Santa Rosa Subregional Long-Term Wastewater Project

TRACE ELEMENT LOADING ANALYSIS FOR THE WEST COUNTY AND SOUTH COUNTY RECLAMATION ALTERNATIVES

SANTA ROSA SUBREGIONAL LONG-TERM WASTEWATER PROJECT

Prepared for

City of Santa Rosa
and
U.S. Army Corps of Engineers

February 1996

Prepared by

QUESTA ENGINEERING CORPORATION
1220 BRICKYARD COVE ROAD, POINT RICHMOND, CA 94807 • 510/236-6114

For

HARLAND BARTHOLOMEW & ASSOCIATES, INC.

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1.0 INTRODUCTION

The term trace metal or trace element refers to chemical elements normally present in the environment in very low concentrations. In small quantities (ug/kg) many elements are essential to plant growth. These include: fluoride (F), silicon (Si), vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), selenium (Se), molybdenum (Mo), tin (Sn) and boron (B). At higher concentrations some of these elements may be toxic to plants, or accumulate in plants at levels that are toxic to animals that feed on them. In some cases, the range in concentration between deficiency and toxicity is narrow (i.e., boron [B]). In other cases, there is no known biological necessity for the trace metal and their occurrence in small quantities may be harmful. Lead (Pb), arsenic (As) and mercury (Hg) are examples of this effect. It is extremely rare for these metals to be present in harmful concentrations in native soils, except in areas surrounding ore deposits or perhaps where they concentrate by evaporation in low lying areas.

Trace metals behave in soils much differently than soluble salts. Unlike soluble salts, most metallic compounds are not readily soluble in water or mobile in the soil, except at a low pH. Because of their affinity to soil particles, including clay and organic colloids, carbonates and iron complexes, they are retained in the soil and normally do not move readily with soil-water. Therefore, metals added to soils from reclaimed water through irrigation may readily accumulate in surface layers. Boron and, to a lesser extent, arsenic and selenium, behave differently in the soil than other metals, and are somewhat soluble and mobile. The amount of the accumulation of metals in soil (soil loading) from irrigation is a function of the concentration of metals in the reclaimed water and the amount of water applied. With the exception of municipal wastewater retrieved from cities with associated extensive heavy industry, most reclaimed water supplies contain low levels of trace metals, relative to levels that can accumulate and adversely affect soil productivity and agricultural sustainability.

2.0 LOADING FROM IRRIGATON WATER

A trace element loading analysis was completed for select metals of particular water quality or environmental health significance for the reclamation alternatives of the Santa Rosa Subregional Long-term Wastewater Project. The calculation process and an example calculation are shown in Attachment A. Long-term average reclaimed water chemistry data and annual average irrigation application rates of 2.0 acre-feet per acre for the West County and 2.9 acre-feet per acre for the South County were utilized in the analysis. The method detection limit (MDL) was used in the calculations when the analytes were reported as non-detected. Total accumulation over a projected 25-year project life is also provided. The analysis is conservative, as it assumes no leaching loss of metals. In reality, approximately 2 to 20 percent of the applied metals may leave the site in leachate or runoff, with a slightly higher amount for boron. Trace element loadings are compared with levels of metals present for a typical project area soil and, where available, California or EPA allowable levels in the soil. Since there are no soil loading limits under California Administrative Code, Title 22, for irrigation with reclaimed water, the EPA limits for metal additions from biosolids (sludge) agricultural land application are provided as a reference point, along with recommendations from the California State Water Resources Control Board (SWRCB) publications, "Irrigation with Municipal Wastewater, a Guidance Manual." Based on the EPA 503 cumulative sludge loading limits, the number of years before the allowable limits are exceeded (assuming average annual application rates) is also calculated.

Table 1 summarizes data and analysis for the South County area and **Table 2** for the West County. As can be seen in the tables, accumulation of nearly all metals in applied reclaimed water, even after 25 years of loading, is very low and will not affect the productivity or toxicity level of the soil. This is largely due to the high quality of the reclaimed water.

Predicted concentrations of boron in the soil after 25 years of accumulation will approach the lower limits which could slightly impact yields of some boron-sensitive crops. Boron concentrations in the reclaimed water, at 0.479 mg/l, are just below the 0.50 mg/l concentration threshold where some crop leaf injury of boron sensitive species begins to occur (Guidelines for Interpretation of Water Quality for Agriculture, U.C. Cooperative Extension Service). However, the forage and pasture crops that could be grown in the South County and West County project areas are not considered to be particularly sensitive to boron. None of the specialty crops that can potentially be grown in the West or South County areas are especially boron sensitive. In addition, some natural leaching of salts and boron will occur from rainfall during winter months, precluding the sort of accumulation we conservatively estimated.

3.0 CUMULATIVE LOADING FROM OTHER SOURCES

Although the reclaimed water contains some modest fertilizer values (principally nitrogen), the irrigation water will likely not meet the total plant nutrition needs for all elements, particularly phosphorous applications for fruit and vegetables crops. Supplemental fertilizers may therefore be required.

In addition to trace metals applied to the soils from reclaimed water applications, small quantities of metals may be applied from other fertilizer sources. These include: 1) impurities associated with commercial chemical fertilization of vegetable or specialty crops; 2) animal manure applications to forage and pasture lands; and, 3) for Baylands areas, the City's Biosolids Beneficial Use Program (sludge additions). Since it would be unusual for farmland to use all three sources of fertilizer (agrochemical, animal manure, biosolids), the cumulative addition of metals from reclaimed water are dealt with separately for the fertilizer and animal manure sources. Biosolids additions will require annual review of cumulative metals loading following EPA 503 rules and regulations, and are therefore not evaluated.

Table 1

Reclaimed Irrigation Water/Metals Loading Analysis, South County Alternative

Metal	Concentration in Reclaimed Water [1]	Annual Soil Loading [2]	Loading After 25 Years [3]	Concentration in Benchmark Soil [4] (Clear Lake)	Common Range in Soils [5]	A Typical Soil Concentration [6]	Predicted Concentration Increase After 25 Years of Loading [7]	Impact on Crop [8]	Loading Limits [9]	Title 22 Toxic Limits [10]
	mg/l	kg/ha	kg/ha	mg/kg	mg/kg	mg/kg	mg/kg		kg/ha	mg/kg
As-Arsenic	.003	.027	.66	NA	.1-40	6	.01	Not required element for growth	--[a]/41[b]	500
B-Boron	.479	4.23	105.86	NA	2-200	10	15.74	Required, wide species differences	--/--	
Cd-Cadmium	.002	.018	.442	0.03	.01-7	.06	.066	Not required, toxic to plants	20/39	100
Cr-Chromium	.004	.035	.88	0.03	5-3,000	100	.13	Not required, low plant toxicity	--/3,000	2,500
Cu-Copper	.013	.115	2.87	3.16	2-100	20	.43	Required 2-4 mg/kg Toxic > 20 mg/kg	500/1,500	2,500
Pb-Lead	.009	.08	1.99	0.99	2-200	10	.23	Low plant toxicity	2,000/300	1,000
Mo-Molybdenum	.039	.34	8.62	0.02	.2-5	2	1.28	Required < 0.1 mg/kg	--/--	3,500
Ni-Nickel	.007	.062	1.55	5.85	10-1,000	4-	.23	Toxic > 50 mg/kg	500/420	2,000
Se-Selinium	.002	.017	.442	<0.01	.1-2.0	.5	1.05	Toxic > 50 mg/kg	--/100	100
Zn-Zinc	.032	.28	7.07	0.92	10-300	50	.170	Toxic > 200 mg/kg	1000/2800	5,000
Ag-Silver [11]	.002	.0177	4.425	NA	.1-5.0	.5	.657	Not required	--/--	500
Hg-Mercury [11]	.001	.025	.625	NA	.01-.08	.04	.0428	Not required, rarely present in toxic amounts in native soils	--/17	20

Table 2

Reclaimed Irrigation Water / Metals Loading Analysis, West County Alternative

Metal	Concentration in Reclaimed Water [1]	Annual Soil Loading [2]	Loading After 25 Years [3]	Concentration in Benchmark Soil [4] (Pajaro)	Common Range in Soils [5]	A Typical Soil Concentration [6]	Predicted Concentration Increase After 25 Years of Loading [7]	Impact on Crop [8]	Loading Limits [9]	Title 22 Toxic Limits [10]
	mg/l	kg/ha	kg/ha	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	kg/ha	mg/kg
As-Arsenic	.003	0.0183	0.4575	NA	.1-40	6	.068	Not required element for growth	--[a]/41[b]	500
B-Boron	.479	2.907	72.68	NA	2-200	10	10.80	Required, wide species differences	--	--
Cd-Cadmium	.002	0.0122	.305	0.04	.01-7	.06	.045	Not required, toxic to plants	20/39	100
Cr-Chromium	.004	0.0244	.061	0.05	5-3,000	100	.01	Not required, low plant toxicity	--/3,000	2,500
Cu-Copper	.013	0.0792	1.98	2.03	2-100	20	.29	Required 2-4 mg/kg Toxic > 20 mg/kg	500/1,500	2,500
Pb-Lead	.009	.055	1.375	0.48	2-200	10	.20	Low plant toxicity	2,000/300	1,000
Mo-Molybdenum	.039	.2378	5.95	0.06	.2-5	2	.88	Required < 0.1 mg/kg	--/18	3,500
Ni-Nickel	.007	0.0427	1.07	0.65	10-1,000	4-	.16	Toxic > 50 mg/kg	500/420	2,000
Se-Selinium	.002	0.0122	0.31	<0.01	.1-2.0	.5	.05	Toxic > 50 mg/kg	--/100	100
Zn-Zinc	.032	0.1951	4.88	14.77	10-300	50	.73	Toxic > 200 mg/kg	1000/280	5,000
Ag-Silver [11]	.002	0.0122	0.305	NA	.1-5.0	.5	.045	Not required	--/--	500
Hg-Mercruy [11]	.001	0.0061	0.1525	NA	.01-.08	.04	.023	Not required, rarely present in toxic amounts in native soils	--/17	20

Table Notes:

1	Concentration in reclaimed water - long-term average dates of monitoring reported by Laguna Treatment Plant Laboratory.
2	Based on 2.9 acre-feet/acre annual irrigation application in South County and 2.0 acre-feet/acre application in West County.
3	Represents cumulative addition of metals after 25 years of irrigation, with no leaching losses.
4	Benchmark soils used were: Clear Lake in the South County; Pajaro in the West County.
5, 6	As reported in **Table 13-2** in SWRCB#84-1. SWRCB#84-1 is Pettygrove, S and T. Asano (July 1984). Irrigation with Municipal Wastewater, A Guidance Manual, California State Water Resources Control Board Report #84-1 WR. Sacramento, California.
7	This represents predicted increase in soil concentration after 25 years of reclaimed water irrigation. It assumes metals accumulate in the upper 1.5 feet of soil with a weight of soil of 4 million pounds per acre-foot. Add column four to this column (seven) to obtain estimated soil concentration after project completion (+25 years).
8	As reported in **Table 13-2** in SWRCB#84-1.
9	a. Suggested loading rate in kg/ha for a clayey soil with a CEC > 15 as contained in **Table 13-3**, SWRCB#84-1. b. Maximum Allowable Cumulative Pollutant Loading rate (CPLR) per EPA Final 503 Rules for sludge additions to agricultural lands.
10	This is the level above which the State of California (Title 22) considers soil concentrations to constitute a toxic level. This number is provided as a relative reference point.
11	Information on silver and mercury from Chapman, H. (1965), Diagnostic Criteria for Plants and Soils, Quality Printing Company, Abilene, Texas.

Ref.: 93012MLA.T1

3.1 FERTILIZER IMPURITIES

Commercial fertilizers are most likely to be applied to fruit and vegetable crops. Computed heavy metal loading from trace element impurities in fertilizers were estimated from information developed by Parsons Engineering Science in 1987 as part of the Monterey Wastewater Reclamation Study for Agriculture (MWRSA).

Table 3 shows annual and 25-year loading rates from fertilizer impurities applied to vegetables, the cumulative additions of this source with project reclaimed water, and the number of years required before the EPA 503 Sludge Rules allowable cumulative loading is exceeded. Since the MWRSA data are a computed annual loading expressed on the basis of mg per kg of soil, it was necessary to convert their data to a kg/ha basis to make them comparable with our other project loading estimates. This was done using the assumption that loading is equally distributed throughout the root zone (1.5 feet) and that an acre-foot of soil weighs 4 million pounds.

3.2 ANIMAL MANURE

Animal manure from dairy operations may also be incorporated into the soils as a source of nitrogen for growing forage and silage crops. Manure application rates will be based on the nitrogen demand of the crop and the nitrogen content of the manure and reclaimed water, as outlined in the Irrigation Management Plan. For calculation purposes, we are estimating N application rates for a typical forage crop as about 20 tons per year (at 11 lbs N per ton).

Table 4 shows annual and 25 year loading rates from heavy metals at 20 tons per acre. The concentrations of metals in dairy manure were estimated from “Manure Production and Characteristics” (ASAE, 1992). Also shown in **Table 4** is the cumulative metals loading for reclaimed water and animal manure additions, and the total number of years before the EPA 503 limits are exceeded.

Table 3 Cumulative Loading from Reclaimed Water and Fertlilizer Impurities

South County

Metal	Annual Fertilizer Loading Rate[1]	Annual Fertilizer Loading Rate[2]	Annual Soil Loading Irrigation[3]	Cumulative Annual Loading[4]	Cumulative Loading 25 Years	Number of Years Until Loading Limits Exceeded
	(mg/kg/yr)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)		
Arsenic	--	--	.027	.027	.675	--/1,518
Boron	--	--	4.23	4.23	105.7	--/--
Cadmium	.001	.0067	.018	.0247	.6175	810/1,579
Chromium	.004	.0023	.035	.0373	.9325	--/80,429
Copper	.0006	.0040	.115	.1190	2.975	4,202/12,605
Lead	.002	.013	.08	.0934	2.2675	21,413/3,212
Molybdenum	--	--	.34	.34	8.5	--/--
Nickel	.003	.0202	.062	.0822	2.055	6,083/5,109
Selenium	--	--	.017	.017	0.425	--/5,882
Zinc	0.01	.0067	.28	.2867	7.167	3,488/9,766
Silver	--	--	.0177	.0177	.4425	--/--
Mercury	--	--	.025	.025	.625	--/680

West County

Metal	Annual Fertilizer Loading Rate[1]	Annual Fertilizer Loading Rate[2]	Annual Soil Loading Irrigation[3]	Cumulative Annual Loading[4]	Cumulative Loading 25 Years	Number of Years Until Loading Limits Exceeded
	(mg/kg/yr)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)		
Arsenic		--	.0183	.0183	.458	--/2,240
Boron	--	--	2.907	2.907	72.68	--/--
Cadmium	.001	.0067	.0122	.0189	.4725	1,058/2,063
Chromium	.004	.0023	.0244	.0267	.668	--/112,360
Copper	.0006	.0040	.0792	.0832	2.08	6,010/18,029
Lead	.002	.0134	.055	.0684	1.71	29,240/4,386
Molybdenum	--	--	.2378	.2378	5.95	--/--
Nickel	.003	.0202	.0427	.0629	1.573	7,949/6,677
Selenium	--	--	.0122	.0122	.31	--/8,197
Zinc	0.01	.0067	.1951	.2018	5.045	4,955/1,388
Silver	--	--	.0122	.0122	0.305	--/--
Mercury	--	--	.0061	.0061	.1525	--/2,787

TABLE 3 (Continued)

Notes:

-- Data are not available
1. Source: MWRSA, 1987
2. Per acre 1.5 feet = 6,000,000 lbs/acre and application rate of 20 tons of manure per year
3. From Tables 1 and 2
4. Sum of columns 2 and 3
5. 1st column SWRCB guidelines,
   2nd column EPA, 503 per table 1

Ref.: 93012MLA.T3

Table 4 Cumulative Loading from Reclaimed Water and Manure

South County

Metal	Estimated Concentration in Manure[1]	Annual Soil Loading - Manure [2]	Annual Soil Loading - Irrigation[3]	Cumulative Annual Loading[4]	Cumulative Loading 25 Years	Number of Years Until Loading Limits Exceeded
	(mg/kg)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)		
Arsenic	--	--	.027	.027	.675	--/1,518
Boron	.059	.002645	4.23	4.233	105.8	--/--
Cadmium	.00025	.0000112	.018	.0180	.45	1,111/2,167
Chromium	--	--	.035	.035	.875	--/85,714
Copper	.0375	.001681	.115	.1167	2.918	4284/12,853
Lead	--	--	.08	.08	2.00	25,000/3,750
Molybdenum	.0061	.000273	.34	.3400	8.50	--/--
Nickel	.023	.001031	.062	.0630	1.515	7,937/6,667
Selenium	--	--	.017	.017	.425	--/5,882
Zinc	.150	.000672	.28	.2871	7.178	3,483/9,753
Silver	--	--	.0177	.0177	.4425	--/--
Mercury	--	--	.025	.025	.625	--/680

West County

Metal	Estimated Concentration in Manure[1]	Annual Soil Loading - Manure [2]	Annual Soil Loading - Irrigation[3]	Cumulative Annual Loading[4]	Cumulative Loading 25 Years	Number of Years Until Loading Limits Exceeded
	(mg/kg)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)		
Arsenic	--	--	.0183	.0183	.4575	--/2240
Boron	.059	--	2.907	2.910	72.75	--/--
Cadmium	.00025	.0000118	.0122	.01231	.3075	1,625/3,168
Chromium	--	--	.0244	.0244	.6100	--/122,951
Copper	.0375	--	.0792	.0810	2.03	6,173/18,519
Lead	--	--	.055	.055	1.375	36,364/5,455
Molybdenum	.0061	--	.2378	.2381	5.953	--/--
Nickel	.023	--	.0427	.0437	1.093	11.442/9,611
Selenium	--	--	.0122	.0122	0.305	--/8197
Zinc	.150	--	.1951	.2018	5.055	4,946/1,387
Silver	--	--	.0122	.0122	0.305	--/--
Mercury	--	--	.0061	.0061	0.1525	--/2,787

TABLE 4 (Continued)

Notes:

-- Data are not available
1 Calculated from information contained in 39th Edition, ASAE Standards, Engineering Practices and Data, 1992, Manure Production and Characteristics ASAED 384.1 American Society Agricultural Engineering, St. Joseph, MI
2 Based on annual application of 20 tons/acre manure = 47,300 kg/ha.
3 From Tables 1 and 2, column 2
4 Columns 2 and 3,; column 3 where no data for 2
5 Annual loading times 25 years
6 1st column SWRCB guidelines for sludge
2nd column EPA 503 rules (Tables 1 and 2, column 9)

Ref.: 93012MLA.T4

4.0 CONCLUSIONS AND RECOMMENDATIONS

The Irrigation Management Plan (IMP) includes provisions for annual monitoring of pH, soluble salts, metals, boron and plant nutrients in the soil and shallow groundwater. Management measures are provided in the IMP which could mitigate impacts should the trends analysis begin to indicate higher than predicted accumulation of salts, boron or trace elements in the soil.

Special consideration will be required for the management of salts and metals in areas of Reyes soils (reclaimed Baylands). These soils are naturally very acidic, with pH levels typically less than 4.5. Together with the presence of a high groundwater table, these conditions in areas of Reyes soils may permit the transport of metals to shallow groundwater, unless properly managed. Some areas of Baylands may also have biosolids (sludge) applied to agricultural lands in addition to irrigation with reclaimed water. The EPA 503E Sludge Rules (and the IMP) will require that metals loading account for source additions from both biosolids and reclaimed water. Typically, only pasture and hay crops will be grown on these lands. The lands will typically also be limed and managed in order to maintain soil pH levels above 6.0.

Cumulative metals loading from either fertilizer impurities or from trace elements present in animal manure, together with the metals present in the reclaimed water, will not begin to approach levels that are toxic in the soil. Because of the good quality of water and generally low levels of metals found in fertilizers and animal wastes, hundred of years of loading would be required before EPA 503 loading limits are exceeded (**Tables 3** and **4**).

5.0 REFERENCES

American Society of Agricultural Engineers (1992). Manure Production and Characteristics, St. Josephs, MI

Chapman, H. (1965). Diagnostic Criteria for Plants and Soils, Quality Printing Company, Abilene, TX.

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