life criteria for hardness-dependent metals (e.g., aluminum, copper, lead, and zinc) were calculated using concurrent hardness values. Hardness results ranged between 2.53 mg/L and 84.6 mg/L $CaCO_3$. To identify water-quality exceedances, toxicity units (TUs) were calculated using the following ratio: result/calculated hardness-dependent water-quality acute aquatic life criteria. If the ratio is greater than 1, the levels are greater than the respective acute aquatic life water-quality criteria. TUs of LANL, townsite, and urban neighborhoods metals differ greatly (Figure 4A-C). Table 4 shows average TU for all three locations.

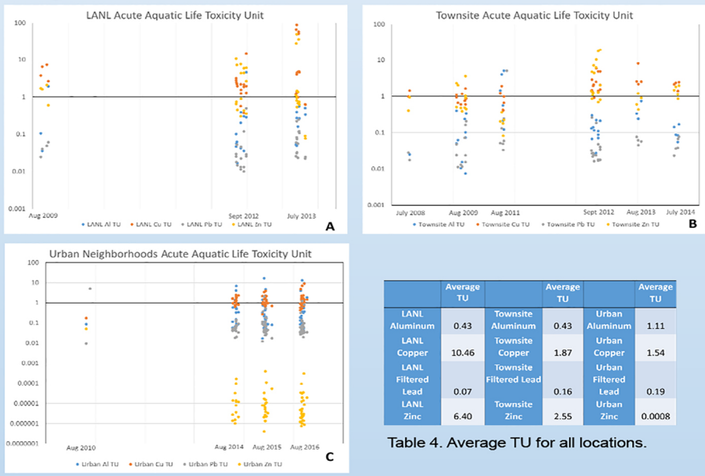

Figure 4A-4C. TU of metals from LANL, townsite, and urban Neighborhoods. Hardness-dependent metal acute aquatic life criterion = $\exp(m_A[\ln(\text{hardness})] + b_A)$(Conversion Factor).

	Average TU		Average TU		Average TU
LANL Aluminum	0.43	Townsite Aluminum	0.43	Urban Aluminum	1.11
LANL Copper	10.46	Townsite Copper	1.87	Urban Copper	1.54
LANL Filtered Lead	0.07	Townsite Filtered Lead	0.16	Urban Filtered Lead	0.19
LANL Zinc	6.40	Townsite Zinc	2.55	Urban Zinc	0.0008

Table 4. Average TU for all locations.

Conclusions

The distribution of constituents in storm water runoff reflects current and historical activities at Los Alamos. Constituents are the result of day-to-day activities, including vehicular traffic and the weathering of infrastructure. This study of the developed LANL landscape, townsite, and urban neighborhoods in LAC shows the different distribution of metals and PCBs detected in storm water. Mean levels of copper at LANL locations were significantly higher than levels at the townsite and in urban neighborhoods. This finding may be attributed to past LANL activities, age and type of buildings, and automobile traffic patterns. Mean zinc levels were lowest in urban neighborhoods and highest at LANL locations, perhaps for the same reason copper is highest at LANL locations. Maximum levels of lead were found at urban locations, probably from vehicles and lead-based paint from older buildings. Mean levels of PCBs were highest at Townsite locations, most likely from historical and current industrial activities, older structures with PCB-stabilizing agents (paint and caulk), and older electrical transformers.

TUs show the distribution and exceedances of key constituents. The average TU of copper at LANL locations was greater than at both townsite and urban locations, while the average TU of urban zinc was significantly lower than at LANL and townsite locations. The average TU of aluminum at LANL and townsite locations was well below exceedance limits, while the average TU of aluminum at urban locations was slightly above the exceedance limit. Continued studies of storm water runoff at LANL, townsite, and urban locations will help further define links between levels of constituents and the different developed locations in LAC.

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