

Additional file 1

Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

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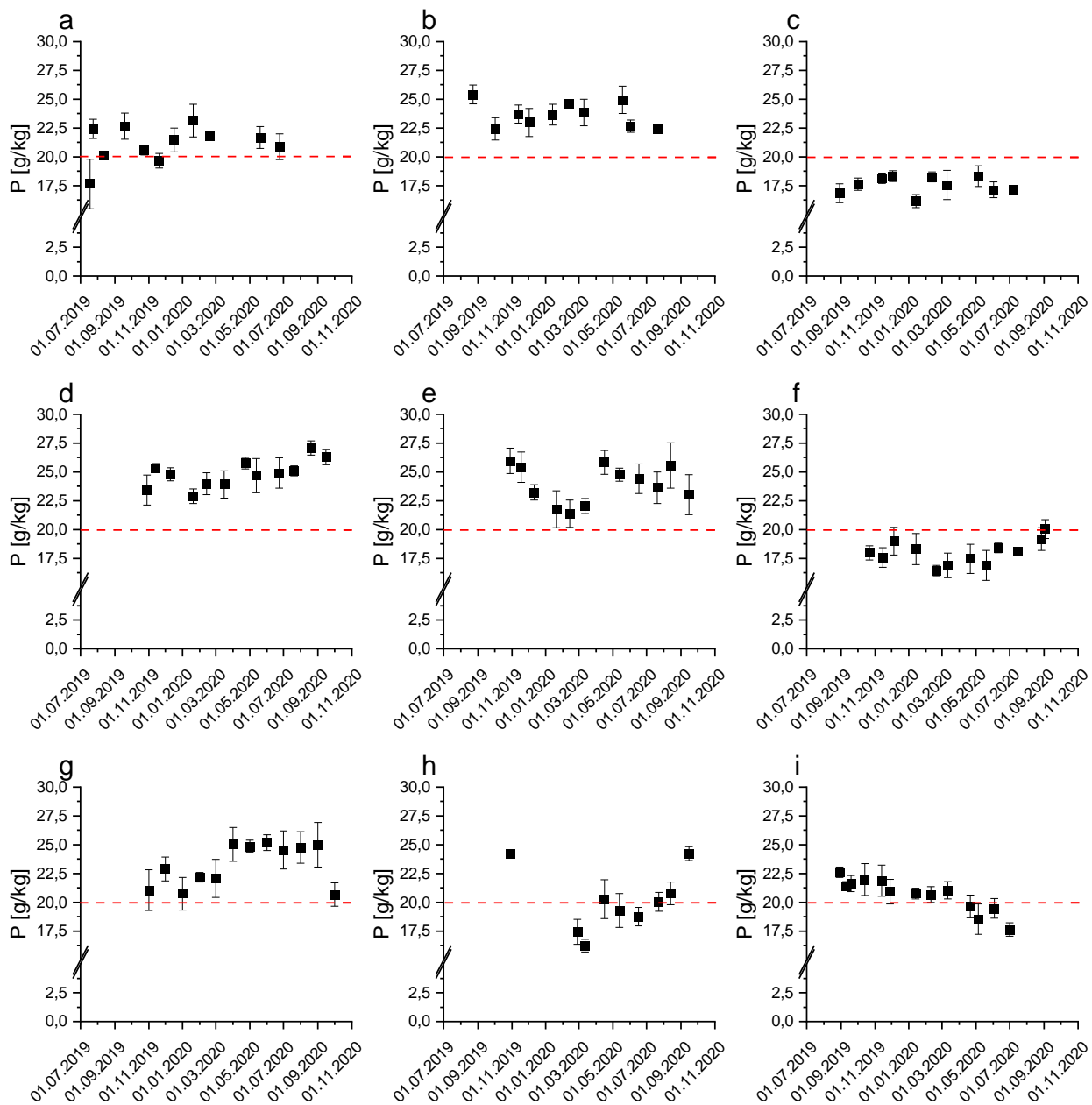


Figure S1: Phosphorus content variations (dry matter) in municipal sewage sludge at 9 WWTPs

The error bars in Figure S1 are shown based on the P measurement standard deviation between the duplicates (ICP-OES) and the standard deviation of the moisture analysis (triplicates). The ICP-OES coefficients of variation (RSD_{OES}) for all duplicates was at maximum 6%, average 2%. However, moisture contents showed higher differences with RSD_{moist} up to 11%, average 3%. In general, further replicates were done in case of $RSDs > 5\%$ but due to the need of higher masses more replicates were not possible for the moisture analysis for all samples. All monthly values for the phosphorus content are also shown in Table S2, S4, S6, S8, S10, S12, S14, S16 and S18 (6th row).

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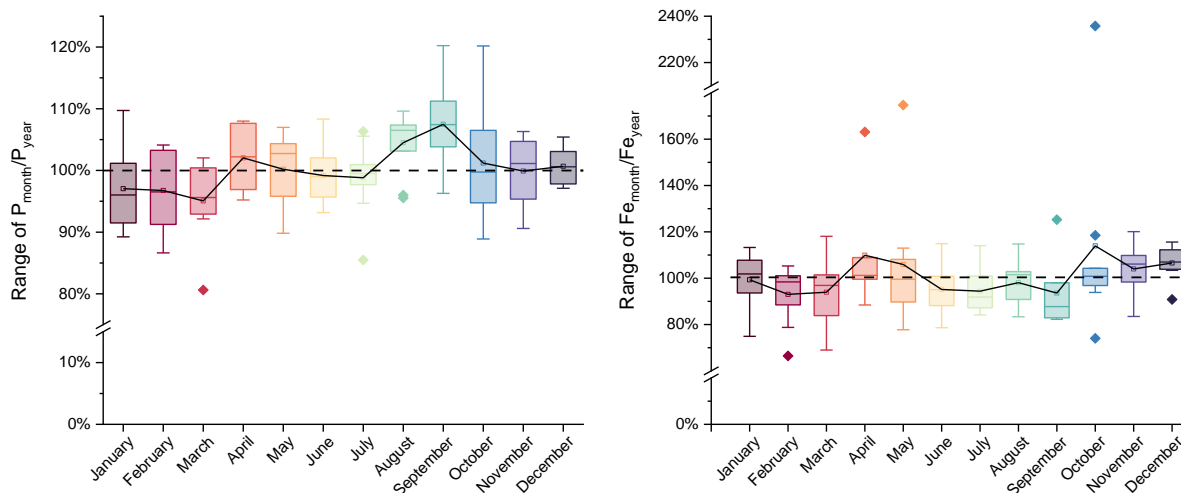


Figure S2: Range of monthly phosphorus and iron content by annual mean during the year

Phosphorus variations from the annual mean are also shown in table S2, S4, S6, S8, S10, S12, S14, S16 and S18 (7th row)

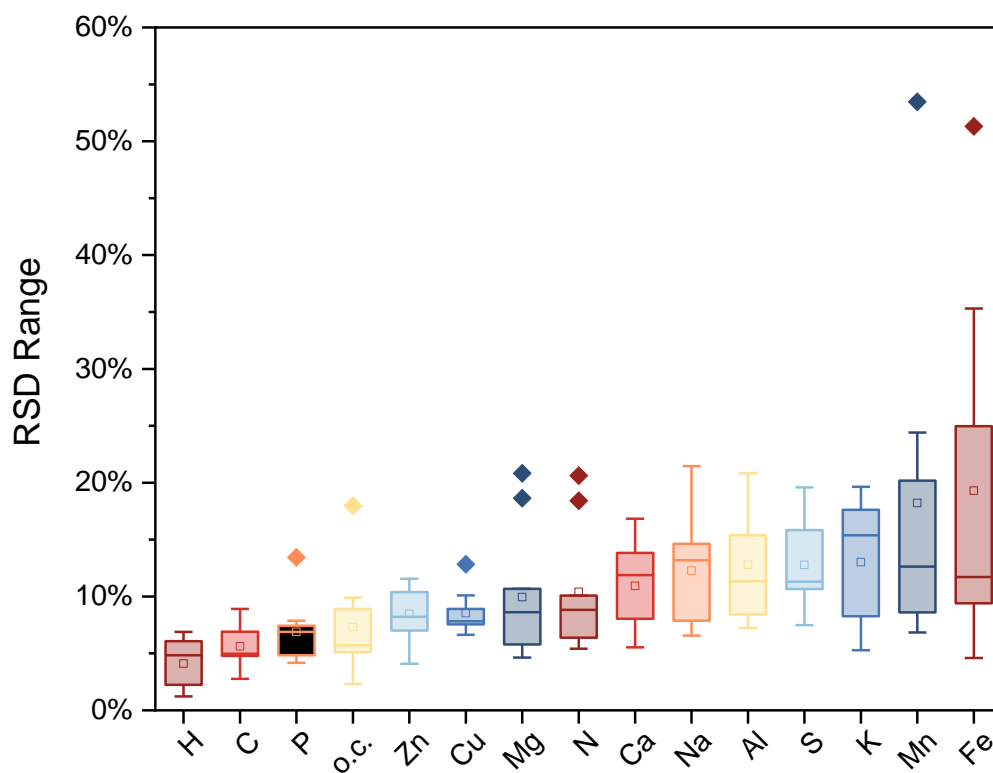


Figure S3: Ranges of relative standard deviation (RSD) of matrix elements and organic content for the 9 WWTPs over the whole year

RSDs were formed by analysis of monthly sewage sludge samples from 9 WWTPs a to i.

All annual RSDs (also trace elements) are shown in table S2, S4, S6, S8, S10, S12, S14, S16 and S18 (last column)

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Table S1: Certified reference material sewage sludges used for analysis and calibration limits

		CRM 029-50G		CRM 031-40G		Calibration Determination limit
		Certified	Range of recovery	Certified	Range of recovery	
As	[mg/kg]	256 ± 9	100-111%	290 ± 6	100%	0.7
Mo	[mg/kg]	155 ± 4	96-100%	112 ± 6	98-100%	0.4
Pb	[mg/kg]	119 ± 5	80-86%	129 ± 10	88-114%	1.0
Cu	[mg/kg]	736 ± 33	100%	487 ± 10	100-105%	5.0
Ni	[mg/kg]	127 ± 4	73-78%	94 ± 15	101-118%	0.6
K	[g/kg]	4.9 ± 1.0	72-79%	5.6 ± 0.5	70-97%	< 0.1
Na	[g/kg]	3.7 ± 0.3	94-100%			< 0.1
Mg	[g/kg]	11.9 ± 0.3	71-77%	15.4 ± 0.9	72-85%	< 0.1
Ca	[g/kg]	38.0 ± 2.8	100%	50.9 ± 1.9	89-98%	0.4
Cr	[mg/kg]	353 ± 12	100%	151 ± 8	96-105%	0.8
Mn	[mg/kg]	264 ± 10	128%	989 ± 123	98-104%	3.2
Fe	[g/kg]	20.2 ± 1.3	100%	32.7 ± 0.7	92-100%	0.3
Zn	[mg/kg]	1.080 ± 20	96-100%	967 ± 21	100-105%	7.5
Sn	[mg/kg]	139 ± 9	117%	156 ± 21	100%	0.5
Al	[g/kg]			19.3 ± 1.5	93-97%	0.2
P	[g/kg]	21.1 ± 2.6	100%	21.5 ± 1.5	92-100%	0.2

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Table S2: Total data for WWTP a, all analyzed values per sample

a	Sample	1	2	3	4	5	6	7	8	9	10	11	RSD
Date		Jul 19	Jul 19	Aug 19	Sep 19	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	May 20	Jun 20	
o.c.	[%]	81	82	76	77	80	80	82	79	81	80	79	2%
C	[g/kg]	440.6	412.6	416.9	410.7	432.2	43.05	440.2	417.1	442.2	437.3	427.5	3%
Ca	[g/kg]	22.2	24.5	23.6	23.0	25.2	24.0	24.3	25.9	24.4	25.7	21.2	6%
P	[g/kg]	17.6	22.4	20.2	22.7	20.6	19.7	21.5	23.1	21.8	21.7	20.9	7%
$\frac{P_{\text{month}}}{P_{\text{year}}}$	[%]	84	106	96	107	97	93	102	110	103	103	99	
N	[g/kg]	39.9	41.5	39.3	43.0	41.6	40.3	44.5	42.1	46.1	44.0	45.5	5%
H	[g/kg]	65.2	62.9	62.9	62.8	64.8	64.0	65.9	63.0	65.5	64.3	61.9	2%
Mg	[g/kg]	2.5	2.2	2.0	2.2	2.3	2.2	2.3	2.3	2.3	2.3	2.1	6%
K	[g/kg]	1.9	1.6	1.4	1.6	1.6	1.5	1.7	1.6	1.5	1.5	1.6	8%
S	[g/kg]	8.7	14.6	20.7	20.8	16.9	15.6	15.8	17.9	15.4	17.0	13.8	21%
Fe	[g/kg]	25.9	43.7	44.0	48.1	37.1	32.0	34.8	43.4	36.7	39.6	36.5	16%
Al	[g/kg]	3.2	3.8	3.9	3.3	3.3	3.3	3.7	3.4	3.8	3.9	3.4	7%
Mn	[mg/kg]	166	271	298	283	274	202	232	260	181	328	282	20%
Na	[mg/kg]	872	697	681	694	738	753	752	708	709	736	600	9%
Zn	[mg/kg]	742	588	599	630	537	569	642	517	611	506	538	12%
Cu	[mg/kg]	430	521				457	521	498	518	497	502	7%
Pb	[mg/kg]	59	22	24	22	18	16	21	15	13	12	18	59%
Cr	[mg/kg]	34	20	21	17	30	23	17	15	19	15	12	33%
Ni	[mg/kg]	34	16	17	14	11	14	15	11	13	11	8	45%
Sn	[mg/kg]	13	14	14	12	13	12	13	12	14	11		9%
Mo	[mg/kg]	3	7	7	6	4	3	4	6	4	5	6	28%
As	[mg/kg]	7	6	7	6	4	4	5	5	4	8		26%

Organic content (o.c.; as loss of ignition at 550 °C) and relative standard deviation (monthly deviation divided by annual average) for all elements.

RSDs in the range of the RSD of phosphorus (6-8% RSD) are marked in green, higher RSDs in yellow and lower RSDs (higher constancy over the year) in red

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Table S3: Relative standard deviation data of the replicates for analyzed values of WWTP a

WWTP a	RSD	1	2	3	4	5	6	7	8	9	10	11
Date		Jul 19	Jul 19	Aug 19	Sep 19	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	May 20	Jun 20
o.c.	[%]	< 0.5	< 0.5	2	< 0.5	1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Moisture	[%]	11	2	1	3	< 0.5	2	3	1	1	3	5
C	[%]	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Ca	[%]	1	1	1	2	2	1	1	8	< 0.5	2	3
P	[%]	1	1	< 0.5	2	2	1	2	5	< 0.5	1	2
N	[%]	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
H	[%]	1	1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Mg	[%]	1	3	1	2	3	1	1	5	1	1	3
K	[%]	1	3	1	2	2	< 0.5	1	2	< 0.5	3	2
S	[%]	3	2	< 0.5	2	2	1	1	16	< 0.5	2	1
Fe	[%]	11	3	1	1	3	1	< 0.5	10	< 0.5	1	3
Al	[%]	2	9	1	2	9	3	1	13	1	2	5
Mn	[%]	5	6	< 0.5	2	1	2	1	18	< 0.5	1	3
Na	[%]	6	7	< 0.5	< 0.5	1	1	2	7	4	5	2
Zn	[%]	6	< 0.5	1	2	3	1	1	12	1	1	3
Cu	[%]	3	4					1	6	< 0.5	1	2
Pb	[%]	2	4	3	1	4	1	< 0.5	9	2	3	8
Cr	[%]	7	8	1	6	79	25	4	16	16	22	5
Ni	[%]	11	11	2	1	6	19	1	13	3	< 0.5	5
Sn	[%]	2	9	5	3	9	1	< 0.5	13	1	2	
Mo	[%]	4	2	1	3	2	6	1	22	3	3	4
As	[%]	3	6	4	2	8	3	1	7	4	3	

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Table S4: Total data for WWTP b, all analyzed values per sample

b	Sample	1	2	3	4	5	6	7	8	9	10	RSD
Date		Aug 19	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	May 20	Jun 20	Jul 20	
o.c.	[%]	41	40	39	37	39	41	37	42	44	38	6%
C	[g/kg]	226.1	202.9	208.8	208.3	215.3	225.6	214.3	232.8	235.0	215.9	5%
Ca	[g/kg]	132.1	162.6	151.6	162.7	159.2	149.4	170.9	155.5	135.9	141.0	8%
P	[g/kg]	25.4	22.4	23.7	23.0	23.7	24.6	23.9	24.9	22.7	22.4	5%
$\frac{P_{\text{month}}}{P_{\text{year}}}$	[%]	107	95	100	97	100	104	101	105	96	95	
N	[g/kg]	27.8	24.8	26.4	26.1	28.1	29.6	28.0	30.5	29.3	26.6	6%
H	[g/kg]	36.2	38.5	37.3	34.8	37.2	27.2	35.2	37.0	36.7	32.3	5%
Mg	[g/kg]	8.7	8.1	7.9	9.2	9.4	9.3	9.3	9.8	8.9	9.0	6%
K	[g/kg]	3.5	3.3	3.5	3.1	3.1	3.2	3.4	3.4		3.1	5%
S	[g/kg]	10.4	9.2	9.8	9.5	10.0	10.5	9.5	11.2	7.9	7.2	13%
Fe	[g/kg]	45.3	45.0	47.9	47.0	46.5	46.3	44.2	38.0	35.4	44.4	9%
Al	[g/kg]	18.9	15.5	15.7	14.1	14.2	13.4	13.5	13.2	11.6	11.0	16%
Mn	[mg/kg]	348	305	321	304	325	347	349	266	248	254	13%
Na	[mg/kg]	818	819	852	806	835	870	832	905	997	867	7%
Zn	[mg/kg]	947	870	848	770	784	785	711	767	706	683	10%
Cu	[mg/kg]	177	150	152	138	147	152	155	161	146	133	8%
Pb	[mg/kg]	32	28	29	25	23	24	24	27	25	25	10%
Cr	[mg/kg]	31	29	26	27	31	28	29	27	27	29	6%
Ni	[mg/kg]	32	29	30	28	28	29	27	22	20	23	15%
Sn	[mg/kg]	24	20	19	18	19	20	21	23			11%
Mo	[mg/kg]	5	3	4	4	4	4	4	5	5	5	11%
As	[mg/kg]	5	4	4	4	4	4	4	4			12%

Organic content (o.c.; as loss of ignition at 550 °C) and relative standard deviation (monthly deviation divided by annual average) for all elements

RSDs in the range of the RSD of phosphorus (4-6% RSD) are marked in green, higher RSDs in yellow and lower RSDs (higher constancy over the year) in red

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Table S5: Relative standard deviation data of the replicates for analyzed values of WWTP b

WWTP b	RSD	1	2	3	4	5	6	7	8	9	10
Date		Aug 19	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	May 20	Jun 20	Jul 20
o.c.	[%]	< 0.5	< 0.5	< 0.5	1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Moisture	[%]	2	3	2	4	3	1	4	3	1	1
C	[%]	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Ca	[%]	2	1	< 0.5	< 0.5	1	2	< 0.5	1	1	1
P	[%]	1	2	1	1	< 0.5	< 0.5	1	1	1	< 0.5
N	[%]	< 0.5	< 0.5	< 0.5	< 0.5	1	< 0.5	1	< 0.5	< 0.5	< 0.5
H	[%]	2	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Mg	[%]	3	< 0.5	< 0.5	< 0.5	1	2	1	1	< 0.5	< 0.5
K	[%]	11	4	1	1	< 0.5	3	< 0.5	8	< 0.5	1
S	[%]	1	2	2	1	1	1	1	2	< 0.5	< 0.5
Fe	[%]	3	2	1	1	3	2	1	1	3	< 0.5
Al	[%]	8	1	1	1	1	3	1	6	4	< 0.5
Mn	[%]	4	3	< 0.5	2	2	4	< 0.5	< 0.5	< 0.5	< 0.5
Na	[%]	4	2	1	1	2	5	1	1	1	4
Zn	[%]	1	2	1	< 0.5	1	1	5	5	5	2
Cu	[%]	4	3	2	1	1	4	3	1	< 0.5	< 0.5
Pb	[%]	3	3	1	3	3	1	4	3	5	5
Cr	[%]	8	8	1	1	1	6	< 0.5	5	1	4
Ni	[%]	7	4	4	7	9	9	2	2	< 0.5	3
Sn	[%]	< 0.5	1	1	< 0.5	3	3	5	1		
Mo	[%]	5	2	4	1	5	4	1	3	< 0.5	1
As	[%]	5	1	2	14	2	3	12	6		

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Table S6: Total data for WWTP c, all analyzed values per sample

c		1	2	3	4	5	6	7	8	9	10	11	12	13	RSD
Date		Aug 19	Sep 19	Sep 19	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	
o.c.	[%]	33	28	30	34	31	29	28	31	32	33	33	30	24	9%
C	[g/kg]	193.3	179.3	184.1	196.3	183.0	177.1	176.1	188.5	195.0	183.9	187.7	170.4	169.1	5%
Ca	[g/kg]	199.9	222.2	211.3	188.3	200.2	211.0	217.9	211.1	182.3	202.4	201.5	215.7	206.1	6%
P	[g/kg]	22.6	21.4	21.6	22.0	21.9	20.9	20.8	20.7	21.0	19.6	18.5	19.5	17.6	7%
$\frac{P_{month}}{P_{year}}$	[%]	110	104	105	106	106	101	101	100	102	95	90	94	86	
N	[g/kg]	16.8	14.6	14.3	17.1	15.6	16.0	16.3	17.6	24.1	22.2	22.9	22.2	19.8	18%
H	[g/kg]									32.4	32.4	33.0	32.6	32.7	1%
Mg	[g/kg]	7.6	7.7	9.3	8.2	8.8	8.8	8.3	7.5	7.8	8.4	8.6	9.9	9.1	9%
K	[g/kg]	1.8	1.8	1.9	1.7	1.9	1.9	2.0	2.0	2.0	2.0	2.4	1.9	1.8	9%
S	[g/kg]	7.6	7.1	7.1	7.8	7.3	7.2	7.1	7.4	7.3	7.1	7.0	6.9	4.7	11%
Fe	[g/kg]	53.9	48.9	49.3	59.8	56.3	53.6	50.3	47.2	49.6	50.0	46.7	42.8	39.6	11%
Al	[g/kg]	5.3	5.0	5.0	5.4	6.0	6.0	6.0	5.8	5.8	5.6	5.8	5.4	3.9	11%
Mn	[mg/kg]	328	306	299	306	354	321	346	308	315	355	320	377	318	7%
Na	[mg/kg]	664	643	679	620	680	650	655	606	568	597	762	625	586	8%
Zn	[mg/kg]	545	496	495	548	528	498	506	512	545	476	486	491	409	7%
Cu	[mg/kg]	244	225	223	249	235	222	220	220	229	205	214	212	181	8%
Pb	[mg/kg]	28	25	26	27	26	25	24	22	23	21	20	19	27	11%
Cr	[mg/kg]	25	26	20	28	25	22	20	18	20	24	22	18	15	17%
Ni	[mg/kg]	16	14	14	16	15	14	14	13	15	19	16	13	10	14%
Sn	[mg/kg]	17	16	16	18	16	15	14	14	15	12	13	13		12%
Mo	[mg/kg]	2	2	2	2	2	2	2	2	2	2	2	2	1	18%
As	[mg/kg]	1	<1	1	<1	<1	<1	<1	<1	1	1	1	1		47%

Organic content (o.c.; as loss of ignition at 550 °C) and relative standard deviation (monthly deviation divided by annual average) for all elements

RSDs in the range of the RSD of phosphorus (6-8% RSD) are marked in green, higher RSDs in yellow and lower RSDs (higher constancy over the year) in red

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Table S7: Relative standard deviation data of the replicates for analyzed values of WWTP c

WWTP c	RSD	1	2	3	4	5	6	7	8	9	10	11	12	13
Date		Aug 19	Sep 19	Sep 19	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20
o.c.	[%]	<0.5	<0.5	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	<0.5
Moisture	[%]	1	1	2	<0.5	5	3	2	3	2	4	4	2	3
C	[%]	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ca	[%]	1	1	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	1	1	1	1
P	[%]	1	1	1	6	1	2	<0.5	<0.5	1	1	3	2	<0.5
N	[%]	1	<0.5	1	1	1	1	1	2	<0.5	<0.5	1	<0.5	1
H	[%]									2	<0.5	<0.5	<0.5	<0.5
Mg	[%]	2	1	1	1	1	1	1	<0.5	<0.5	1	1	1	<0.5
K	[%]	2	2	1	<0.5	1	<0.5	3	1	1	1	<0.5	2	3
S	[%]	1	<0.5	1	2	<0.5	1	1	<0.5	1	1	<0.5	1	1
Fe	[%]	1	<0.5	<0.5	1	1	1	1	<0.5	<0.5	1	<0.5	2	1
Al	[%]	2	1	<0.5	2	1	1	3	1	1	1	3	1	2
Mn	[%]	2	1	<0.5	1	1	1	1	<0.5	<0.5	1	<0.5	2	<0.5
Na	[%]	2	1	2	<0.5	<0.5	3	2	2	2	1	1	2	2
Zn	[%]	1	<0.5	<0.5	1	<0.5	2	1	1	1	1	<0.5	5	2
Cu	[%]	2	1	<0.5	<0.5	1	1	1	<0.5	1	1	1	1	<0.5
Pb	[%]	1	1	1	1	<0.5	2	2	<0.5	<0.5	1	1	1	4
Cr	[%]	10	10	1	27	14	4	4	1	1	2	5	1	3
Ni	[%]	3	1	2	2	3	2	9	<0.5	<0.5	<0.5	2	4	1
Sn	[%]	2	2	1	2	1	5	3	<0.5	1	2	1	3	
Mo	[%]	3	2	6	2	2	1	3	1	<0.5	1	3	5	13
As	[%]	2	28	25	13	15	56	42	3	30	21	12	7	

Additional file 1 - Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

Table S8: Total data for WWTP d, all analyzed values per sample

d	Sample	1	2	3	4	5	6	7	8	9	10	RSD
Date		Aug 19	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	May 20	Jun 20	Jul 20	
o.c.	[%]	25	24	25	27	22	28	25	30	30	27	10%
C	[g/kg]	158.4	169.0	169.1	176.4	152.8	171.7	173.7	178.9	177.1	174.1	5%
Ca	[g/kg]	251.4	257.8	251.9	242.3	273.9	251.8	220.2	219.2	183.7	202.9	12%
P	[g/kg]	16.8	17.6	18.1	18.3	16.1	18.3	17.6	18.3	17.1	17.1	4%
$\frac{P_{\text{month}}}{P_{\text{year}}}$	[%]	96	100	103	104	92	104	100	104	98	98	
N	[g/kg]	5.0	8.5	8.8	9.6	8.6	9.6	10.9	11.5	9.3	11.7	21%
H	[g/kg]	31.7	32.2	32.4	32.8	31.9	33.6	33.0	33.0	33.5	31.5	2%
Mg	[g/kg]	6.9	6.8	7.0	7.1	6.8	7.3	6.9	6.9	6.4	6.2	5%
K	[g/kg]	1.2	1.3	1.3	1.4	1.6	1.8	2.2	1.8	1.6	1.5	20%
S	[g/kg]	21.2	19.9	21.2	21.0	20.6	21.6	14.6	16.5	15.6	15.3	15%
Fe	[g/kg]	37.4	34.2	37.0	37.6	35.7	36.8	36.0	39.2	36.7	33.4	5%
Al	[g/kg]	4.7	4.9	4.9	4.9	4.5	5.0	4.5	4.3	3.8	3.6	11%
Mn	[mg/kg]	244	254	260	247	239	254	262	246	214	216	7%
Na	[mg/kg]	825	989	943	935	880	890	959	1.049	1.013	863	8%
Zn	[mg/kg]	447	454	479	463	383	430	431	414	393	422	7%
Cu	[mg/kg]	196	204	209	206	166	198	182	192	172	185	8%
Pb	[mg/kg]	12	11	11	11	9	9	12	11	12	15	15%
Cr	[mg/kg]	11	11	11	11	9	10	10	11	10	11	6%
Ni	[mg/kg]	15	13	15	16	12	13	14	12	13	12	10%
Sn	[mg/kg]	8	9	9	8	7	8	7	8			9%
Mo	[mg/kg]	3	4	4	4	2	3	3	3	3	2	19%
As	[mg/kg]	<1	<1	<1	<1	1	<1	<1	<1			35%

Organic content (o.c.; as loss of ignition at 550 °C) and relative standard deviation (monthly deviation divided by annual average) for all elements

RSDs in the range of the RSD of phosphorus (3-5% RSD) are marked in green, higher RSDs in yellow and lower RSDs (higher constancy over the year) in red

Additional file 1 - Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

Table S9: Relative standard deviation data of the replicates for analyzed values of WWTP d

WWTP d	RSD	1	2	3	4	5	6	7	8	9	10
Date		Aug 19	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	May 20	Jun 20	Jul 20
o.c.	[%]	< 0.5	1	< 0.5	< 0.5	< 0.5	< 0.5	1	< 0.5	< 0.5	< 0.5
Moisture	[%]	3	2	1	2	3	2	5	5	2	< 0.5
C	[%]	< 0.5	1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Ca	[%]	1	< 0.5	2	< 0.5	< 0.5	< 0.5	3	1	2	1
P	[%]	2	1	2	< 0.5	< 0.5	< 0.5	2	< 0.5	2	1
N	[%]	4	3	1	< 0.5	< 0.5	1	1	< 0.5	< 0.5	< 0.5
H	[%]	3	3	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1
Mg	[%]	2	1	2	< 0.5	< 0.5	< 0.5	3	1	1	< 0.5
K	[%]	2	1	3	< 0.5	1	< 0.5	< 0.5	2	< 0.5	1
S	[%]	2	1	2	1	< 0.5	< 0.5	2	< 0.5	< 0.5	1
Fe	[%]	2	< 0.5	2	< 0.5	< 0.5	< 0.5	2	1	5	9
Al	[%]	3	1	2	< 0.5	< 0.5	1	5	4	< 0.5	1
Mn	[%]	1	< 0.5	2	1	1	< 0.5	3	2	1	1
Na	[%]	3	< 0.5	1	3	3	3	1	4	2	5
Zn	[%]	3	< 0.5	2	1	< 0.5	1	2	1	2	1
Cu	[%]	1	< 0.5	2	< 0.5	< 0.5	1	2	3	1	1
Pb	[%]	6	4	4	2	4	< 0.5	4	3	< 0.5	1
Cr	[%]	5	< 0.5	2	2	6	12	5	4	2	< 0.5
Ni	[%]	4	1	3	5	1	3	7	5	2	4
Sn	[%]	8	1	< 0.5	3	1	5	2	3		
Mo	[%]	3	< 0.5	1	< 0.5	2	8	4	1	7	2
As	[%]	86	17	4	82	7	214	3	29		

Additional file 1 - Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

Table S10: Total data for WWTP e. all analyzed values per sample

e		1	2	3	4	5	6	7	8	9	10	11	12	RSD
Date		Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20	
o.c.	[%]	64	64	64	68	67	60	66	65	66	65	61	65	4%
C	[g/kg]	331.6	432.2	349.4	364.2	348.8	307.4	348.8	343.8	339.4	337.5	311.0	332.3	5%
Ca	[g/kg]	13.0	12.2	11.5	11.2	11.7	11.2	13.1	12.1	12.3	12.6	14.1	14.1	8%
P	[g/kg]	23.4	25.4	24.8	22.9	24.0	23.9	25.8	24.7	24.9	25.1	27.1	26.3	5%
$\frac{P_{month}}{P_{year}}$	[%]	94	102	100	92	97	96	104	99	100	101	109	106	
N	[g/kg]	37.5	41.7	42.4	46.2	47.4	42.4	45.1	46.3	53.4	45.5	42.4	42.8	9%
H	[g/kg]	51.4	52.9	54.1	56.1	53.8	49.3	52.9	53.3	46.8	51.8	49.2	52.6	5%
Mg	[g/kg]	3.7	3.4	3.1	3.4	3.7	4.6	3.5	3.5	3.6	3.9	4.2	3.9	11%
K	[g/kg]	4.3	4.4	4.2	4.5	4.7	6.7	4.2					4.4	18%
S	[g/kg]	5.4	5.5	5.4	5.1	5.4	4.9	6.4	5.4	5.1	5.3	6.2	5.8	8%
Fe	[g/kg]	28.0	26.2	25.3	23.0	24.1	27.9	23.9	22.0	20.8	21.3	21.5	19.6	12%
Al	[g/kg]	23.6	25.0	25.2	22.8	24.8	33.0	26.7	26.1	25.3	27.1	30.9	31.4	12%
Mn	[mg/kg]	366	351	328	213	218	282	211	204	195	202	224	265	24%
Na	[mg/kg]	990	949	954	944	917	819	1.165	934	780	1.022	1.060	1.238	13%
Zn	[mg/kg]	1.088	1.089	1.011	948	1.012	1.136	890	991	975	1.026	1.115	1.035	7%
Cu	[mg/kg]	164	163	157	176	183	182	146	155	151	151	162	152	8%
Pb	[mg/kg]	57	55	52	48	52	77	50	44	43	44	46	48	18%
Cr	[mg/kg]	42	40	37	35	36	52	35	34	29	31	33	32	17%
Ni	[mg/kg]	21	20	19	18	19	28	21	20	18	19	21	19	12%
Sn	[mg/kg]	21	21	20	26	27	25	23						11%
Mo	[mg/kg]	4	4	4	4	4	4	4	5	5	5	7	5	19%
As	[mg/kg]	4	3	4	3	3	8	4						38%

Organic content (o.c.; as loss of ignition at 550 °C) and relative standard deviation (monthly deviation divided by annual average) for all elements

RSDs in the range of the RSD of phosphorus (4-6% RSD) are marked in green. higher RSDs in yellow and lower RSDs (higher constancy over the year) in red

Additional file 1 - Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

Table S11: Relative standard deviation data of the replicates for analyzed values of WWTP e

WWTP e	RSD	1	2	3	4	5	6	7	8	9	10	11	12
Date		Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20
o.c.	[%]	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1	< 0.5
Moisture	[%]	2	1	1	2	1	1	1	2	4	1	1	2
C	[%]	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Ca	[%]	1	< 0.5	2	1	< 0.5	< 0.5	1	3	< 0.5	1	< 0.5	< 0.5
P	[%]	3	1	2	< 0.5	3	4	1	4	1	1	1	1
N	[%]	1	< 0.5	1	< 0.5	< 0.5	1	< 0.5	< 0.5	4	1	< 0.5	< 0.5
H	[%]	4	1	< 0.5	< 0.5	1	2	3	3	4	1	1	< 0.5
Mg	[%]	1	1	2	< 0.5	< 0.5	2	< 0.5	1	2	1	< 0.5	< 0.5
K	[%]	1	< 0.5	1	2	5	5	1					1
S	[%]	1	1	2	< 0.5	< 0.5	4	1	2	1	< 0.5	1	< 0.5
Fe	[%]	1	2	1	< 0.5	< 0.5	4	< 0.5	3	4	4	1	1
Al	[%]	1	1	1	1	< 0.5	3	1	1	3	1	< 0.5	1
Mn	[%]	2	2	1	< 0.5	< 0.5	3	1	1	2	< 0.5	< 0.5	2
Na	[%]	2	1	3	1	< 0.5	4	< 0.5	2	3	3	3	1
Zn	[%]	1	5	1	< 0.5	1	5	< 0.5	1	1	< 0.5	< 0.5	1
Cu	[%]	2	2	1	< 0.5	< 0.5	3	< 0.5	2	< 0.5	< 0.5	2	1
Pb	[%]	< 0.5	2	1	< 0.5	< 0.5	3	< 0.5	2	5	2	2	< 0.5
Cr	[%]	1	3	2	2	< 0.5	6	3	6	8	4	< 0.5	3
Ni	[%]	1	2	1	1	< 0.5	3	4	2	1	2	< 0.5	3
Sn	[%]	1	1	1	2	< 0.5	4	< 0.5					
Mo	[%]	2	9	4	1	2	4	1	1	11	3	4	2
As	[%]	1	12	6	8	15	2	3					

Additional file 1 - Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

Table S12: Total data for WWTP f. all analyzed values per sample

f		1	2	3	4	5	6	7	8	9	10	11	12	RSD
Date		Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20	
o.c.	[%]	63	64	63	65	65	65	64	63	60	57	57	57	5%
C	[g/kg]	318.2	329.0	315.0	336.6	339.7		329.1	317.8	309.9	291.6	294.1	289.1	6%
Ca	[g/kg]	19.4	18.9	17.5	15.9	15.6	14.8	17.7	20.3	21.4	21.8	23.0	20.0	14%
P	[g/kg]	26.0	25.4	23.2	21.8	21.4	22.0	25.8	24.8	24.4	23.6	25.6	23.0	7%
$\frac{P_{\text{month}}}{P_{\text{year}}}$	[%]	109	106	97	91	89	92	108	104	102	99	107	96	
N	[g/kg]	49.3	50.5	48.9	51.7	50.2		49.9	48.3	45.8	43.6	44.3	44.3	6%
H	[g/kg]	54.0	54.8	55.4	55.5	55.4		55.2	53.9	50.9	48.5	48.6	47.3	6%
Mg	[g/kg]	4.7	4.7	3.9	4.1	4.2	4.2	4.6	4.9	6.1	6.6	6.6	6.5	21%
K	[g/kg]	4.0	4.2	3.9	4.8	4.6	4.8	5.8	5.7	5.7	6.2	5.9	5.6	16%
S	[g/kg]	5.2	5.1	4.7	4.5	4.4	4.3	5.1	5.1	5.6	5.3	5.5	4.9	8%
Fe	[g/kg]	8.9	9.0	8.1	9.0	9.6	10.0	9.3	9.2	14.2	12.1	11.4	17.1	25%
Al	[g/kg]	61.8	61.5	66.1	53.3	52.4	56.1	64.5	66.9	59.0	60.5	60.1	48.7	10%
Mn	[mg/kg]	299	277	218	208	216	212	209	232	276	325	319	311	18%
Na	[mg/kg]	1.123	1.155	1.121	1.016	953	918	1.217	1.458	1.619	1.623	1.695	1.351	21%
Zn	[mg/kg]	1.073	1.088	1.052	1.009	1.096	1.037	1.126	1.109	1.099	1.056	1.010	993	4%
Cu	[mg/kg]	229	229	251	203	198	205	247	262	241	240	222	216	9%
Pb	[mg/kg]	65	63	63	59	62	65	30	21	44	48	42	62	29%
Cr	[mg/kg]	35	35	30	31	32	34	36	39	48	45	44	41	15%
Ni	[mg/kg]	29	29	22	24	27	26	28	30	38	35	36	36	17%
Mo	[mg/kg]	5	5	3	3	3	3	4	4	6	6	7	8	37%

Organic content (o.c.; as loss of ignition at 550 °C) and relative standard deviation (monthly deviation divided by annual average) for all elements

RSDs in the range of the RSD of phosphorus (6-8% RSD) are marked in green. higher RSDs in yellow and lower RSDs (higher constancy over the year) in red

Additional file 1 - Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

Table S13: Relative standard deviation data of the replicates for analyzed values of WWTP f

WWTP f	RSD	1	2	3	4	5	6	7	8	9	10	11	12
Date		Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20
o.c.	[%]	< 0.5	< 0.5	< 0.5	1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1	1
Moisture	[%]	3	3	2	5	4		2	2	3	5	5	7
C	[%]	< 0.5	1	< 0.5	1	< 0.5		1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Ca	[%]	1	1	< 0.5	3	3		2	2	2	2	4	1
P	[%]	1	3	1	2	2	3	2	< 0.5	2	1	3	< 0.5
N	[%]	2	2	1	2	1		1	1	1	1	1	< 0.5
H	[%]	1	1	1	< 0.5	< 0.5		1	1	< 0.5	1	< 0.5	1
Mg	[%]	3	2	1	3	1	1	2	2	2	2	3	2
K	[%]	6	3	2	3	8	2	1	3	< 0.5	2	4	2
S	[%]	< 0.5	1	< 0.5	2	< 0.5	< 0.5	3	< 0.5	1	1	3	4
Fe	[%]	2	1	6	1	1	< 0.5	5	< 0.5	31	1	3	48
Al	[%]	1	1	1	2	1	< 0.5	2	< 0.5	2	1	3	3
Mn	[%]	2	1	1	1	3	1	1	< 0.5	1	2	3	2
Na	[%]	1	1	1	3	1	< 0.5	3	3	2	2	2	2
Zn	[%]	2	1	2	1	2	6	7	1	1	1	3	13
Cu	[%]	< 0.5	< 0.5	3	2	3	< 0.5	< 0.5	1	4	2	2	19
Pb	[%]	3	2	5	3	2	< 0.5	1	2	8	4	3	40
Cr	[%]	5	2	< 0.5	3	2	< 0.5	2	< 0.5	3	2	4	5
Ni	[%]	< 0.5	< 0.5	2	2	3	1	2	1	1	2	3	4
Mo	[%]	3	2	12	2	3	2	2	2	7	2	2	46

Additional file 1 - Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

Table S14: Total data for WWTP g. all analyzed values per sample

g	Sample	1	2	3	4	5	6	7	8	9	RSD
Date		Oct 19	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20	
o.c.	[%]	65	78	70	76	74	74	72	70	77	6%
C	[g/kg]	329.4	422.8	397.0	417.3	416.0	400.5	391.3	400.5	402.2	7%
Ca	[g/kg]	2.3	7.9	7.2	10.2	9.6	9.7	9.7	10.9	11.8	17%
P	[g/kg]	24.2	17.4	16.2	20.3	19.3	18.8	20.0	20.8	24.2	13%
$\frac{P_{month}}{P_{year}}$	[%]	120	87	81	101	96	93	100	103	120	
N	[g/kg]	53.5	75.0	68.9	77.7	75.3	72.5	71.3	72.0	70.8	10%
H	[g/kg]	51.8	65.2	59.5	65.3	64.5	61.3	59.2	60.6	62.8	7%
Mg	[g/kg]	3.1	3.4	3.4	3.6	3.5	3.5	3.6	3.4	4.2	9%
K	[g/kg]	3.8	6.2	4.8	5.2	4.9	4.6	4.2	3.5	6.0	19%
S	[g/kg]	5.9	5.3	4.6	5.8	5.8	5.7	7.4	9.0	6.3	21%
Fe	[g/kg]	48.5	16.2	15.0	18.2	16.0	16.2	17.9	19.1	18.1	51%
Al	[g/kg]	10.5	8.2	8.5	7.1	6.5	6.2	6.6	6.4	6.4	20%
Mn	[mg/kg]	538	158	167	154	143	157	268	311	253	53%
Na	[mg/kg]	656	562	508	820	617	564	567	670	615	15%
Zn	[mg/kg]	872	815	755	677	678	693	688	673	752	10%
Cu	[mg/kg]	192	166	139	144	150	145	185	191	164	13%
Pb	[mg/kg]	51	50	45	35	33	33	46	43	45	16%
Cr	[mg/kg]	38	26	27	25	23	24	30	29	23	17%
Ni	[mg/kg]	23	19	18	19	18	17	22	21	23	11%
Mo	[mg/kg]	3	5	2	2	3	2	4	5	3	38%

Organic content (o.c.; as loss of ignition at 550 °C) and relative standard deviation (monthly deviation divided by annual average) for all elements

RSDs in the range of the RSD of phosphorus (12-14% RSD) are marked in green. higher RSDs in yellow and lower RSDs (higher constancy over the year) in red

Additional file 1 - Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

Table S15: Relative standard deviation data of the replicates for analyzed values of WWTP g

WWTP g	RSD	1	2	3	4	5	6	7	8	9
Date		Oct 19	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20
o.c.	[%]	< 0.5	< 0.5	< 0.5	< 0.5	2	1	< 0.5	1	< 0.5
Moisture	[%]	< 0.5	2	2	5	6	2	< 0.5	3	1
C	[%]	< 0.5	1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Ca	[%]	2	1	1	1	2	< 0.5	5	3	2
P	[%]	< 0.5	4	1	3	1	2	4	2	2
N	[%]	1	1	< 0.5	1	< 0.5	1	< 0.5	< 0.5	< 0.5
H	[%]	1	1	1	< 0.5	< 0.5	< 0.5	1	1	< 0.5
Mg	[%]	< 0.5	2	1	< 0.5	1	1	2	6	2
K	[%]	10	2	< 0.5	< 0.5	1	< 0.5	3	9	3
S	[%]	< 0.5	2	< 0.5	< 0.5	1	1	2	4	1
Fe	[%]	2	11	< 0.5	1	1	2	1	4	5
Al	[%]	13	2	1	2	2	1	1	11	2
Mn	[%]	1	4	< 0.5	1	2	1	3	3	9
Na	[%]	3	4	3	5	1	3	3	7	3
Zn	[%]	6	7	< 0.5	2	3	6	2	3	3
Cu	[%]	2	10	< 0.5	2	2	1	4	2	5
Pb	[%]	1	8	1	2	1	1	< 0.5	4	2
Cr	[%]	10	< 0.5	< 0.5	1	< 0.5	5	4	7	6
Ni	[%]	< 0.5	2	< 0.5	3	< 0.5	< 0.5	8	6	38
Mo	[%]	2	34	2	2	< 0.5	5	1	2	7

Additional file 1 - Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

Table S16: Total data for WWTP h. all analyzed values per sample

h		1	2	3	4	5	6	7	8	9	10	11	12	RSD
Date		Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20	
o.c.	[%]	25	21	24	23	18	23	23	26	31	30	32	32	18%
C	[g/kg]	166.5	160.0	172.2	168.8	162.3	170.1	166.7	181.9	193.0	194.5	201.5	204.6	9%
Ca	[g/kg]	193.5	216.3	200.1	204.0	219.4	211.4	216.0	203.9	178.9	147.3	148.9	161.2	14%
P	[g/kg]	18.0	17.6	19.0	18.3	16.4	16.9	17.5	16.9	18.4	18.1	19.2	20.0	6%
$\frac{P_{\text{month}}}{P_{\text{year}}}$	[%]	100	98	105	102	91	94	97	94	102	100	106	111	
N	[g/kg]	17.2	17.4	18.6	18.8	17.5	18.5	18.2	18.9	20.3	20.5	21.4	21.6	8%
H	[g/kg]	30.5	31.6	30.8	31.1	30.4	31.1	30.1	31.9	32.4	32.2	31.8	32.2	2%
Mg	[g/kg]	6.0	5.7	5.7	5.6	5.6	6.1	5.9	6.2	6.5	5.9	6.3	6.5	5%
K	[g/kg]	1.9	2.3	2.4	2.0	2.0					2.1	2.4		8%
S	[g/kg]	4.7	3.4	3.6	4.6	4.3	3.4	3.6	3.9	4.2	4.2	4.4	4.3	11%
Fe	[g/kg]	41.7	44.8	47.8	44.6	40.7	42.3	41.5	40.8	43.5	34.8	34.4	39.1	9%
Al	[g/kg]	8.3	8.4	8.1	7.5	7.8	10.0	9.1	9.2	10.1	9.1	9.7	10.8	11%
Mn	[mg/kg]	300	261	248	246	265	284	263	288	314	284	302	316	9%
Na	[mg/kg]	561	530	558	529	480	425	448	526	534	618	662	739	16%
Zn	[mg/kg]	617	592	611	593	547	598	523	583	648	621	718	644	8%
Cu	[mg/kg]	164	146	155	138	128	149	145	145	162	164	178	179	10%
Pb	[mg/kg]	23	21	20	17	17	21	19	23	26	29	36	34	26%
Cr	[mg/kg]	30	29	29	26	25	29	27	30	31	28	31	34	8%
Ni	[mg/kg]	19	17	17	18	18	20	19	20	24	18	20	21	10%
Sn	[mg/kg]	16	13	13	12	11	12	12	13	15				11%
Mo	[mg/kg]	1	1	1	1	1	1	1	1	2	2	2	2	32%
As	[mg/kg]	3	1	1	2	2	3	2	2	2				23%

Organic content (o.c.; as loss of ignition at 550 °C) and relative standard deviation (monthly deviation divided by annual average) for all elements

RSDs in the range of the RSD of phosphorus (5-7% RSD) are marked in green. higher RSDs in yellow and lower RSDs (higher constancy over the year) in red

Additional file 1 - Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

Table S17: Relative standard deviation data of the replicates for analyzed values of WWTP h

WWTP h	RSD	1	2	3	4	5	6	7	8	9	10	11	12
Date		Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20
o.c.	[%]	2	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Moisture	[%]	3	2	4	5	3	6	6	5	2	1	4	3
C	[%]	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Ca	[%]	1	< 0.5	1	1	< 0.5	< 0.5	1	4	< 0.5	< 0.5	2	4
P	[%]	1	3	2	3	< 0.5	1	1	2	< 0.5	< 0.5	1	1
N	[%]	< 0.5	1	1	1	1	1	2	1	1	< 0.5	1	1
H	[%]	3	1	< 0.5	< 0.5	< 0.5	< 0.5	3	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Mg	[%]	1	1	1	1	< 0.5	1	1	3	1	< 0.5	1	4
K	[%]	4	7	1	7	1	< 0.5	< 0.5	< 0.5	< 0.5	1	< 0.5	< 0.5
S	[%]	2	1	3	4	1	2	1	4	1	1	1	1
Fe	[%]	< 0.5	1	1	3	< 0.5	1	1	3	1	< 0.5	1	1
Al	[%]	5	3	3	4	1	4	6	4	8	1	1	10
Mn	[%]	1	1	1	2	< 0.5	1	1	2	1	< 0.5	< 0.5	1
Na	[%]	3	7	2	4	4	3	3	12	5	1	2	1
Zn	[%]	< 0.5	< 0.5	2	3	< 0.5	1	< 0.5	3	1	1	1	3
Cu	[%]	1	1	2	3	< 0.5	< 0.5	2	3	1	< 0.5	1	2
Pb	[%]	3	3	3	1	1	< 0.5	1	4	3	< 0.5	2	< 0.5
Cr	[%]	2	4	5	1	2	3	3	5	5	3	< 0.5	4
Ni	[%]	2	7	7	1	< 0.5	1	1	6	14	1	1	1
Sn	[%]	< 0.5	2	1	3	1	8	2	3	< 0.5			
Mo	[%]	2	4	9	2	1	4	10	1	1	2	2	1
As	[%]	6	20	24	12	17	19	5	11	16			

Additional file 1 - Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

Table S18: Total data for WWTP i. all analyzed values per sample

i		1	2	3	4	5	6	7	8	9	10	11	12	RSD
Date		Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20	Oct 20	
o.c.	[%]	58	63	65	63	63	61	61	61	61	55	57	51	7%
C	[g/kg]		341.5	348.4	353.5	343.2	330.9	323.2	326.5	302.9	305.5	312.0	280.6	7%
Ca	[g/kg]	36.4	32.5	26.4	27.0	24.8	25.5	26.5	31.7	35.1	32.7	33.9	25.9	14%
P	[g/kg]	21.1	22.9	20.7	22.2	22.1	25.0	24.9	25.2	24.5	24.8	25.0	20.7	8%
$\frac{P_{\text{month}}}{P_{\text{year}}}$	[%]	91	98	89	95	95	108	107	108	106	107	107	89	
N	[g/kg]		52.7	56.9	56.5	55.9	50.7	49.9	48.7	45.3	45.8	46.6	41.6	10%
H	[g/kg]		52.1	53.1	54.2	52.9	51.4	50.3	51.0	47.3	47.9	48.6	43.6	6%
Mg	[g/kg]	6.6	6.4	7.4	8.2	8.0	5.2	4.6	5.0	5.8	5.8	6.0	5.5	19%
K	[g/kg]	3.7	3.6	3.8	3.8	4.1	2.9					4.2	5.0	15%
S	[g/kg]	9.6	10.1	10.1	9.7	9.5	9.3	9.6	9.3	9.6	8.8	9.5	11.7	7%
Fe	[g/kg]	1.2	34.2	24.6	21.8	22.6	53.6	57.4	37.7	30.7	28.2	27.6	24.3	35%
Al	[g/kg]	19.1	18.9	17.5	18.0	20.0	16.8	17.7	24.4	23.6	27.8	23.3	25.9	18%
Mn	[mg/kg]	975	827	809	881	852	751	709	703	705	695	717	657	12%
Na	[mg/kg]	657	469	536	553	497	460	473	554	712	679	624	622	14%
Zn	[mg/kg]	848	826	806	818	793	703	700	750	761	783	768	1.035	11%
Cu	[mg/kg]	368	365	341	351	339	325	316	329	314	320	334	398	7%
Pb	[mg/kg]	46	42	44	44	46	42	44	37	33	32	38	46	12%
Cr	[mg/kg]	56	51	48	49	51	47	48	48	50	51	46	54	6%
Ni	[mg/kg]	43	42	46	45	44	37	32	31	31	33	30	64	24%
Mo	[mg/kg]	18	18	19	19	17	16	16	16	13	13	13	16	14%

Organic content (o.c.; as loss of ignition at 550 °C) and relative standard deviation (monthly deviation divided by annual average) for all elements

RSDs in the range of the RSD of phosphorus (7-9% RSD) are marked in green. higher RSDs in yellow and lower RSDs (higher constancy over the year) in red

Additional file 1 - Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

Table S19: Relative standard deviation data of the replicates for analyzed values of WWTP i

WWTP i	RSD	1	2	3	4	5	6	7	8	9	10	11	12
Date		<i>Nov</i>	<i>Dec</i>	<i>Jan</i>	<i>Feb</i>	<i>Mar</i>	<i>Apr</i>	<i>May</i>	<i>Jun</i>	<i>Jul 20</i>	<i>Aug</i>	<i>Sep</i>	<i>Oct</i>
		<i>19</i>	<i>19</i>	<i>20</i>	<i>20</i>	<i>20</i>	<i>20</i>	<i>20</i>	<i>20</i>		<i>20</i>	<i>20</i>	<i>20</i>
o.c.	[%]	< 0.5	< 0.5	1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1	< 0.5	< 0.5	< 0.5
Moisture	[%]	6	3	4	2	5	4	2	2	6	2	6	5
C	[%]		< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Ca	[%]	3	< 0.5	1	2	3	2	2	2	< 0.5	< 0.5	1	1
P	[%]	3	2	3	< 0.5	2	2	< 0.5	1	1	3	1	< 0.5
N	[%]		< 0.5	< 0.5	< 0.5	1	< 0.5	2	2	1	< 0.5	< 0.5	1
H	[%]		< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	2	< 0.5	1	< 0.5	< 0.5	< 0.5
Mg	[%]	3	< 0.5	< 0.5	1	2	1	1	< 0.5	< 0.5	1	1	< 0.5
K	[%]	7	9	10	4	3	1					< 0.5	< 0.5
S	[%]	2	1	2	1	2	2	< 0.5	2	1	< 0.5	< 0.5	1
Fe	[%]	2	2	2	2	2	2	< 0.5	2	1	8	2	< 0.5
Al	[%]	2	5	6	1	3	2	1	2	< 0.5	< 0.5	1	1
Mn	[%]	3	2	1	4	3	2	2	4	< 0.5	3	1	2
Na	[%]	2	4	1	2	2	1	2	6	1	< 0.5	2	1
Zn	[%]	2	1	2	1	2	2	1	< 0.5	1	4	1	1
Cu	[%]	3	2	2	3	2	2	2	3	< 0.5	2	< 0.5	1
Pb	[%]	2	< 0.5	< 0.5	2	< 0.5	2	7	4	3	1	< 0.5	1
Cr	[%]	1	1	1	3	4	3	1	5	3	4	2	1
Ni	[%]	3	1	2	5	3	2	2	4	1	3	2	1
Mo	[%]	2	1	3	3	2	2	1	4	1	2	< 0.5	1

Additional file 1 - Variation of the element composition of municipal sewage sludges in the context of new regulations on phosphorus recovery in Germany

Table S20: Share of in neutral ammonia citrate (NAC) extractable phosphorus (P_{NAC}) in several sewage sludge samples and molar ratios of P and potential precipitation agents Fe and Al

WWTP	Sample no.	Date	P	P_{NAC}	Share of P_{NAC}	Molar ratio Fe:P	Molar ratio Al:P	(Fe+Al):P	P elimination
			[g/kg]	[g/kg]	[%]				
a	4	Sep 19	22.7	19.5	86	1.2	0.1	1.3	EBPR. FeCl ₃
	5	Oct 19	20.6	15.7	76	1.0	0.2	1.2	
	8	Jan 20	23.1	19.4	84	1.0	0.2	1.2	
b	2	Oct 19	22.4	19.9	89	1.1	0.8	1.9	FeCl ₃ . AlCl ₃
	9	Jun 20	22.7	20.7	91	0.9	0.6	1.5	
c	1	Aug 19	22.6	20.3	90	1.2	0.3	1.5	FeCl ₃ . AlCl ₃
	13	Jul 20	17.6	16.7	95	1.3	0.3	1.6	
d	3	Nov 19	18.1	16.1	89	1.1	0.3	1.4	EBPR. FeCl ₃
	9	Jun 20	17.1	17.1	100	1.2	0.2	1.4	
e	1	Oct 19	23.4	20.6	88	0.7	1.2	1.8	FeCl ₃ . sodium aluminate
f	9	Jun 20	24.4	18.8	77	0.3	2.8	3.1	Sodium aluminate
	11	Aug 20	25.6	19.2	75	0.2	2.7	2.9	
g	2	Feb 20	17.4	11.5	66	0.5	0.6	1.1	EBPR. FeCl ₃
	8	Aug 20	24.2	17.9	74	0.5	0.4	0.9	
h	2	Nov 19	17.6	16.7	95	1.4	0.5	2.0	EBPR. FeCl ₃
i	2	Nov 19	22.9	19.7	86	0.8	1.0	1.9	FeCl ₃
	6	Mar 20	22.1	17.9	81	0.6	1.0	1.6	