Statistical Analysis of DOE EML QAP Data from 1982 to 1998

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The historical database from the Environmental Measurements Laboratory's Quality Assessment Program from 1982 to 1998 has been analyzed to determine control limits for future performance evaluations of the different laboratories contracted to the U.S. Department of Energy. Seventy-three radionuclides in four different matrices (air filter, soil, vegetation, and water) were analyzed. The evaluation criteria were established based on a z-score calculation.

INTRODUCTION

The Environmental Measurements Laboratory (EML), a government-owned, government-operated laboratory, programmatically under the Office of Environmental Management (EM) in the U.S. Department of Energy (DOE), administers the semiannual Quality Assessment Program (QAP) for environmental radiological analyses.[1] The quality of environmental radiological measurements reported by DOE contractor and subcontractor laboratories is tested by the EML QAP, an external, independent performance evaluation program. This program allows DOE to compare environmental radiological analyses across their laboratories and field stations. To support its assessments of radionuclide levels in the environment and supplement data collected with in situ techniques, EML collects samples of media such as air filters, soil, vegetation, tissue (terminated in 1987), and water. Water and air filters are spiked with solutions, not collected in the field. EML collects, prepares, and analyzes the samples to determine the EML "reference" values which are used to assess the results of the results of the participating analytical laboratories.[2] Participants can use any analytical method and are required to analyze only those matrices/nuclides for which they contract to DOE.

In this paper, EML's QAP data from 1982 to 1998 are summarized to determine the quality of the reported environmental data, to assess the level of analytical variability for each radionuclide/matrix pair, and to determine the reliability of participating laboratories over the past 17 years. The control limits established (vide infra) are available as guidelines both to the participating analytical laboratories and for DOE agencies using the analytical data.

OBJECTIVE AND SCOPE

The EML QAP historical database is one of the most comprehensive environmental radiological data sets in existence. It contains data on some 73 radionuclide/matrix pairs from 1982 to 1998 in four matrices. The objective of the current study is to analyze the quality of the data in order to generate representative control limits for each of the radionuclide/matrix pair for performance evaluation and to compare the existing EML method with the proposed method. The radionuclide/matrix data analyzed in this report are listed in Table 1.

Table 1. Summary of Radionuclide/Matrix Pair Analyzed

air filter	soil	vegetation	water
	^{228}Ac		
^{241}Am	^{241}Am	^{241}Am	^{241}Am
^{7}Be			
	^{212}Bi		
	^{214}Bi		
^{144}Ce			^{144}Ce
	^{244}Cm	^{244}Cm	
^{57}Co			^{57}Co
^{60}Co	^{60}Co	^{60}Co	^{60}Co
^{134}Cs			^{134}Cs
^{137}Cs	^{137}Cs	^{137}Cs	^{137}Cs
			^{55}Fe
Gross Alpha			Gross Alpha
Gross Beta			Gross Beta
			^{3}H
	^{40}K	^{40}K	
^{54}Mn			^{54}Mn
			^{63}Ni
	^{210}Pb		
	^{212}Pb		
	^{214}Pb		
^{238}Pu	^{238}Pu	^{238}Pu	^{238}Pu
^{239}Pu	^{239}Pu	^{239}Pu	^{239}Pu
	^{226}Ra		
^{106}Ru			
^{125}Sb			
^{90}Sr	^{90}Sr	^{90}Sr	^{90}Sr
	^{228}Th		
	^{234}Th		
	^{208}Tl		
^{234}U	^{234}U	^{234}U	^{234}U
^{235}U	^{235}U		^{235}U
^{238}U	^{238}U	^{238}U	^{238}U
U (μg g^{-1})	U (μg g^{-1})		U (μg mL^{-1})
U (Bq kg^{-1})	U (Bq kg^{-1})		U (Bq L^{-1})

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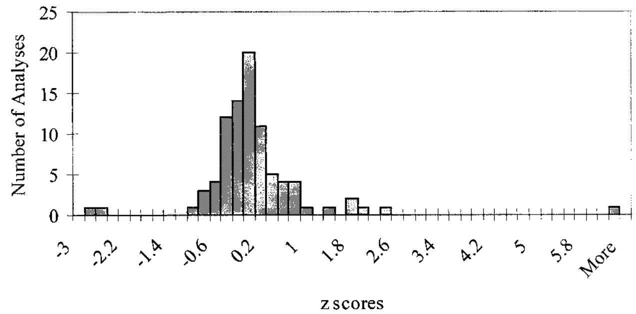

Figure 1. Frequency histogram for ^{60}Co in vegetation by calculating mean and SDs.

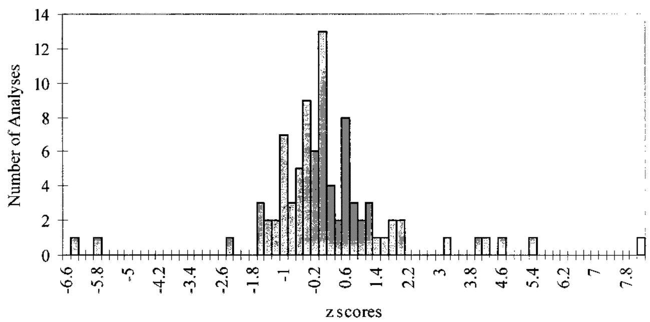

Figure 2. Frequency histogram for ^{60}Co in vegetation by calculating trimmed mean and trimmed SDs (9809).

Table 2. Evaluation Criteria

acceptable "A"	acceptable with warning "W"	not acceptable "N"
$-2 \leq z \leq +2$	$-3 \leq z < -2$	$z < -3$
	$+3 \geq z > +2$	$z > +3$

METHODS OF QAP DATA ANALYSIS

Existing EML Method. According to DOE Report EML-564 (1995),[3] the control limits were established from percentiles of historic QAP data distributions from 1982 to 1992. EML control limits are reevaluated on an annual basis using the most recent 5 years of QAP data. Based on the historical analytical abilities for individual radionuclides/matrix pairs, participants' analytical performances were evaluated. A frequency distribution was calculated from all reported measurements relative to the EML value for each radionuclide/matrix pair. The evaluation criteria used by EML are given below:

Acceptable performance, "A", has been chosen to be between the 15th (middle lower limit, MLL) and the 85th (middle upper limit, MUL) percentile of the cumulative normalized distribution, which would be the middle 70% of all historic measurements.

The acceptable with warning, "W", is between the 5th (lower limit, LL) and 15th (MLL) percentile or the 85th (MUL) and 95th (upper limit, UL) percentile. In other words, the middle 70% of all reported values are acceptable, while the outer 5th−15th (10%) and 85th−95th percentiles (10%) are in the warning area.

The not acceptable, "N", is established at less than the fifth percentile or greater than the 95th percentile, that is, the outer 10% of the historical data.

Proposed Statistical Method for Determining Control Limits. According to Pan (1995),[3] the historical QAP data have both systematic and random errors within them because the participants are not required to utilize a prescribed method of analysis. For this reason, the EML reported value was not considered as a reference value in this report during data analyses.

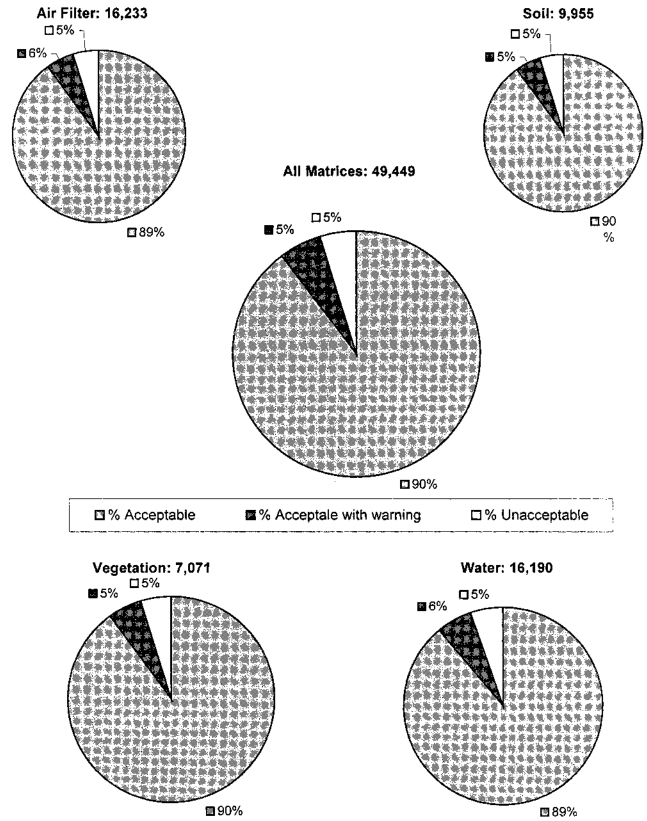

Figure 3. Summary of all matrices.

Due to the presence of some outliers in the historic data series, a trimmed mean and a trimmed standard deviation were calculated for each radionuclide/matrix pair. A trimmed mean is calculated by discarding a certain percentage of the lowest and the highest scores and then computing the mean of the remaining scores. In this case, the 5% lower and the 5% higher scores were discarded, and the trimmed mean and trimmed SDs were calculated.

A standardized score, or z-score, was calculated for each observation instead of a percentile. A z-score is the number of standard deviations (SD) an observation deviates from the mean. Normal distributions can be transformed to standard normal distributions, or z-score, by the formula

$$z = \frac{x - \mu}{\sigma} \qquad (1)$$

where x is a score from the original distribution, μ is the mean of the original normal distribution, or calculated trimmed mean, and σ is the SD of the original normal distribution or the calculated trimmed SDs.[4]

The evaluation criteria were set based on calculated z-scores. According to the empirical rule for any normal curve: 68% of the values fall within 1 SD of the mean, 95% of the values fall within 2 SDs of the mean, and 99.7% of the values fall within 3 SDs of the mean. The evaluation criteria are given below:

Acceptable, "A", has been chosen to be between $-2 \leq z \leq +2$, which would be the middle 95% of all historic measurements if they are distributed normally.

Table 3. Summary for Different Radionuclide Analyses

matrix	isotope	no. of participation	total no. of analyses	% A	% W	% U
air filter	^{241}Am	32	921	91.7	3.9	4.4
	^{7}Be	1	58	86.0	5.0	9.0
	^{144}Ce	19	1176	89.8	4.2	6.0
	^{57}Co	20	1281	87.9	6.9	5.2
	^{60}Co	29	1658	88.8	5.7	5.5
	^{134}Cs	18	1186	88.3	7.3	4.4
	^{137}Cs	32	1769	88.7	6.8	4.5
	gross alpha	8	527	88.5	8.0	3.5
	gross beta	8	524	89.1	6.3	4.6
	^{54}Mn	28	1598	89.4	5.6	5.0
	^{238}Pu	15	708	88.6	4.7	6.7
	^{239}Pu	31	1045	88.4	5.4	6.2
	^{106}Ru	4	262	88.5	6.3	5.2
	^{125}Sb	12	910	87.8	5.2	7.0
	^{90}Sr	32	826	91.8	3.6	4.6
	^{234}U	32	620	94.8	2.7	2.5
	^{235}U	2	16	94.0	6.0	0.0
	^{238}U	32	671	92.9	4.1	3.0
	Bq U	12	175	92.0	3.9	4.1
	μg U	12	302	91.3	3.3	5.4
soil	^{228}Ac	1	48	90.0	8.0	2.0
	^{241}Am	28	671	91.4	4.8	3.8
	^{212}Bi	1	42	98.0	2.0	0.0
	^{214}Bi	1	51	94.0	2.0	4.0
	^{244}Cm	2	19	93.5	6.5	0.0
	^{60}Co	4	229	90.3	3.8	5.9
	^{137}Cs	32	1773	89.0	5.9	5.1
	^{40}K	32	1607	88.8	4.9	6.3
	^{210}Pb	1	13	92.0	8.0	0.0
	^{212}Pb	1	51	86.0	8.0	6.0
	^{214}Pb	1	52	88.0	6.0	6.0
	^{238}Pu	18	607	91.1	3.4	5.5
	^{239}Pu	32	1252	88.3	5.1	6.6
	^{226}Ra	1	44	89.0	7.0	5.0
	^{90}Sr	32	885	90.4	5.9	3.7
	^{228}Th	1	34	85.0	12.0	3.0
	^{234}Th	1	35	91.0	6.0	3.0
	^{208}Tl	1	49	90.0	6.0	4.0
	^{234}U	31	712	91.7	5.3	3.0
	^{235}U	2	25	94.0	6.0	0.0
	^{238}U	31	806	90.8	5.7	3.5
	Bq U	19	263	94.6	3.7	1.7
	μg U	26	471	93.7	3.8	2.5
vegetation	^{241}Am	27	621	91.2	4.8	4.0
	^{244}Cm	8	228	90.3	4.9	4.8
	^{60}Co	18	949	89.7	4.9	5.4
	^{137}Cs	32	1506	88.7	6.1	5.2
	^{40}K	32	1384	88.9	6.7	4.4
	^{238}Pu	16	299	92.8	5.2	2.0
	^{239}Pu	32	956	89.8	4.9	5.3
	^{90}Sr	32	882	91.6	3.5	4.9
	^{234}U	10	62	98.8	1.2	0.0
	^{238}U	10	80	95.3	4.0	0.7
water	^{241}Am	32	1063	90.1	5.3	4.6
	^{144}Ce	13	601	89.8	4.8	5.4
	^{57}Co	9	353	87.3	6.8	5.9
	^{60}Co	29	1784	88.0	6.6	5.4
	^{134}Cs	16	901	87.5	7.1	5.4
	^{137}Cs	32	1880	87.4	7.0	5.6
	^{55}Fe	12	166	95.0	4.5	0.5
	gross alpha	8	539	88.4	5.5	6.1
	gross beta	8	537	89.4	5.6	5.0
	^{3}H	12	867	87.6	3.8	8.6
	^{54}Mn	31	1794	88.0	6.0	6.0
	^{63}Ni	1	14	93.0	7.0	0.0
	^{238}Pu	14	784	87.5	4.6	7.9
	^{239}Pu	32	1300	88.3	6.1	5.6
	^{90}Sr	32	1113	90.0	4.8	5.2
	^{234}U	32	748	90.6	6.3	3.1
	^{235}U	2	26	92.5	7.5	0.0
	^{238}U	31	739	90.9	5.4	3.7
	Bq U	19	285	93.2	2.6	4.2
	μg U	28	606	92.6	3.3	4.1

Acceptable with warning, "W", is between $-3 \le z < -2$ and $+3 \ge z > +2$. In other words, the middle 95% of all reported values is acceptable, while the outer 0.15th−2.5th (2.35%) and 97.5th−99.85th percentiles (2.35%) are in the warning area if they are distributed normally.

Table 4. Summary for Different Matrices

matrix	total no. of analyses	% A	% W	% U
air filter	16233	89.9	5.5	4.6
soil	9955	90.1	5.2	4.8
vegetation	7071	90.0	5.3	4.7
water	16190	89.0	5.8	5.2

Not acceptable, "N", is established at $z < -3$ and $z > +3$, that is, the outer 0.3% of the historical data if they are distributed normally.

The control limits for the evaluation criteria are summarized in Table 2.

RESULTS AND DISCUSSION

The effects of the presence of outliers on the data series and the purpose of calculating trimmed mean and trimmed SDs are shown in Figures 1 and 2, respectively. For example, mean, SD, and z-scores for ^{60}Co in vegetation were calculated, and the values for mean and SD were 21.94 and 7.30, respectively. Due to the presence of outliers, the mean and SDs were affected and so were z-scores for the whole data series. In this case only one datum was found not acceptable. But when trimmed mean and trimmed SDs were calculated, values for trimmed mean and trimmed SDs were 21.49 and 3.28, respectively. In this case eight data were found not acceptable. On the other hand, according to the existing method the high and low four measurements were found not acceptable, which clearly includes two decent low measurements and does not include two questionable high measurements.

A summary for different radionuclide analyses using the new method is presented in Table 3. One can recognize that for most of the isotopes the average % N data are less than 6% of the total data analyses. Only ^{7}Be (9.0%), ^{238}Pu (6.7%0, ^{239}Pu (6.2%), and ^{125}Sb (7.0%) in air filters; ^{40}K (6.3%) and ^{239}Pu (6.6%) in soil; and gross alpha (6.1%), ^{3}H (8.6%), and ^{238}Pu (7.9%) in water show average % N results greater than 6% but still less than 9.1% of all historical data analyses.

From the analysis of the different matrices (see Table 4), one can realize that there is no significant difference between average % N data for all four matrices [air filters (4.6), soil (4.8), vegetation (4.7), and water (5.2)]. Artificially spiked matrices (air filter and water) show slightly different results than those of natural matrices (soil and vegetation).

Analysis of the longitudinal data shows that most laboratories improved from 1982 to 1998. For most of the laboratories the % N results are less than 10% of the total data analyses. Only 52 laboratories out of 195 laboratories have % N results greater than 10% (33 laboratories have % N results: $10.1 \le$ % N ≤ 20; 10 laboratories have % N results: $20.1 \le$ % N ≤ 30; four laboratories have % N results: $30.1 \le$ % N ≤ 40; and five laboratories have % N results: $40.1 \le$ % N ≤ 90). From Table 5, it is clear that those laboratories that have % N results more than 20.1% participated less than 10 times, and those laboratories that have % N result from 10.1%−20.0% participated from 1 to 30 times. For example, BM, CS, LB, and RI have % N results 10.6%, 10.7%, 17.6%, and 10.5%, respectively, and partici-

Table 5. Summary for Different Laboratory Performance

lab code	name	no. of QAPs	total no. of analyses	% A	% W	% U
AC	Argonne National Lab	21	530	95.1	3.3	1.6
AE	Analytical Resources, Inc., Seattle, WA	7	120	99.1	0.9	0.0
AF	Air Force Analytical Lab, Brooks AFB	5	177	66.4	7.6	26.0
AG	Paragon Analytics, Inc., Fort Collins, CO	12	557	94.3	2.9	2.8
AI	Nuclear Technology Services, Inc., GA	6	223	76.5	9.8	13.7
AL	Ames Laboratory, Ames, IA	18	234	69.8	13.7	16.5
AM	American Radiation Services, Inc., Baton Rouge	7	236	68.5	12.9	18.6
AN	Argonne National Laboratory	32	1,037	97.9	0.8	1.3
AP	Aberdeen Porving Ground, MD	7	133	73.5	10.4	16.1
AR	Accu-Labs Research Inc., Golden, CO	21	783	90.0	4.3	5.7
AS	USACHPPM, Aberdeen Proving Ground, MD	15	486	89.4	8.4	2.2
AT	ATL International Inc., MD	7	151	80.5	10.1	9.4
AU	ORISE RSAT/ESSAP, Oak Ridge	25	788	85.6	6.4	8.0
AW	Argonne National Laboratory, Idaho Falls	9	127	75.3	10.4	14.3
AZ	Radiation Measurements Facility, AZ	9	156	93.5	3.9	2.6
BA	Bettis Atomic Power Lab, PA	24	372	88.6	7.5	3.9
BC	BWX Technologies, Inc., NNFD, Lynchburg, VA	11	233	89.8	4.6	5.6
BE	RUST Geotech, Grand Junction, CO	26	803	89.3	5.0	5.7
BK	Brookhaven National Lab Division, NY	5	20	95	0.0	5.0
BL	Barringer Laboratories Inc., Golden, CO	13	799	93.0	3.8	3.2
BM	Battelle Memorial Institute, OH	24	775	81.9	7.5	10.6
BN	Brookhaven National Laboratory, NY	31	1,009	90.4	6.8	2.8
BP	Battelle Pacific Northwest National Lab	26	536	94.9	3.5	1.6
BQ	Becquerel Laboratories Inc., Canada	10	182	87.4	5.0	7.6
BR	US Army Research Laboratory, Aberdeen Proving Grnd.	12	205	69.7	17.5	12.8
BS	B & W Nuclear Envir. Services, PA	8	172	86.9	10.0	3.1
BU	Autoridad Regulatoria, Argentina	8	250	91.4	5.0	3.6
BW	Brookhaven National Lab, DOE	3	14	75.0	16.7	8.3
BX	B & W Nuclear Envir. Services, VA	13	520	89.4	4.8	5.8
BZ	US Testing Corp., Richland, WA	13	363	94.8	4.5	0.7
CA	Atomic Energy Control Board, Canada	21	292	93.4	4.4	2.2
CB	Radiation Protection Bureau, Canada	2	19	100.0	0.0	0.0
CC	Compuchem Envir. Corp, RTP, NC	8	218	95.9	3.3	0.8
CD	Gentilly-2 Nuclear Power Plant, Canada	2	42	93.0	0.0	7.0
CH	California State Department Health Serv.,	7	306	97.3	2.3	0.4
CL	Core Laboratories, Casper, WY	15	503	75.6	11.6	12.8
CM	Metropolitan Water Reclamation Dist. of Greater Chicago	1	29	100.0	0.0	0.0
CN	China Institute for Radiation Protection	4	54	86.5	6.5	7.0
CO	Bedford Institute of Oceanography, Canada	4	51	88.2	4.8	7.0
CP	Controls of Environmental Pollution, Santa Fe	10	290	84.6	7.0	8.4
CR	Laboratorio de Fisica Nuclear Aplicada, Costa Rica	4	52	62.4	10.8	26.8
CS	Rocketdyne Propulsion & Power, CA	30	519	77.6	11.7	10.7
CW	Carlsbad Envir. Monitoring Research Center, NM	3	60	93.7	6.3	0.0
CZ	ACZ Laboratories, Inc., CO	7	11	71.4	3.6	25.0
DC	Datachem Laboratories, Salt Lake City	12	425	87.6	3.2	9.2
DH	Duke Engineering Services Hanford	4	44	91.7	2.8	5.5
DP	Duke Power Company, NC	3	93	82.0	8.7	9.3
EB	AEB Consultants Pine Bluff, AR	4	114	37.2	17.3	45.5
EC	Envirocare of Utah	4	112	83.9	6.8	9.3
EE	Rust Remedial Services, Anderson, SC	12	235	83.9	3.2	12.9
EG	LMITCO/INEL, Scoville	15	495	93.4	3.0	3.6
EI	Eichrom Industries, Inc., Argonne	9	141	81.0	6.9	12.1
EL	Energy Laboratory Inc., WY	6	159	69.3	11.2	19.5
EM	3M, Empore Disks, St. Paul, MN	1	11	36.0	9.0	55.0
EN	WINCO Scoville, ID	24	669	89.8	8.2	2.0
EP	US EPA, Las Vegas	25	396	88.4	7.6	4.0
ES	Environmental Sci. & Engr. Inc., FL	12	461	91.8	2.9	5.3
ET	Ecotek Lab Services Inc., Atlanta, GA	8	296	84.1	5.1	10.8
FG	FGL Environmental, Santa Paula, CA	10	227	82.6	7.0	10.4
FJ	The University of the South Pacific, Fiji Islands	3	30	75.0	7.7	17.3
FL	Florida Department of Health & Rehab. Serv., Orlando	18	440	94.5	2.4	3.1
FM	Florida Mobile Emergency Rad. Laboratory, Orlando	9	91	96.1	2.9	1.0
FN	Fermi Lab, Batavia, IL	31	524	95.3	3.0	1.7
FR	CEA/DAM − SPR/B3, France	3	92	89.0	7.3	3.7
FS	Florida State University, Tallahassee	9	72	96.3	2.4	1.3
FZ	Fermi Contractor (TIML)	4	21	63.0	22.5	14.5
GA	Lockheed Martin, Pikton, OH	29	652	97.0	1.9	1.1
GC	Georgia Power Company Environ. Lab	3	48	94.0	3.7	2.3
GE	General Engineering Labs, SC	15	536	94.2	3.9	1.9
GP	GPU Nuclear, Inc., Harrisburg, PA	4	170	83.2	5.0	11.8
GS	USGS/NWQL, Arvada, CO	8	23	95.9	4.1	0.0
GT	Georgia Institute of Technology	5	153	94.6	3.8	1.6

Table 5. (Continued)

lab code	name	no. of QAPs	total no. of analyses	% A	% W	% U
HA	NUS Lab Pittsburgh, PA	7	135	86.7	9.3	4.0
HC	Lawrence Livermore Laboratory, California	12	44	100.0	0.0	0.0
HI	Heritage Labs, Indianapolis, IN	5	84	66.4	13.2	20.4
HL	Heritage Labs, Romeoville, IL	7	114	81.8	7.1	11.1
HR	Hazen Research, Golden, CO	4	49	71.9	3.8	24.3
HS	RESL − US DOE, Idaho Falls	14	740	96.4	3.0	0.6
HT	Technical University, Budapest, Hungary	1	13	7.0	8.0	85.0
HU	Water Resources Research Center (VITUKI), Hungary	3	42	78.7	12.3	9.0
IA	Bhabha Atomic Research Center, India	3	136	66.7	25.3	8.0
ID	Institute of Radiation Protection & Dosimetry, Brazil	9	281	83.3	8.7	8.0
IE	Severn Trent Laboratories, NJ	14	456	95.7	2.4	1.9
IL	ISU Environ. Monitoring Program, ID	5	89	65.8	12.4	21.8
IN	Lockheed Martin Idaho Technical Corp., Anal. Laboratory	15	346	90.4	7.5	2.1
IR	Idaho National Engineering Laboratory	11	33	85.7	7.9	6.4
IS	Quanterra- St. Louis	15	546	84.4	8.8	6.8
IT	Quanterra- Richland Laboratory	16	685	94.0	3.6	2.4
JE	Jacobs Engineering, Oak Ridge, TN	3	22	92.3	0.0	7.7
JL	Jefferson Labs, Newport News, VA	4	34	50.9	9.8	39.3
JP	Japan Chemical Analysis Center	3	128	95.0	5.0	0.0
KA	Knolls Atomic Power Lab, Schenectady	32	405	98.7	0.7	0.6
KO	Korea Institute of Nuclear Safety	3	91	99.3	0.0	0.7
KR	Korea Atomic Energy Research Institute	2	24	100.0	0.0	0.0
LA	Los Alamos National Laboratory, NM	32	1,602	85.3	6.6	8.1
LB	Lawrence Berkeley Lab UCB	19	249	72.7	9.7	17.6
LE	Lyle Environmental Management, OH	1	2	0.0	100.0	0.0
LH	Lockheed Analytical Laboratory, Las Vegas	11	510	89.0	7.5	3.5
LL	LLNL Chemistry & Material Science/Environmental	31	652	89.9	3.4	6.7
LM	Los Alamos National Lab, NV	9	123	50.1	8.0	41.9
LN	Los Alamos National Lab, ES&H	3	38	78.4	16.3	5.3
LV	UNLV, Department of Health Physics	6	155	80.7	8.3	11.0
LW	Lawrence Livermore National Lab	12	103	97.2	2.8	0.0
MA	ORNL Health Sciences Research Division	10	81	84.0	7.9	8.1
ME	Radiation Control Program, MA	8	161	72.3	16.8	10.9
MH	Maine Health & Environmental Testing Laboratory	3	71	98.7	1.3	0.0
MI	Massachusetts Institute of Technology	10	138	72.5	8.7	18.8
ML	Babcock & Wilcox of Ohio, OH	31	630	91.8	3.8	4.4
MO	CNESTEN, Morocco	1	12	92.0	0.0	8.0
MS	Manufacturers Sciences Corporation, Oak Ridge	6	88	94.0	2.5	3.5
MX	Centro Nacional de Metrologia (CENAM), Mexico	1	7	100.0	0.0	0.0
NA	US EPA NAREL, Montgomery, AL	12	392	86.6	4.9	8.5
NC	Nuclear Services North Carolina State University	7	90	99.1	0.9	0.0
ND	Department of Envir. Health & Safety, NC State University	3	25	100.0	0.0	0.0
NF	Nuclear Fuel Services, Erwin, TN	2	17	65.5	25.5	9.0
NJ	NJ Department of Health and Senior Services	12	181	95.3	2.2	2.5
NL	Fluor Daniel Fernald, Inc., Ohio	25	295	85.3	7.2	7.5
NM	Environmental Evaluation Group, NM	5	80	92.0	3.0	5.0
NP	JAF Environmental Laboratory, NY	5	86	79.2	15.0	5.8
NQ	New Mexico Department of Health, Albuquerque	1	31	91.0	6.0	3.0
NR	Naval Reactors Facility Chemistry, ID	10	46	98.0	2.0	0.0
NS	State Lab of Public Health, NC	4	54	65.9	3.8	30.3
NY	NYU Medical Center, NIEM, NY	14	150	93.6	5.1	1.3
NZ	National Radiation Laboratory, New Zealand	3	204	92.3	2.0	5.7
OA	Oak Ridge Analytical Services, TN	4	123	94.7	1.3	4.0
OB	OBG Laboratories, East Syracuse, NY	8	65	62.3	5.9	31.8
OC	Radiation Protection Service Laboratory, Ontario, Canada	1	82	98.0	2.0	0.0
OD	ORNL, Radiobioassay Lab	10	207	92.7	6.7	0.6
OI	Oak Ridge Research Institute Inc., TN	5	79	49.6	10.0	40.4
OK	Outreach Laboratories, OK	3	42	82.3	14.0	3.7
OL	ORNL Environmental Sciences Division	11	217	96.4	0.0	3.6
OR	Oak Ridge National Lab	27	816	95.5	3.3	1.2
OS	Oregon Health Division Radiation Controls Sec., Portland	18	337	83.5	9.7	6.8
OT	ORNL Radioactive Mat. Analysis Lab	8	272	94.1	2.4	3.5
OU	Outreach Laboratory, OK	4	100	72.7	14.0	13.3
PA	Mason & Hanger-Silas Mason Co., TX	30	264	90.8	5.6	3.6
PB	Mason & Hanger-Silas Mason Co. Inc., TX	4	46	95.0	0.0	5.0
PC	Pace Inc., Golden, CO	9	204	85.3	3.6	11.1
PI	Lockheed M. Specialty Components, FL	26	130	87.3	9.2	3.5
PK	Pakistan Institute of Nuclear Science & Technology	2	13	83.5	0.0	16.5
PO	Institute of Oceanology PAN, Poland	4	61	93.7	3.0	3.3
PR	Princeton Plasma Physics Lab	18	141	92.4	3.2	4.4
RA	V. G. Khlopin Radium Institute, St. Petersburg, Russia	10	307	92.2	4.0	3.8
RC	US NRC Region I Laboratory, PA	5	59	100.0	0.0	0.0

Table 5. (Continued)

lab code	name	no. of QAPs	total no. of analyses	% A	% W	% U
RD	Radiation Detection Company	6	10	66.6	16.7	16.7
RE	Bechtel Nevada, Mercury, NV	32	924	88.8	5.3	5.9
RF	EG&G Rocky Flats Plant, Golden	17	193	80.5	5.4	14.1
RG	Thermo Nutech Rocky Flats Plant, Golden	18	123	99.6	0.0	0.4
RI	Waste Management Services of Hanford, Inc., 222S Lab	27	622	81.2	8.3	10.5
RK	Rock Island Arsenal, Illinois	3	6	44.3	55.7	0.0
RL	Bechtel Hanford − Raiological Counting Facility	5	91	70.6	6.0	23.4
RM	Moscow State University, Russia	1	13	31.0	54.0	15.0
RO	Radiation Hygiene Laboratory, Romania	1	8	88.0	0.0	12.0
SA	Sandia Labs Radioactive Sample Diag. Prog., NM	26	316	87.0	8.4	4.6
SB	SC Department of Health & Envir. Control Radiological Lab	3	48	61.0	18.3	20.7
SC	Sacubed Division Maxwell Labs, CA	11	182	86.3	6.8	6.9
SE	Defence Research Establishment of Sweden (FOA)	3	71	79.3	11.7	9.0
SH	Savannah River Ecology Lab	1	11	64.0	0.0	36.0
SK	Savannah River Plant	17	303	96.9	1.9	1.2
SL	Stanford Linear Accelerator Center	5	17	100.0	0.0	0.0
SN	Sanford Cohen Associates, Inc., AL	6	143	94.7	3.8	1.5
SR	Savannah River Environmental Laboratory	32	817	88.7	4.9	6.4
SS	Savannah River Tech. Center	9	136	89.7	8.2	2.1
ST	SC DHEC, Aiken, South Carolina	4	76	97.9	1.3	0.8
SV	Savannah Lab & Environmental Services, Inc., TX	6	17	91.7	0.0	8.3
SW	Southwest Research Institute, TX	8	294	67.4	11.8	20.8
TE	Teledyne Isotopes Midwest Lab, IL	6	212	91.0	4.8	4.2
TI	Teledyne Brown Eng. Envir. Services, Westwood, NJ	13	500	93.6	3.7	2.7
TM	Thermo Nutech, Albuqueque Lab, NM	16	619	94.2	4.7	1.1
TN	Thermo NuTech, Richmond, CA	13	536	93.1	3.6	3.3
TO	Thermo Nutech, Oak Ridge Laboratory	13	470	84.4	8.5	7.1
TP	Taiwan Power Company, Taipei, Taiwan	5	114	94.0	2.4	3.6
TR	University of Istambul, Turkey	2	36	58.5	16.5	25.0
TT	Tracer Technologies International, Inc., Cleveland	3	23	77.3	22.7	0.0
TW	Taiwan Radiation Monitoring Center	6	230	92.0	5.8	2.2
TX	Texas Department of Health/Laboratories, Austin	6	240	97.4	1.8	0.8
TY	Scientific Production Association, Russia	6	73	87.5	4.7	7.8
UC	United States Enrichment Corporation, KY	29	441	88.3	6.0	5.7
UK	Lockheed Martin Energy System, Oak Ridge	29	492	88.6	6.1	5.3
UN	Ministry of Agriculture, UK	2	55	98.0	0.0	2.0
UP	Lockheed Martin Energy Systems, Y-12 Plant, Oak Ridge	9	252	88.1	8.7	3.2
UY	Lockheed Martin Energy Systems, Y-12 Plant, Oak Ridge	31	703	87.5	5.6	6.9
VE	Universidad Simon Bolivar, Venezuela	1	6	100.0	0.0	0.0
WA	Envir. Radiation Lab, Seattle	23	897	96.5	1.8	1.7
WC	West Management Federal Services of Hanford	8	291	89.8	6.8	3.4
WE	Westinghouse Electric Corp., Madison, PA	6	172	74.4	7.3	18.3
WI	WIPP Site, Westinghouse Electric Corp.	13	176	82.7	9.1	8.2
WN	State Health Radiation Protection Section, Madison, WI	8	229	91.9	4.3	3.8
WP	Washington Public Power Supply System, Richland	20	436	92.3	6.3	1.4
WS	Weldon Springs Site, St Charles, MO	11	42	83.2	6.0	10.8
WV	West Valley Nuclear Services Co, Inc., NY	27	644	91.2	5.4	3.4
YA	Duke Eng. & Sci. Envir. Lab., MA	10	371	98.5	0.2	1.3
YP	US Army Proving Ground, Yuma, AZ	18	46	94.4	5.6	0.0
YU	Institute of Occupational & Radio. Health, Yugoslovia	3	47	76.0	12.3	11.7

Table 6. Comparison of the Results Obtained by Using Proposed Method on QAP Data 9809 with that of the Existing EML Method

	existing EML method[5]				proposed method			
matrix	total no. of analyses	% A	% W	% N	total no. of analyses	% A	% W	% N
air filters	878	77	13	10	878	89	3	8
soil	953	88	7	5	953	88	7	5
vegetation	430	75	17	8	430	89	3	8
water	956	77	13	10	956	86	7	7

pated 24, 30, 19, and 27 times, respectively. Some of the laboratories participated 32 times and have still lower % N results, e.g., AN (1.3%), and KA (0.6%).

APPLICATION OF CONTROL LIMITS

Control limits from the historical data analyses have been applied to the analysis of the whole QAP database (1982−1998). Figure 1 represents the proportion of "acceptable", "acceptable with warning", and "not acceptable" evaluations for the individual four matrices and cumulative total of the reported data. From Figure 1, it is understood that % N (i.e., not acceptable data) for air filters, soil, vegetation, and water is 5%, and the cumulative percentage is also 5%. Percentage W (or acceptable with warning data) for air filters and water is 6%, and for soil and vegetation it is 5%, and the cumulative percentage is 5%. On the other hand, percentage A (or acceptable data) for air filters and water is 89%, that for soil, and vegetation is 90%, and the cumulative percentage is 90%.

The proposed control limits were also applied to the analysis of EML QAP data 9809 and compared with the reported results obtained from U.S. Department of Energy Report, EML-600.[5] Results are shown in Table 6.

CONCLUSION

To evaluate the control limits for the performance of different laboratories contracted to DOE, the EML QAP historical database has been reevaluated. All of the radionuclide/matrix pair have been analyzed individually. It is observed from the analyses that there is no significant effect of matrix on radionuclides. The criteria for control limits were established based on a z-score calculation. To calculate z-scores, trimmed means and trimmed SDs were calculated by discarding 5% of the bad outliers from both sides (lowest and highest). Due to the presence of some bad outliers in the historical database, it is advantageous to calculate trimmed means and trimmed SDs instead of means (or medians) and SDs. As the actual distribution of reported measurements is not necessarily symmetrical, the new method is an improvement over the old method because it does not insist on labeling equal numbers of measurements on each side as not acceptable.

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