SEPTAGE QUALITY AND ITS EFFECT ON FIELD LIFE FOR LAND APPLICATIONS[1]

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ABSTRACT: Maintenance of the more than 24 million septic tanks in the U.S. requires removal and disposal of septage. Disposal options include application to agricultural lands where the nutrients and organic matter can provide soil benefits. However, pathogens and contaminants are also contained in septage. An extensive search turned up very few data on septage quality, and those reveal high variability. The data used by the U.S. Environmental Protection Agency (EPA) in developing regulations had the lowest metal concentrations among the nine data sets that could be compared. Based on these data, EPA assumed that septage could be applied to agricultural land for more than 100 applications before reaching unacceptable cumulative loading of metals. They thus did not establish federal standards for metals in septage, and no monitoring is required under federal rules governing septage disposal. Analysis of the nine data sets we found showed that field site life would be reached in less than 100 applications for most septage and cumulative loading limits established by EPA for sewage sludges will be exceeded in 16 applications for some septage as opposed to the 100 application estimate used by EPA. Determination of acceptable cumulative loading depends on numerous technical and policy considerations. All septage sources reached the more restrictive loading limits such as those established by the New York State Department of Environmental Conservation (NYSDEC) and the recommendations in Cornell publications in less than 100 applications. In one case the cumulative limit for copper was exceeded in a single application. These findings suggest additional data are needed on septage quality and that the federal and state agencies responsible for regulating application of septage to agricultural land should reassess their standards.

(KEY TERMS: septage; land application; Part 503 standards, site life, septic tank, septic waste, loading limits, cumulative limits.)

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INTRODUCTION

More than 24 million septic systems are used as the method for treating domestic wastewater in approximately one quarter of the households in the United States (U.S.) (Eddy, 1999). Federal regulations, 40 CFR Part 503, define domestic septage as "either liquid or solid material removed from a septic tank, cesspool, portable toilet, Type III marine sanitation device, or similar treatment works that receive only domestic sewage" (USEPA, 1994). Periodic emptying of the solids in septic systems is required for proper maintenance, and that septage must be disposed of. Disposal of septage via discharge to a sewage treatment plant is generally the preferred option from an environmental perspective. In some locations, however, there are no wastewater plants that can accept septage, which is more concentrated than typical sewage flows.

Application of septage to land is an option for disposal. There are environmental and health considerations, particularly concerning pathogens, nutrients, and contaminants such as some metals, which have led to federal and state rules for land application. While the liquid percolate from septic systems may present similar concerns, some contaminants such as metals are likely to be preferentially concentrated in septage solids. The potential sources of metals in domestic septage include products leaching from piping and appliances, products used, and carry-over from other wastes in the hauling vehicle (Cooper, 1980).

Under federal rules, septage can be land applied to "nonpublic contact sites," including agricultural fields,

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forest land, and reclamation sites (USEPA, 1993). To meet federal regulations to minimize attraction of vectors (such as flies and rats), land applied septage must be treated by one of three means: "subsurface injection, incorporation (surface application followed by plowing within six hours), or alkali stabilization (pH of 12 or greater for 30 minutes prior to application)" (USEPA, 1994). The federal regulations also include various restrictions on the crops that may be grown on the site and on access to the site by the public (USEPA, 1993, 1994). The maximum application rate of domestic septage depends on the "septage nitrogen content, the amount of nitrogen required by the crop and the planned yield of the crop" (USEPA, 1994). The federal guidelines (USEPA, 1994) instruct septage applicators to use the following equation:

$$\text{Annual Application Rate} = \text{Nitrogen Required for the Crop}/0.0026 \quad (1)$$

This rate, in gallons per acre per year, is "based on the amount of nitrogen needed by the crop or vegetation grown [lbs per acre per year]... and on the concentration of available nitrogen" (USEPA, 1992). Using various assumptions regarding crop nutrient needs and septage nitrogen content, the EPA calculated a reasonable maximum annual application rate of 116,000 gal/ac/yr (USEPA, 1992).

To protect the environment and public health, the EPA developed cumulative pollutant loading rates for several heavy metals in land applied sewage sludges (USEPA, 1992). The EPA used these values to evaluate the potential risks from metals in land applied septage. It calculated the loading of these metals that would be expected if 116,000 gal/ac/yr of septage were applied. The cumulative limits were used to calculate the number of times that septage could be applied to a field without exceeding the cumulative pollutant loading rates. In this paper, "field site life" refers to the number of applications required to reach the cumulative loading limit.

The EPA cumulative limits for sewage sludge application are based on a risk assessment that evaluated risks to people and to agricultural productivity (USEPA, 1992). Application of different assumptions and policy choices will lead to significantly different cumulative loading limits (see Table 1). The EPA loading limits are significantly higher than those of most other countries and have been criticized as nonprotective by some scientists (Harrison *et al.*, 1999).

In developing the federal rules for septage, EPA calculated that it would take more than 100 applications of septage before the cumulative pollutant loading rates it established were exceeded. That led EPA not to regulate metal levels in septage (USEPA, 1992). Rather, nitrogen was established as the limiting factor. This conclusion was based on a very limited set of septage quality data. This paper demonstrates that metal levels used by EPA are not representative and that cumulative pollutant loading limits established by EPA and others may be exceeded much sooner than 100 applications.

States are allowed to make rules more stringent than the federal rules and New York State (NYS) does (NYSDEC, 1985, 1998). For small septage haulers (two or fewer trucks) the New York State Department of Environmental Conservation (NYSDEC) limits application to a maximum of 25,000 gal/ac/yr. This is not established in regulations, but is a condition of each septage hauler's permit (Ly Lim, personal communication, NYSDEC, 2000). For larger operations, septage requirements are essentially the same as

TABLE 1. Cumulative Loading Limits for Metals Applied to Agricultural Soils From Sewage Sludges and Septage.

Element	USEPA Sludge CFR Part 503 (lbs/acre)	NYSDEC 6 NYCRR Part 360 Sludge and Large Scale Septage* (lbs/acre)	Cornell Cooperative Extension Sludge Recommendations** (converted to lbs/acre)
As	36	36	–
Cd	32	3	3.6
Cu	1335	75	100
Hg	15	15	1.8
Mo	–	–	3
Ni	373	30	44
Pb	267	267	–
Se	89	89	9.2
Zn	2492	150	130

*NYSDEC cumulative loading limits depend on soil classification. The most stringent limits pertaining to the best agricultural soils are shown.

**Cornell recommendations for some elements vary depending on soil texture. The mid-point of the ranges are shown.

sewage sludge land application rules (NYSDEC, 1998). For these larger operations, NYS has established cumulative loading limits for some metals that are more stringent than EPA's (Table 1), and testing for nutrients and contaminants is required. Application rates for these larger operations are based on agronomic nitrogen calculations. An additional set of recommendations for cumulative loading limits is found in the 2002 Cornell Guide for Integrated Field Crop Management (Cornell, 2002) (Table 1).

SEPTAGE CHEMICAL CHARACTERISTICS

All available sources of data on septage quality were examined in this study. Twelve sources characterizing the physical and chemical characteristics of domestic septage and one source of recreational vehicle septage have been compared for nutrients and metals. All of these data were compiled before 1992, except for the NYSDEC data that were collected in the fall of 2000 and the data collected from a recreational vehicle park in 1997. The majority of sampling was performed before 1980. This paper will make frequent reference to the "Source I" study (USEPA, 1992). This was the study used by EPA to justify requirements for the disposal of domestic septage different from those for sewage sludges, based on perceived differences in chemical characteristics.

Table 2 displays the available U.S. septage quality data as reported in the literature. The letters correlate to the sources found in the Source List that follows the table, which describes, where possible, how samples were retrieved and their location. The sources are arranged chronologically and cover a span of approximately two decades.

Due to the varying total solids values of the different sources, the wet weights for the sources that supplied total solid measurements were converted to dry weights to make comparisons (Table 3). It is clear that the EPA's 1992 reported dry weight values (Source I) for the metals cadmium (Cd), chromium (Cr), mercury (Hg), nickel (Ni), lead (Pb), and zinc (Zn) are the lowest values when compared with the other domestic septage data sources. For Hg and Pb, the EPA's mean values are more than an order of magnitude lower than the mean values of other septage samples. EPA's 95th percentiles for Hg and Pb were lower than all other studies' means (Table 3). Unfortunately, the very low solids contents of samples J1, J2, and J3 make comparisons based on dry weight conversion inaccurate; thus these samples are not included in Table 3. Data set H was also excluded from further analysis because total solids were only estimated, not measured.

Mean values for all the septage data sources, except Source I, showed higher concentrations than those of sewage sludge concentrations for Cd and Hg (Table 3). Three are higher in both Cu and Zn, and all but one are higher than the mean Pb sludge concentrations reported in an EPA survey of sewage sludge quality performed in 1988 (USEPA, 1990). With the implementation of federal pretreatment programs, mean sludge quality nationally has improved for some of these contaminants so that the disparity between septage and sludge quality has likely increased since there have been no programs directed at improving septage quality. Although there are too few data to permit analysis of trends of metal concentrations, there is nothing in the data to suggest that septage quality has improved with time.

Metal concentrations in recreational vehicle wastes (Source K) are far higher than those in other septage samples when compared on a dry weight basis (Table 3). Recreational vehicle waste is very concentrated compared to other domestic septages (USEPA, 1995). If applied at the same rates, this would lead to a large over application of nitrogen and potentially heavy loading of any contaminants present in that type of septage.

Since many of the total solids values of the septage samples were so low (Table 1), conversion to dry weights may not be an accurate way of normalizing the data. Given the very low solids content, a small error in measurement of percent solids can result in large inaccuracies in concentrations of constituents when converted to dry weights.

As another approach, the data were normalized using total Kjeldahl nitrogen (TKN), since nitrogen is the determining factor for calculating the agronomic rate of application. The concentration of each metal for each source was divided by its TKN concentration. Due to data limitations, these calculations could only be performed on nine of the 12 septage data sets (Table 4). The TKN value of 2.88 mg/L for J1 is unreliable, as it is not possible for septage to have such a low value for TKN. Thus it is not included in Table 4. Data set H was not included in the analysis because TKN was given as a percent, and total solids were not measured, so there was no way to develop comparable values.

As with the dry weight calculations, when normalized by TKN, the mean values for metals used by EPA (Source I) were lower than all the other domestic septage data, except for selenium (Se) and Zn. Even the 95th percentile values for Source I were less than the mean values for the other septage sources for Cd, Cu, Hg, Ni and Pb. When normalized by TKN, metal concentrations in recreational vehicle wastes are similar to those found in septage samples.

TABLE 2. Septage Quality Data as Reported in the Literature.

Septage Characteristics	A Mean (mg/L)	A Stand. Dev. (mg/L)	B Mean (mg/L)	C Mean (mg/L)	D Mean (mg/L)	E Mean (mg/L)	E Stand. Dev. (mg/L)	F Mean (mg/L)	G Mean (mg/L)
TS	22,400	26,900	38,000	11,600	34,106	13,753	13,820	15,000–17,500	
Al			48		48				
As			0.16		0.16				0.141
Cd			0.71	0.1	0.27			0.2	0.097
Co									0.406
Cr			1.1	0.6	0.92				0.49
Cu			6.4	87	8.27	7.05	14.8	21.83	4.835
Fe			200		191				39.287
Hg			0.28		0.23				0.005
Mn			5		3.97				6.088
NH3	72	41.7	160	100	97	58.1	34.1		
TKN			680	410	588	138.6	106.7		
Ni			0.9	0.4	0.75			<1	0.526
P (total)			250	190	210	30.1		92	
Pb			8.4	2	5.2	0.97	1.14	3.75	1.21
Se			0.1		0.076				
Zn			49	9.7	27.4	16.8	25.3	18.01	9.971
TSS	2,350	1,410	13,300	9,500	12,862				
TVS			25,300	8,170	23,100				
VSS	1,819	1,390	8,700	7,650	9,027				
BOD	4,794	4,410	5,000	5,890	6,480	2,256	2,352		
COD(total)	26,162	26,900	42,900	19,500	31,900	11,130	13,053	9,900	

Septage Characteristics	H* De-watered Mean (mg/L)	I Mean (mg/L)	I 95% (mg/L)	J1 (mg/L)	J2 (mg/L)	J3 (mg/L)	K Rec. Vehicle Mean (mg/L)	F Rec. Vehicle Range (mg/L)
TS	20,000 (est.)	24,900	96,400	6,200	3,890	4,980	13,000	8,000-21,000
Al								
As				0.119	0.0518	0.0219		
Cd	3.27	0.0059	0.0193	0.0456	0.0764	0.0184	1.5	1.0-2.0
Co								
Cr	20	0.0513	0.155	0.324	0.266	0.0701		
Cu	1,069	0.545	2.030	11.7	4.22	2.7	220	35-808
Fe								
Hg	1.6	0.001	0.004	0.0162	0.0205	0.0111		
Mn								
NH3				189	112	113		
TKN	0.44%	115	352	2.88**	103	406	26,000	20,000-35,000
Ni	13	0.005	0.11	0.347	0.266	0.107	6.2	4.5-8.0
P (total)	1.08%	36.1	122	0.282	2.6	10.7	4,400	3,500-6,200
Pb	104	0.0512	0.135	9.0	0.613	0.504	23	14-30
Se		0.024	0.073	0.110	0.0131	0.0201		
Zn	1,379	7.060	26.8	24.7	13.9	8.35	450	175-840
TSS								
TVS				69.6	4,000	1,940		
BOD							11,000	4,900-15,000
COD							33,000	29,000-38,000

*Note that this is dewatered septage with an average of 20 percent TS. Lack of data on TS and TKN as percent precluded use of this data set in analysis based on dry weight or normalized based on nitrogen content.

**TKN value is an outlier and assumed to be in error.

Sources of Septage Data for Tables 2 Through 6

A. Kolega, J.J. *et al.*, 1977. The 180 samples were primarily from vehicles carrying septage to the E. Hartford, Connecticut Water Pollution Control Facility. Samples of septage were collected at the beginning, mid-point, and near end of loading. Most septage was from households, but samples included schools, convalescent home, restaurants, motels, apartments, a food chain store, and light industry.

B. Cooper, I. A. and J. W. Rezek, 1980. Data compiled by EPA's Municipal Environmental Research Lab in Ohio. Metal data from studies in Lebanon, Ohio, and Blue Plains in Washington, D.C.

C. Segall, B.A. *et al.*, 1979. Samples were from individual trucks and from storage tanks containing up to 67,000 gallons of waste. Concentrations reported are averages of the results of all sources and may include some nondomestic septage.

D. U.S. Environmental Protection Agency (USEPA), 1984. Literature review of 12 studies conducted in the U.S. prior to 1980.

E. Ritter, W. F. *et al.*, 1992. Twenty-five loads of Sussex County, Delaware, lime stabilized septage from a single hauler that were applied to agricultural land as part of an experiment were randomly sampled. Included domestic septage from businesses as well as homes.

F. Rubin, A. R., 1991. The average of 100 samples collected from pump trucks during land application events from three North Carolina counties is reported. The first flush, mid-tank loads, and end of tank loads were sampled.

G. U.S. Environmental Protection Agency (USEPA), 1991. Monitoring data from 1986 to 1991 spot checks of septage hauler loads discharged to nine Waste Water Treatment Plants (WWTPs).

H. Williams, T. *et al.*, 1991. Samples from a septage dewatering and composting facility in Thompson, New York, at an existing Waste Water Treatment Plant (WWTP). Variance in results due in part to degree of dewatering that ranged from 14.5 percent solids to 27.8 percent solids with a 20 percent total solids average for 1990.

I. U.S. Environmental Protection Agency (USEPA), 1992. Nine trucks delivering septage to the Madison Metropolitan Sewage District in Madison, Wisconsin, were each sampled once in 1991.

J(1-3) Samples from three 1000-gallon trucks of septic services in New York State (one in Pembroke, New York, and two in Rotterdam, New York) in late 2000 by the NYSDEC.

K. Rubin, A.R., 2000 (unpublished data). Recreation vehicle septage. Samples are of the waste from a receiving station at a recreational vehicle park. The data reflect composite monthly samples from May through September from multiple vehicle owners.

TABLE 3. Septage Quality Data Converted to Dry Weight (reported in mg/kg).

Septage Characteristics	A	B	C	D	E	F	I Mean	I 95%	K Rec. Vehicle	U.S. Sludge Mean
Conversion Factor	45	26	86	29	73	62	As Reported by EPA	As Reported by EPA	77	Reported by EPA
Al		1,250		1,400						
As		4		5						10
Cd		19	9	8		12	3.21	9.18	116	7
Cr		29	52	27			15.5	59.6		119
Cu		170	7,500	240	510	1350	317	1,110	16,940	741
Fe		5,200		5,540						
Hg		7		7			0.118	0.456		5
Mn		130		115						
NH3	3,240	4,160	8,600	2,800	4,240					
TKN		17,700	35,300	17,000	10,100		48,400	187,000	2,002,000	
Ni		23	34	22			8.32	29.8	480	43
P (total)		6,500	16,300	6,100	2,200	5,700	6,410	22,400	339,000	
Pb		218	170	150	70	230	12.1	44.6	1,800	134
Se		3		2			4.02	9.46		5
Zn		1,270	830	800	1,230	1,120	678	2,170	35,000	1,202

TABLE 4. Septage Quality Data Normalized by Nitrogen Concentration.

Septage Characteristics	B	C	D	E	I Mean	I 95%	J2	J3	K Rec. Vehicle
TKN	680	410	588	138.6	115	352	103	406	26,000
As/TKN x 1000	0.2		0.3				0.5	0.05	
Cd/TKN x 1000	1.0	0.2	0.5		0.05	0.05	0.7	0.05	0.06
Cu/TKN x 1000	9	210	14	51	5	6	41	7	8
Hg/TKN x 1000	0.4		0.4		0.01	0.01	0.2	0.03	
Mo/TKN x 1000							1.2	0.1	
Ni/TKN x 1000	1.3	1	1.3		0.04	0.3	3	0.3	0.2
Pb/TKN x 1000	12	5	9	7	0.5	0.4	6	1.2	0.9
Se/TKN x 1000	0.2		0.1		0.2	0.2	0.1	0.05	
Zn/TKN x 1000	72	24	47	120	62	76	135	21	17

Septage quality can be highly variable. The standard deviations are approximately equal to the means for most constituents in the two sources for which standard deviations are reported (Sources A and E, Table 2). Each of these sources included samples from a number of facilities or loads that were taken at approximately the same time and location and analyzed by the same laboratory. The samples taken by the NYSDEC at the same time from similar septic hauling vehicles in upstate New York (thus expected to be comparable) (samples J1, J2, and J3) show considerable variability. Metal concentrations in one of these (J3) were among the lowest values and another (J2) had metal concentrations among the highest values when normalized by TKN (Table 4). Sources of the variability have not been identified, but they might include the age of the septage, household habits and characteristics, tank design, sampling procedures, and previous contamination of the hauling vehicle (Cooper, 1980).

NITROGEN IN SEPTAGES

Fertilization is the primary rationale for using septage on agricultural lands. The goal is to apply septage at an agronomic rate sufficient to provide for crop nitrogen needs but not at excessive rates that might lead to pollution of ground water. An important aspect of agronomic application of nitrogen relates to the rate of mineralization of organic N, which is not well characterized for septage. Recent work on sewage sludges demonstrates large variation in the mineralization rates of different sludges under different conditions (Gilmore *et al.,* 2000). Since mineralization rates for septage are not known, for this paper, EPA's assumptions for yearly residual organic nitrogen were used in calculating agronomic application rates. EPA states that "fifty percent of the organic nitrogen is assumed to become available to the crop or vegetation in the first year after application of domestic septage; 20 percent in the second year; 10 percent in the third year; and the remainder at 3 percent per year until no more of the organic nitrogen remains." The low rate assumed after the third year led EPA to suggest that in calculating agronomic application rates, no organic nitrogen be considered available to the crop or vegetation in the fourth and subsequent years (USEPA, 1992).

EPA provides a method for calculating the amount of plant available nitrogen in septage. The first step is to calculate the amount of Ammonia-N:

$$\text{Ammonia-N} = 0.43 \ \text{TKN} \quad (2a)$$

$$\text{Organic-N} = \text{TKN-Ammonia-N} \quad (2b)$$

Note: Comparing the measured TKNs of the sources reported here and the measured NH_3s also reported, the relationship is closer to 0.25, instead of 0.43, but to facilitate comparisons, EPA's assumption was used in these calculations.

Available N is calculated based on assumed mineralization rates. Beginning with the third year, "the Agency assumes 'steady state conditions' are achieved with respect to the available nitrogen concentration" (USEPA, 1992).

The following example was provided by the EPA for septage applied annually:

TKN = 352 mg/L
NH_3 = 150 mg/L
Organic-N = 202 mg/L

Available N in mg/L			
	Year 1	Year 2	Year 3
Ammonia-N	150	150	150
Organic-N	101	101	101
		⋮	⋮
		41	41
			⋮
			21
Totals	251	292	313

Going back to Equation (1), the equation is changed to

$$AAR = N/(ANC \times 8.34/1{,}000{,}000) \qquad (3)$$

where AAR = Annual Application Rate = gal/ac/yr; N = nitrogen required by crop (lbs/ac/yr); and ANC = Available Nitrogen Concentration (313 mg/L in the above example).

Calculated hypothetical annual application rates based on reported TKN measurements for the septage sources are shown in Table 5. They are based on the amount of septage applied if septage applicators tested their septage for TKN and sought to apply 300 lbs available N/acre (300 lbs/acre is the amount assumed by EPA in its calculation of a reasonable maximum loading rate).

TABLE 5. Annual Application Rates Needed to Supply 300 lbs N/ac/yr.

Source	Annual Application Rate (gallons/acre/year)
B	60,000
C	100,000
D	75,000
J2	375,000
J3	100,000

REACHING CUMULATIVE LOADING LIMITS

Calculations were performed to determine how many applications could be made of each septage source before cumulative loading limits were reached (Table 6). The number of applications depends both on the rate of application of septage as well as on the specific cumulative loading limit established or recommended. The first row in each section of Table 6 uses EPA's calculated reasonable maximum annual application rate of 116,000 gal/ac/yr and EPA's cumulative loading limits for sewage sludges, as stated in 40 CFR Part 503 (see Table 1). The second row uses EPA's estimated maximum annual application rate of 116,000 gal/ac/yr and recommended loading limits as stated in the 2002 Cornell Guide for Integrated Field Crop Management (Cornell, 2002). The third row uses NYSDEC's maximum annual application rate of 25,000 gal/ac/yr for small haulers and NYSDEC's loading limits for land applied sewage sludges as stated in 6 NYCRR Part 360 (NYSDEC, 1998). The fourth row uses NYSDEC's maximum annual application rate for small haulers and the Cornell recommended loading limits for land applied sewage sludges.

Where nitrogen data are available, the fifth, sixth, and seventh rows use application rates based on application of 300 lbs/ac of available N (Table 5) and calculate the number of applications before exceeding EPA, NYSDEC, and Cornell loading limits. Calculated field site life is based on these calculations (USEPA, 1992):

$$FL = CL/AL = CL/(PC \times AAR \times 8.34) \qquad (4)$$

where FL = the number of years that a field can receive annual applications of domestic septage at the calculated application rate before reaching the cumulative metal loading limit; CL = cumulative loading rate in lbs/ac; AL = annual loading rate in lbs/ac/yr; PC = pollutant concentration in mg/L; AAR = annual application rate in million gal/ac/yr; and 8.34 = conversion factor.

Table 7 calculates field site life based on the different application rates and cumulative loading limits shown in Table 6. It demonstrates that using EPA's reasonable maximum application rate of 116,000 gal/ac/yr and the cumulative loading limits set by EPA for sewage sludges, field life would be reached in less than 100 applications for five of the nine septage samples (Table 7, column 1). Field site life of only 16 applications based on Cu is predicted for one septage source (Table 6, Source C). Pb was the most frequently limiting metal, with four of the nine samples having a field site life of less than 100 applications and one as short as 31 applications under the assumption of the EPA application rate and sludge cumulative limits.

The second column of Table 7 demonstrates how many sources would not be able to apply more than 100 applications using EPA's calculated reasonable maximum annual application rate of 116,000 gal/ac/yr

TABLE 6. Calculated Field Site Life (number of applications) for Each Septage Source.

Application Rate/ Loading Limit	As	Cd	Cu	Hg	Ni	Pb	Se	Zn	Mo
				Source B					
EPA/EPA	233	**47**	216	**55**	428	**33**	920	**53**	
EPA/CU		**5**	**16**	**7**	**51**		**95**	**3**	
NYSDEC/NYSDEC	1,079	**20**	**56**	257	160	152	4,269	**15**	
NYSDEC/CU		**24**	**75**	**31**	234		441	**13**	
TKN/EPA	450	**90**	417	107	828	**64**	1,779	102	
TKN/NYSDEC	450	**8**	**23**	107	**67**	**64**	1,779	**6**	
TKN/CU	NA	11	**44**	**14**	167		200	**11**	
				Source C					
EPA/EPA		331	**16**		964	138		266	
EPA/CU		**37**	1		114			**14**	
NYSDEC/NYSDEC		144	**4**		360	640		**74**	
NYSDEC/CU		173	**6**		528			**64**	
TKN/EPA		384	**18**		1,118	160		308	
TKN/NYSDEC		**36**	**1**		**90**	160		**19**	
TKN/CU		**48**	**2**		225			**35**	
				Source D					
EPA/EPA	233	123	167	67	514	**53**	1,210	**94**	
EPA/CU		**14**	**12**	**8**	**61**		125	**5**	
NYSDEC/NYSDEC	1,079	**53**	**43**	313	192	246	5,617	**26**	
NYSDEC/CU		**64**	**58**	**38**	281		581	**23**	
TKN/EPA	360	189	258	104	795	**82**	1,872	145	
TKN/NYSDEC	360	**18**	**14**	104	**64**	**82**	1,872	**9**	
TKN/CU	**NA**	**24**	**27**	**14**	160		210	**16**	
				Source E					
EPA/EPA			196			285		153	
EPA/CU			**15**					**8**	
NYSDEC/NYSDEC			**51**			1,320		**43**	
NYSDEC/CU			**68**					**37**	
				Source F					
EPA/EPA		165	**63**			**74**		143	
EPA/CU		**19**	**5**					**7**	
NYSDEC/NYSDEC		**72**	**16**			341		**40**	
NYSDEC/CU		**86**	**22**					**35**	
				Source G					
EPA/EPA	264	341	285	3,101	733	228		258	
EPA/CU		**38**	**21**	372	**86**			**13**	
NYSDEC/NYSDEC	1,225	148	**74**	14,388	274	1,058		**72**	
NYSDEC/CU		178	**99**	1727	401			**63**	

TABLE 6. Calculated Field Site Life (number of applications) for Each Septage Source (cont'd.).

Application Rate/ Loading Limit	As	Cd	Cu	Hg	Ni	Pb	Se	Zn	Mo
				Source J1					
EPA/EPA	313	725	118	957	1,111	31	836	104	
EPA/CU		**82**	**9**	115	131		**86**	**5**	**14**
NYSDEC/NYSDEC	1,451	316	**31**	4,441	415	142	3,881	**29**	
NYSDEC/CU		379	**41**	533	608		401	**25**	**66**
				Source J2					
EPA/EPA	718	433	327	756	1,449	450	7,023	185	
EPA/CU		**49**	**24**	**91**	171		726	**10**	**25**
NYSDEC/NYSDEC	3,333	188	**85**	3,509	541	2,089	32,585	**52**	
NYSDEC/CU		226	114	421	793		3,368	**45**	116
TKN/EPA	222	134	101	234	448	139	2,172	**57**	
TKN/NYSDEC	222	**13**	**6**	234	36	139	2,172	**3**	NA
TKN/CU	NA	**17**	11	**31**	**90**		244	**6**	**21**
				Source J3					
EPA/EPA	1,699	1,798	511	1,397	3,603	548	4,577	308	
EPA/CU		202	**38**	168	425		473	**16**	**80**
NYSDEC/NYSDEC	7,884	782	133	6,481	1,345	2,541	21,237	**86**	
NYSDEC/CU		938	178	778	1,972		2,195	**75**	369
TKN/EPA	1,971	2,085	593	1,620	4,180	635	5,309	358	
TKN/NYSDEC	1,971	195	**33**	1,620	336	635	5,309	**22**	NA
TKN/CU	NA	261	**62**	216	840		597	**40**	246

Note: Values less than 100 applications are indicated in bold.

and the recommended loading limits for sewage sludges in the Cornell Guide for Integrated Field Crop Management. Under this scenario, all sources would have a field site life of far less than 100 applications. All metals exceeded cumulative limit recommendations in less than 100 applications for at least one source. Field site life was as short as one application for Cu, three for Zn, five for Cd, and seven for Hg. Cu and Zn would be limiting for all sources, and Cd and Mo would limit all but one source.

The third column of Table 7 demonstrates that even using the NYSDEC low application rate of 25,000 gal/ac/yr and NYSDEC cumulative load limits, all sources exceeded one or more of the cumulative limits in less than 100 applications. One source exceeded the field life of Cu in four applications. It should be noted, however, that this source (C) had unusually high copper levels that may reflect some nondomestic inputs.

The fourth column demonstrates that all nine sources exceed the Cornell recommended loading limits in less than 100 applications even using the low NYSDEC application rate of 25,000 gal/ac/yr. Under this scenario, Cu and Zn are most frequently limiting, but Cd and Hg, are limiting in several samples. Calculations of field site life based on agronomic N application rates show that four out of five septage sources exceeded EPA cumulative limits in less than 100 applications and all septage sources exceeded the NYSDEC and Cornell recommended cumulative loading limits for one or more metals in less than 100 applications (Table 7, columns 5, 6, and 7). Cu, Cd, Zn and Pb were the most frequently exceeded limits, with field site life as short as a single application (Table 6).

CONCLUSIONS

The federal and state agencies responsible for regulating application of septage to agricultural land should reassess their standards. The current federal standards are based on data from one study in which

TABLE 7. Number of Septage Sources Reaching Cumulative Loading Limits in Less Than 100 Applications.

	EPA Application Rate (116 gal/ac/yr)		NYSDEC Application Rate (25,000 gal/ac/yr)		Agronomic-N Application Rate		
Metal	EPA Loading Limit	CU Recommended Loading Limit	NYSDEC Loading Limit	CU Recommended Loading Limit	EPA Loading Limit	NYSDEC Loading Limit	CU Recommend Loading Limit
Any*	5/9	9/9	9/9	9/9	4/5	5/5	5/5
As	0/6	NA	0/6	NA	0/4	0/4	NA
Cd	1/8	7/8	3/8	3/8	1/5	3/5	4/5
Cu	2/9	9/9	8/9	7/9	1/5	4/5	5/5
Hg	2/6	3/6	0/6	2/6	0/4	1/4	3/4
Mo	NA	3/3	NA	1/3	NA	NA	1/2
Ni	0/7	3/7	0/7	0/7	0/5	2/5	1/5
Pb	4/9	NA	0/9	NA	2/5	2/5	NA
Se	0/5	2/5	0/5	0/5	0/4	0/4	0/4
Zn	2/9	9/9	9/9	9/9	1/5	5/5	5/5

Notes: Numerator = number of sources that have metal concentrations that limit the number of field applications to less than or equal to 100 at the specified rate of application and cumulative loading limit.
Denominator = number of sources that analyzed for that metal.
NA indicates that no cumulative limit value is established.

*"Any" is the number of sources that exceeded the cumulative loading limit in less than 100 applications for one or more of the metals.

septage metal concentrations were far lower than in other studies. Few data are available on septage quality and the available data show large variation, thus conclusions must be considered preliminary and suggest a need for further testing of septage.

Septage metal levels have been assumed to be lower than those in sewage sludges, but this is not reflected in the available data. The data used by EPA to establish regulations for land application of septage had very low metal concentrations, not reflective of septage quality reported in other studies. Using those data and a risk assessment that developed cumulative loading limits for metals in land applied sewage sludges, EPA assumes that septage can be applied for 100 or more applications before reaching unacceptable cumulative loading of metals in soils. However, in this paper using all available septage quality data, a field site life of less than 100 applications is predicted for most septage. Cumulative loading limits established by EPA for sewage sludges will be exceeded in as few as 16 applications for some septage. Other agencies and organizations have established cumulative loading limits more restrictive than EPA based on different assumptions and assessment of risks. All septage sources reached the stricter loading limits such as those established by NYSDEC and the recommendations in the Cornell Guide for Integrated Field Crop Management in less than 100 applications, in one case in a single application. Cu and Zn are the most frequently limiting elements when considering septage land application, but other elements are found to be elevated and are thus limiting in certain septage sources. More restrictive rates of septage application, such as the NYSDEC application rate limit for small septage hauling operations, will help to limit the over application of some metals but may not supply most of a crop's nitrogen requirements. However, even at this low rate of application, the NYSDEC cumulative loading limits would be exceeded by all of the septage sources in less than 100 applications.

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