COPPER

SOURCE IDENTIFICATION

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Prepared for
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SUMMARY

The Palo Alto Regional Water Quality Control Plant (RWQCP) conducted this study to investigate sources of copper in the plant’s influent. The goals of this effort were to identify and quantify, to the extent possible, sources of copper in the RWQCP influent; to identify areas where more data and analysis are needed, if any; and to identify sources that may offer the best opportunities for future pollution prevention efforts. The largest source of copper discharged to the RWQCP has been determined to be the corrosion of copper pipes. Over half, about 58%, of the copper in the RWQCP’s influent results from this corrosion. Corrosion associated with cooling towers and circulating hot water systems accounts for another 6% and 3% of the copper load, respectively. About 7% of the copper in the influent originates from the water supply. All the remaining copper sources each contribute less than 7% of the total. These include human waste, storm water inflow, infiltration and groundwater discharges, Stanford University, permitted industries, identified commercial sources (vehicle service facilities and machine shops), septage, and residential waste sources (excluding human waste). Although uncertainties exist in these results, the relative contributions of these sources are probably roughly proportional to the results stated here. No major copper sources are believed to remain unidentified because estimated copper loads for the sources identified in this report account for 103% of the copper load actually measured at the RWQCP. Because corrosion by far contributes the greatest amount of copper to the influent load, efforts to reduce copper discharges from corrosion could substantially reduce the observed copper levels.

BACKGROUND AND PURPOSE

Copper is a naturally occurring metal that exists by itself as an element or in combination with other elements in various minerals and compounds. In its elemental form, it is a reddish-brown, lustrous, ductile, and malleable metal. It is commercially available in the form of ingots, sheets, wire, tubing, and powder. Copper is used to manufacture bronze, brass, and other copper alloys; electrical conductors; ammunition; and copper salts. Metallic copper becomes dull when exposed to air. In moist air, it gradually becomes coated with green copper carbonate, as can be observed on copper architectural adornments and roofs. Water soluble forms of copper are often tinted blue or green (*Merck Index* 1983).

Traces of copper are essential to the survival of many plants and animals. It occurs in several important biological complexes necessary to sustain life. Copper has little potential for human toxicity, but soluble salts, notably copper sulfate, may irritate skin and mucous membranes (*Merck Index* 1983). When discharged into aquatic systems such as San Francisco Bay, however, too much copper can be harmful to aquatic life. Copper levels less than 5 ug/l have been observed to adversely affect some species.

Although recent RWQCP copper discharges do not exceed current regulatory limits, the effluent levels are of concern because of copper’s potential effects on species in San Francisco Bay and because of the potential for permit modifications to reduce copper discharge limits. For these reasons, since 1990 the RWQCP has extensively studied sources of copper in sewer discharges contributing to the plant's influent loading. From 1994 through 1998, the results of the RWQCP's copper source identification studies have been presented in its annual *Clean Bay Plan*. The goals of these ongoing efforts have been to identify and quantify sources of copper in the RWQCP influent; to identify areas where more data and analysis are needed, if any; and to identify sources that may offer the best opportunities for future pollution prevention efforts. The 1998 results presented in this report reflect the success of past copper reduction efforts.

PAST FINDINGS

The RWQCP has been monitoring its copper discharges for some time, and copper discharges have decreased over the years. As shown in Figure 1, the RWQCP discharged about 7,500 pounds of copper per year about 15 years ago in 1983, but in 1998, it discharged about 580 pounds. Influent copper levels have also decreased. In 1983, the influent copper load was about 28,000 pounds, but by 1998, it dropped to about 3,750 pounds. In 1998, the effluent copper concentration discharged to San Francisco Bay averaged 6.9 micrograms per liter, with a high of 10.2 micrograms per liter (RWQCP 1999).

This downward trend in copper levels reflects both treatment process improvements and copper discharge reduction programs. Since 1990, the RWQCP has conducted a major pollution prevention and regulatory program to reduce copper discharges. This program has reduced influent copper loads by 46% and influent copper concentrations by 58%. The influent copper concentration has dropped from an average of 105 micrograms per liter in 1990 to an average of 44 micrograms per liter in 1998 (RWQCP 1999). The program has eliminated or greatly reduced many past sources of copper discharges. For example, copper-based root control products have been eliminated, and metal finishing copper discharges have been greatly reduced. The observed copper reductions demonstrate the success of the RWQCP's numerous pretreatment and pollution prevention program activities.

1998 RESULTS

In 1998, the overall influent copper load observed at the RWQCP was about 3,750 pounds. Table 1 lists and Figure 2 illustrates the relative contributions of the major sources of this total copper load. As shown in Table 1 and Figure 2, over half (about 58%) of the copper in the RWQCP's influent results from the corrosion of copper pipes. Corrosion associated with cooling towers and circulating hot water systems account for

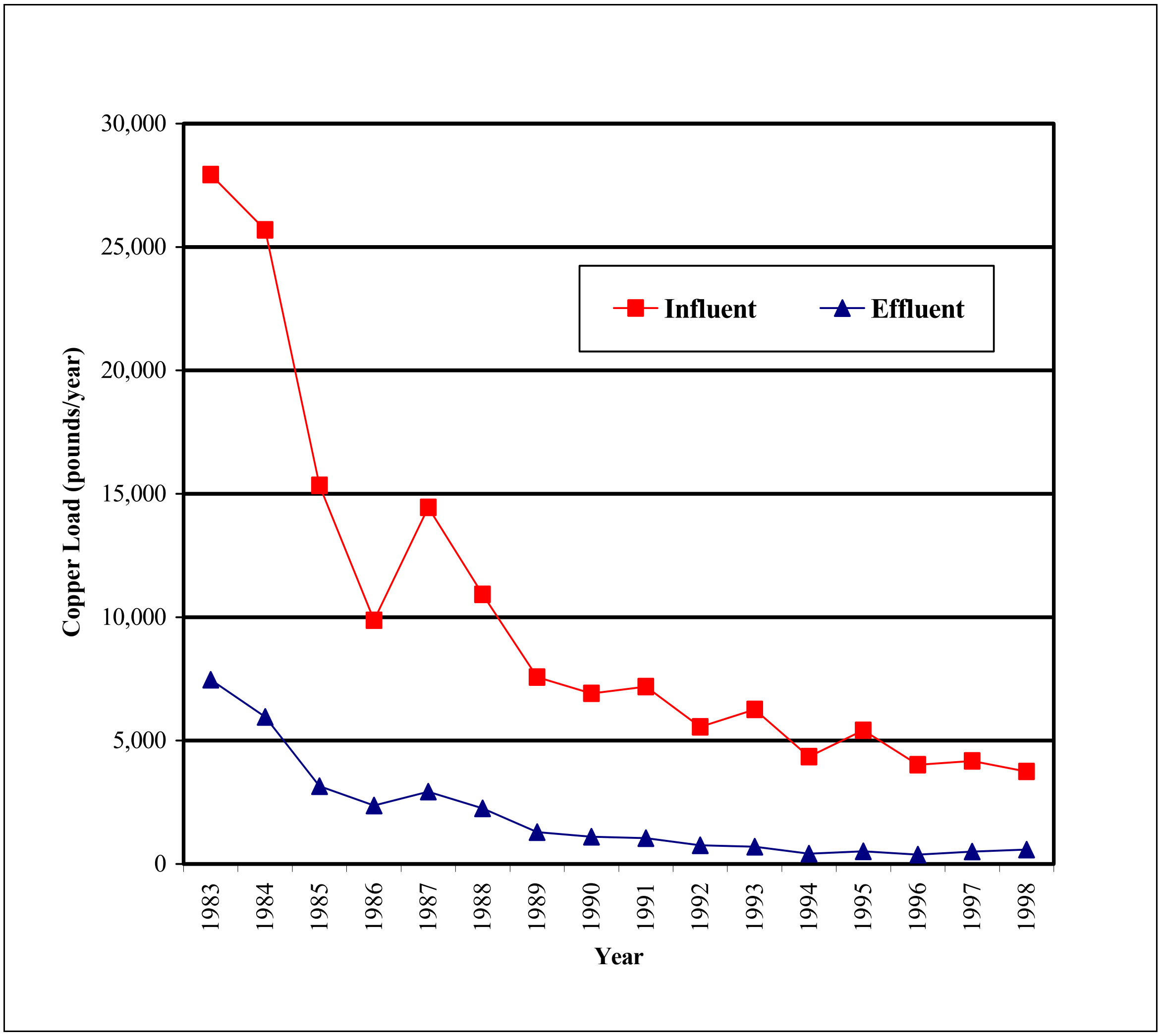

FIGURE 1: Copper Load Trend

another 6% and 3%, respectively. The water supply adds an additional 7%, and all the remaining copper sources each contribute less than 7%. Human waste, storm water inflow, and groundwater infiltration and direct discharges each contribute about 6%. Stanford University discharges about 4%, and all permitted industries combined discharge another 4%. Identified commercial sources (vehicle service facilities, including car washes, and machine shops), septage, and residential waste sources (excluding human waste) each contribute about 1% of the total copper influent load. An appendix contains supporting calculations for these results and provides references to data sources.

The sum of the individual load estimates for all the copper sources is about 3,850 pounds per year, which is about 103% of the actual measured copper influent load of 3,750 pounds per year. Because the sum of the individual load estimates exceeds 100% of the actual copper load, no large sources of copper are believed to remain unidentified.

TABLE 1: 1998 Copper Sources

Source	Copper Load (pounds/year)
Water Supply	270
Corrosion	2,180
Cooling Towers	210
Circulating Hot Water Systems	120
Human Waste	240
Residential Waste (excluding human waste)	25
Permitted Industries	160
Identified Commercial Sources	34
Stanford University	135
Storm Water Inflow	210
Infiltration and Groundwater	240
Septage	25
TOTAL of Estimated Sources	3,850
TOTAL Measured in RWQCP Influent	3,750

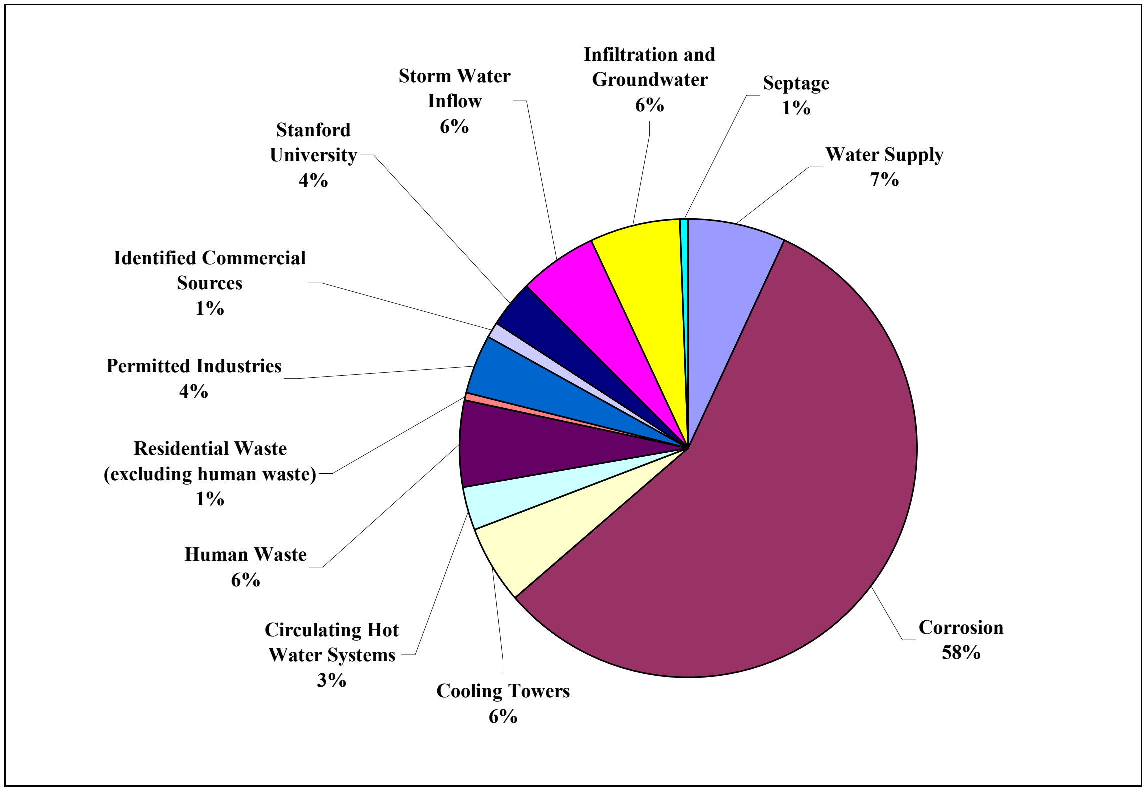

FIGURE 2: 1998 Copper Sources

DISCUSSION

The 1998 results reflect certain circumstances specific to the RWQCP. These circumstances eliminate or substantially reduce copper discharges from sources that, in other areas of the country, could be important.

- ***Industrial Dischargers***. In the early 1990s, the RWQCP surveyed its industrial dischargers and learned that, with the exception of some limited use of copper-containing substances by local laboratories, the only intentional use of copper in industrial processes is by the metal finishing industry. This industry includes metal plating and printed circuit board manufacturing. The RWQCP has incorporated pollution prevention within its regulation of metal finishers, and since 1992, copper discharges from this source have decreased by 42% (RWQCP 1999).

- ***Copper-Based Root Killers***. Copper-based root killers are a major source of copper in many parts of the country, but California banned the sale and use of copper-based root killers in the nine San Francisco Bay Area counties. Studies had projected that the ban could reduce influent copper loads between 5% and 15%. In 1995 and 1996, shortly after the ban became effective, the RWQCP observed a drop of about 25% in its residential trunk line copper load, which translated into a reduction of roughly 9% reduction in the plant's influent load. Most of this reduction is attributed to the regional ban. The effectiveness of banning copper-based root killers may actually be greater than 9% because, in 1992, local cities within the RWQCP service area had already banned use of copper-based root killers. However, this earlier local ban was difficult to enforce because several major retailers and most plumbers are located outside the service area boundaries (RWQCP 1999).

- ***Cooling Water Discharges***. Both corrosion and cooling system additives can elevate copper levels in cooling water system discharges. Elsewhere in the country, cooling water additives can contain copper as an active ingredient. In California, however, the state has not registered for sale any cooling water additives containing copper as an active ingredient. Some California-registered cooling water additives contain copper as in "inert" ingredient (an ingredient not listed among the active ingredients), and "inert" ingredients need not be identified on product labels. The RWQCP has conducted an educational and regulatory program to discourage facility managers from using copper-containing cooling water additives. The RWQCP's cooling water system educational program encourages the use of copper-free additives to reduce system corrosion. In 1995, when the educational program was initiated, the average copper concentration in cooling tower discharges to the RWQCP was 0.34 milligrams per liter, but in 1998, it was 0.26 milligrams per liter, a 25% reduction (RWQCP 1999).

- ***Copper Sulfate***. Unlike in many areas of the country, copper sulfate is not routinely added to the water supplies serving the RWQCP service area (a process called "bluestoning"). Of the estimated 270 pounds of copper in the RWQCP water supply in 1998, about 60 pounds (less than 2% of the total influent copper load) can be attributed to the addition of copper sulfate (Copper and Selenium Steering Committee 1994).

UNCERTAINTY

The individual load estimates presented here are believed to accurately represent typical loads at the RWQCP with reasonable confidence, but there are uncertainties in the exact loads. But because the corrosion copper load is by far the largest of all the identified sources, the absolute magnitude of its uncertainty could also be substantial. However, the relative uncertainty in the copper load estimate for corrosion is believed to be similar to the relative uncertainty of the other estimates. The other load estimate calculations were each adjusted to reflect the corrosion contribution; therefore, the uncertainty in the corrosion load estimate was carried through each of the other calculations. Because the total of the individual estimated copper loads for all the sources combined adequately account for the observed influent copper load, the uncertainties in the corrosion load estimate and the other estimates do not appear to affect the utility of the results. All major copper sources are believed to have been identified and the relative proportions among the sources appear reasonable.

CONCLUSION

The results of the analysis clearly show that corrosion from copper pipes is by far the largest source of copper in the RWQCP influent. The RWQCP has studied copper corrosion in depth (Kennedy/Jenks Consultants 1996) and additional study is unnecessary to recognize the importance of this source. Because all the other copper sources are relatively small (7% or less of the total influent load), no further study is likely to change the relatively small role they play in the overall copper load. Therefore, the corrosion of copper pipes could offer the greatest opportunity for pollution prevention.

ACKNOWLEDGEMENTS

Key Staff: Bill Johnson, EIP Associates
Kelly Moran, Ph.D., Palo Alto RWQCP

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APPENDIX

Calculations

WATER SUPPLY

Supply Water Flow = 23.9 x 10^6 gal/day (*Source:* EIP Associates 1999a)

Average Cu Concentration = 0.0037 mg/l (*Source:* Montgomery Watson 1994)

> Cu concentrations for San Francisco and Santa Clara Valley water and Mountain View and Los Altos groundwater have been calculated individually.
>
> The San Francisco Water System calculation is based on 42 concentration measurements of the San Francisco water supply. Copper was detected in all the samples. The detection limit was 0.00026 mg/l.
>
> The Santa Clara Valley Water District calculation is based on 46 concentration measurements of the Santa Clara Valley Water District water supply. Copper was detected in all the samples. The detection limit was 0.00026 mg/l.
>
> Mountain View and Los Altos groundwater calculations are based on the midpoint between the range of values (0.0021 mg/l to 0.0084 mg/l) reported by the Mountain View Utilities Department in 1992. Measurements reported by the California Water Service Company (Los Altos) involved detection limits too high to provide meaningful information. The City of Mountain View's 1992 report does not indicate the number of samples collected. Because groundwater accounts for a relatively small portion of the total water supply, it contributes relatively little to the overall concentration of Cu in the water supply.

Water Supply Load =
0.0037 mg/l x 8.346 x 10^{-6} l-lb/mg-gal = 3.10 x 10^{-8} lb/gal
3.10 x 10^{-8} lb/gal x 23.9 x 10^6 gal/day x 365 days/yr = **269 lb/yr**

CORROSION

1992 Cu Corrosion Load = 5.0 lb/day (*Source:* Montgomery Watson 1994)

1992 Water Use = 20.0 x 10^6 gal/day (*Source:* EIP Associates 1999a)

1998 Water Use = Supply Water Flow = 23.9 x 10^6 gal/day (*Source:* EIP Associates 1999a)

1998 Cu Corrosion Load =
1992 Cu Corrosion Load x 1998 Water Use ÷ 1992 Water Use =
5.0 lb/day x 23.9 x 10^6 gal/day ÷ 20.0 x 10^6 gal/day = 5.975 lb/day
5.975 lb/day x 365 days/yr = **2,181 lb/yr**

Corrosion of copper pipes is by far the greatest contributor to the copper load at the RWQCP; therefore, the RWQCP has studied corrosion in depth. The 1992 copper corrosion load estimate of 5.0 lb/yr reported in 1994 (Montgomery Watson 1994) was revised in 1996 (Kennedy/Jenks Consultants 1996). The revised estimate of the 1992 copper load was 20% greater, or 6.0 lb/day. Because different methods were used to estimate the same corrosion loads, different results were obtained. While the latter estimate reflects additional information, the level of uncertainty in the estimate is similar to that of the original estimate. The original estimate was used for purposes of this copper source identification study because the data presented elsewhere in this analysis support the use of the lower estimate. With the lower estimate, the total of all copper sources identified in this report is 103% of the copper load actually measured in the influent. In contrast, using the higher 1992 load estimate, the estimated 1998 corrosion load would be about 2,600 lb/yr and the total copper load from all identified sources would be about 15% greater than the observed influent load.

COOLING TOWERS

The total cooling tower load is estimated by completing four separate calculations, as described more fully in a technical memorandum (EIP Associates 1999b). Cooling tower flows and Cu loads are estimated separately for the following:

1) Cooling towers that discharge through industrial discharger sampling locations. Since the Cu contribution from such cooling towers must be subtracted from total industry loads to estimate the net industrial process loads, the industrial calculations include load estimates for these cooling towers;

2) Other industry cooling towers for which the RWQCP Industrial Waste Program has established sampling locations and conducted sampling and analysis (excluding those included in the permitted industry calculations);

3) Remaining industry cooling towers (i.e., those identified in a 1995 survey that still exist and are not included in the categories above); and

4) Commercial cooling towers.

Cooling Towers Included in Permitted Industry Calculations

Load = 109 lb/yr (*Source:* RWQCP data, "industrycuload.xls")

Flow = 147,000 gal/day (*Source:* RWQCP data, "industrycuload.xls")
147,000 gal/day x 365 days/yr = 53.66 x 10^6 gal/yr

Other Industry Cooling Towers with Actual Flow and Concentration Monitoring Data

Load = 8.2 lb/yr (*Source:* RWQCP data, "coolingtower_98.xls")

Flow = 9,716 gal/day (*Source:* RWQCP data, "coolingtower_98.xls")
9,716 gal/day x 365 days/yr = 3.546 x 10^6 gal/yr

Remaining Industry Cooling Towers

Flow = 41,956 gal/day
(*Source:* Kennedy/Jenks Consultants 1995; RWQCP data, "leftoverkjctowers.xls")
41,956 gal/day x 365 days/yr = 15.31 x 10^6 gal/yr

Average Cooling Tower Cu Discharge Concentration from Permitted Industry Cooling Tower Locations Monitoring Data = 0.26 mg/l (*Source:* RWQCP data, "coolingtower_98.xls")

Remaining Industry Cooling Tower Load =
0.26 mg/l x 8.346×10^{-6} l-lb/mg-gal = 2.17×10^{-6} lb/gal
2.17×10^{-6} lb/gal x 15.31×10^{6} gal/yr = 33.2 lb/yr

Commercial Cooling Towers

Flow = 41×10^{6} gal/yr (*Source:* Kennedy/Jenks Consultants 1995)

Average Cooling Tower Cu Discharge Concentration from Permitted Industry Cooling Tower Locations Monitoring Data = 0.26 mg/l (*Source:* RWQCP data, "coolingtower_98.xls")

Remaining Industry Cooling Tower Load =
0.26 mg/l x 8.346×10^{-6} l-lb/mg-gal = 2.17×10^{-6} lb/gal
2.17×10^{-6} lb/gal x 41×10^{6} gal/yr = 89.0 lb/yr

Total Cooling Tower Load

Total Cooling Tower Load =
Load from Cooling Towers Included in Permitted Industry Calculations +
Load from Other Industry Cooling Towers with Actual Flow and Concentration Data +
Load from Remaining Industry Cooling Towers +
Load from Commercial Cooling Towers =
109 lb/yr + 8.2 lb/yr + 33.2 lb/yr + 89.0 lb/yr = 239 lb/yr

Water Supply and Corrosion Correction

Total Cooling Tower Flow =
Flow from Cooling Towers Included in Permitted Industry Calculations +
Flow from Other Industry Cooling Towers with Actual Flow and Concentration Data +
Flow from Remaining Industry Cooling Towers +
Flow from Commercial Cooling Towers =
53.66×10^{6} gal/yr + 3.546×10^{6} gal/yr + 15.31×10^{6} gal/yr + 41×10^{6} gal/yr =
113.5×10^{6} gal/yr

Cu Concentration in Tap Water = 0.0298 mg/l (*Source:* Montgomery Watson 1994)

> Cooling towers in the RWQCP service area receive essentially all of their water from the San Francisco Water System (i.e., groundwater supply water is used primarily for residential purposes). Cu concentrations in San Francisco tap water are assumed to be representative of combined water supply and corrosion concentrations. The tap water concentration is estimated on the basis of 188 concentration measurements of first and full

flush samples of hot and cold water. Copper was detected in all samples. The detection limit was 0.001 mg/l.

Water Supply and Corrosion Load in Cooling Tower Waste =
0.0298 mg/l x 8.346 x 10^{-6} l-lb/mg-gal = 2.487 x 10^{-7} lb/gal
2.487 x 10^{-7} lb/gal x 113.5 x 10^{6} gal/yr = 28.2 lb/yr

Net Cooling Tower Waste Load

Net Cooling Tower Waste Load =
Total Cooling Tower Waste Load - Water Supply and Corrosion Load =
239 lb/yr - 28.2 lb/yr = **211 lb/yr**

CIRCULATING HOT WATER SYSTEMS

The total circulating hot water system load is estimated by modifying calculations performed in 1995 for industrial and commercial circulating hot water systems (Kennedy/Jenks Consultants 1995). A more detailed description of these calculations is provided in a technical memorandum (EIP Associates 1999c).

Industrial Circulating Hot Water Systems

Industrial circulating hot water systems included in the 1995 study are segregated into three groups. Circulating hot water system flows and Cu loads are estimated separately for the following:

1) Systems that discharge through industrial discharger sampling locations. To estimate the net industrial process load, the Cu contribution from these circulating hot water systems must be subtracted from the total industry load (see "Permitted Industries," below).

2) Systems for which the RWQCP Industrial Waste Program has not established sampling locations.

3) Systems that require special Cu load calculations because (a) the circulating hot water system load reported in 1995 exceeds the total load calculated for the facility using 1998 monitoring data, or (b) better information is available. The Cu contribution from these circulating hot water systems must also be subtracted from the total industry load (see "Permitted Industries," below).

Cu Load from Systems that Discharge through Industrial Discharger Sampling Locations
= 9.35 lb/yr (*Source:* RWQCP data, "circulatinghotwateratiu.xls")

Cu Load from Systems that do Not Discharge through Industrial Discharger Sampling Locations
= 29.2 lb/yr (*Source:* RWQCP data, "circulatinghotwateratiu.xls")

Cu Load from Systems that Require Special Load Calculations
= 49 lb/yr (*Source:* RWQCP data, "circulatinghotwateratiu.xls")

> These Cu loads are corrected to account for Cu from the water supply and corrosion. With one exception, "special" load calculations amount to replacing the load estimated for a facility's systems in 1995 with the load estimated for that entire facility using 1998 monitoring data. In these three cases, the total load calculated using 1998 monitoring data is less than the load estimated for just the circulating hot water system in 1995. The exception is Stanford University Hospital. Its circulating hot water system Cu load is estimated on the basis of a study that focused specifically on Stanford University Hospital (Torke 1999).

Total Industrial Circulating Hot Water Systems Load =
Cu Load from Systems that Discharge through Industrial Discharger Sampling Locations +
Cu Load from Systems that do Not Discharge through Sampling Locations +
Cu Load from Systems that Require Special Load Calculations =
9.35 lb/yr + 29.2 lb/yr + 49 lb/yr = **87.6 lb/yr**

Commercial Circulating Hot Water Systems

Cu Load = 48 lb/yr
(*Source:* Kennedy/Jenks Consultants 1995; RWQCP data, "modified-kjc-tables.xls")

> This load is not corrected for water supply or corrosion. The 1995 study included a survey of commercial facilities. The residential facilities for which circulating hot water system data were obtained for the survey include 10 facilities, each of which stands at least 4 stories tall. Information about the circulating hot water systems at these facilities was used to extrapolate information for residential facilities of at least 30,000 square feet, regardless of the height of these facilities. For purposes of the analysis presented here, the 4-story and greater high-rise residential complexes are not considered representative of shorter, more spread out residential facilities. Low-rise complexes are believed to be less likely to have circulating hot water systems and, if they have them, their flow and Cu concentrations may not be similar to the high-rise complexes. Because no satisfactory data were available for the low-rise residences, they are excluded from this analysis. As a result, the commercial Cu load reported here may be understated by a small degree.

Water Supply and Corrosion Correction

Flow = 68×10^6 gal/yr
(*Source:* Kennedy/Jenks Consultants 1995; RWQCP data, "modified-kjc-tables.xls")

Cu Concentration in Tap Water = 0.0298 mg/l (*Source:* Montgomery Watson 1994)

> Commercial facilities receive the majority of their water from the San Francisco Water System. Cu concentrations in San Francisco tap water are assumed to be representative of combined water supply and corrosion concentrations. The tap water concentration is estimated on the basis of 188 concentration measurements of first and full flush samples of hot and cold water. Copper was detected in all samples. The detection limit was 0.001 mg/l. To the extent that commercial facilities could use water provided by suppliers other than the San Francisco Water System, this correction could slightly overstate the net Cu load.

Water Supply and Corrosion Load in Commercial Circulating Hot Water Systems Waste =
0.0298 mg/l x 8.346×10^{-6} l-lb/mg-gal = 2.487×10^{-7} lb/gal
2.487×10^{-7} lb/gal x 68×10^{6} gal/yr = 16.9 lb/yr

Net Commercial Circulating Hot Water Systems Load

Net Commercial Circulating Hot Water Systems Load =
Commercial Circulating Hot Water Systems Load - Water Supply and Corrosion Load =
48 lb/yr - 16.9 lb/yr = **31 lb/yr**

Total Circulating Hot Water Systems Load

Total Circulating Hot Water Systems Load =
Total Industrial Circulating Hot Water Systems Load +
Net Commercial Circulating Hot Water Systems Load =
87.6 lb/yr + 31 lb/yr = **119 lb/yr**

PERMITTED INDUSTRIES

Total Permitted Industry Cu Load = 404 lb/yr
(*Source*: RWQCP data, "industrycuload.xls" and "metalfinishers.xls")

> The Cu loads for metal finishers were calculated separately from the Cu loads for other permitted industries. The total metal finishers Cu load was 146 lb/yr. The total Cu load for the other permitted industries was 258 lb/yr. The results of these two independent calculations are combined in the 404 lb/yr load reported here.

Water Supply and Corrosion Correction

Net Process Flow = 1.27 x 10^6 gal/yr (*Source:* RWQCP data, "industrycuload.xls")
Industrial Sanitary Flow = 0.76 x10^6 gal/yr (*Source:* RWQCP data, "industrycuload.xls")

Effective Permitted Industry Flow =
Net Process Flow + Industrial Sanitary Flow =
1.27 x 10^6 gal/yr + 0.76 x10^6 gal/yr = 2.03 x 10^6 gal/yr

> Industrial Sanitary Flow is added to the net process flow because, although the human waste load was subtracted from the estimated permitted industry load above, the water supply and corrosion load associated with the sanitary flow was not subtracted.

Cu Concentration in Tap Water = 0.0298 mg/l (*Source:* Montgomery Watson 1994)

> Permitted industries within the RWQCP service area receive essentially all their water from the San Francisco Water System. (El Camino Hospital is the primary exception. Its average flow is small compared to the combined flow from all permitted industries.) Therefore, Cu concentrations in San Francisco tap water are assumed to be representative of combined water supply and corrosion concentrations. The tap water concentration is estimated on the basis of 188 concentration measurements of first and full flush samples of hot and cold water. Copper was detected in all samples. The detection limit was 0.001 mg/l.

Water Supply and Corrosion Load in Permitted Industry Waste =
0.0298 mg/l x 8.346 x 10^{-6} l-lb/mg-gal = 2.487 x 10^{-7} lb/gal
2.487 x 10^{-7} lb/gal x 2.03 x 10^6 gal/day x 365 days = 184 lb/yr

Circulating Hot Water Systems Correction

Cu Load from Systems that Discharge through Industrial Discharger Sampling Locations
= 9.35 lb/yr (See "Circulating Hot Water Systems," above)

Cu Load from Systems that Require Special Load Calculations
= 49 lb/yr (See "Circulating Hot Water Systems," above)

Circulating Hot Water Systems Load =
Cu Load from Systems that Discharge through Industrial Discharger Sampling Locations +
Cu Load from Systems that Require Special Load Calculations =
9.35 lb/yr + 49 lb/yr = 58 lb/yr

Net Permitted Industry Waste Load

Net Permitted Industry Waste Load =
Total Permitted Industry Load -
Water Supply and Corrosion Load -
Circulating Hot Water Systems Load =
404 lb/yr - 184 lb/yr - 58 lb/yr = **162 lb/yr**

HUMAN WASTE

Cu Discharge per Human = 1.179 mg/day (*Source:* Larry Walker Associates 1994)
1.179 mg/day x 365 days/year ÷ 1,000 mg/g = 0.4303 g/year

> According to a Central Contra Costa County study of residential metals discharges (Larry Walker Associates 1994), the Washington Toxics Coalition identified 6 sources of information about dietary copper intake and copper in urine and feces. Because measuring copper directly in urine and feces probably represents human waste discharges better than estimates based on dietary intake, only the urine and feces data are used here. The average total amount of copper in human waste (both urine and feces) is about 1,179 ug/day/person. (The Washington Toxics Coalition study reported an average of 1,300 ug/day/person, but the average of the data presented in the report is about 1,179 ug/day/person [Moran and Johnson 1999])

Residential Population of Service Area = 226,300
(*Source:* Association of Bay Area Governments 1997)

Employed Residents of Service Area (whether employed inside the service area or not) = 118,200 (*Source:* Association of Bay Area Governments 1997)

Jobs in Service Area (whether held by residents or not) = 185,230
(*Source:* Association of Bay Area Governments 1997)

Non-Working Service Area Residents =
Residential Population of Service Area - Employed Residents of Service Area =
226,300 - 118,200 = 108,100

> Non-working residents are assumed to discharge 100% of their human waste at home as residential human waste.
>
> Workers (whether residents of the service area or not) are assumed to discharge 64.3% of their human waste at home as residential human waste and 35.7% of their human waste at work as employee human waste. This assumption is based on the following:
>
> > Each employee is assumed to work 5 days/week and stay home 2 days/week. During a typical work day, each employee is assumed to spend 8 hours sleeping, 8 hours awake at home, and 8 hours awake at work. Because during the work day half of the employee's waking hours are at home and half are at work, 50% of his or her human waste is assumed to be discharged at home and 50% is assumed to be discharged at

work. Therefore, the residential discharge of a worker is 0.643 times that of a non-worker (i.e., fraction of employee discharge excreted at home = [2 days + {0.5 x 5 days}] ÷ 7 days = 0.643). Consequently, the employee human waste discharge of each worker is 0.357 times the total amount he or she excretes both at work and at home (i.e., fraction of employee discharge excreted at work = 1 - fraction excreted at home = 1 - 0.643 = 0.357).

Residential Human Waste

Residential Human Waste Load of Non-Workers =
Cu Discharge per Human x Non-Working Service Area Residents =
0.4303 g/yr x 108,100 = 4.652 x 10^5 g/yr
4.652 x 10^5 g/yr x 0.002205 lb/g = 102.6 lb/yr

Residential Human Waste Load of Workers =
Cu Discharge per Human x
Employed Residents of Service Area x
Fraction of Employee Discharge Excreted at Home =
0.4303 g/yr x 118,200 x 0.643 = 3.270 x 10^4 g/yr
3.270 x 10^4 g/yr x 0.002205 lb/g = 72.1 lb/yr

Total Residential Human Waste Load =
Residential Human Waste Load of Non-Workers + Residential Human Waste Load of Workers
= 102.6 lb/yr + 72.1 lb/yr = **174.7 lb/yr**

Employee Human Waste

Employee Human Waste Load =
Cu Discharge per Human x
Jobs in Service Area x
Fraction of Employee Discharge Excreted at Work =
0.4303 g/yr x 185,230 x 0.357 = 2.845 x 10^4 g/yr
2.845 x 10^4 g/yr x 0.002205 lb/g = **62.7 lb/yr**

Total Human Waste Load

Total Human Waste Load =
Residential Human Waste Load + Employee Human Waste Load =
174.7 lb/yr + 62.7 lb/yr = **237 lb/yr**

RESIDENTIAL WASTE
Other than Human Waste

Total Residential Waste (Including Human and Non-Human Waste)

RWQCP Residential Flow = 14.7×10^6 gal/day (*Source:* EIP Associates 1999a)

Cu Concentration in Palo Alto Residential Flow = 0.03425 mg/l
(*Source:* RWQCP data, "residential_98.xls")

> Residential Cu loads for Palo Alto are used to estimate the proportional Cu load from all residents in the RWQCP service area. Calculation is based on 20 samples gathered by RWQCP staff during 1998. Detected concentrations were reported for each sample. The detection limit was 0.0006 mg/l.

Total Residential Waste Load =
0.03425 mg/l x 8.346×10^{-6} l-lb/mg-gal = 2.859×10^{-7} lb/gal
2.859×10^{-7} lb/gal x 14.7×10^6 gal/day x 365 days/yr = 1,534 lb/yr

Water Supply and Corrosion Correction

Cu Concentration in Tap Water = 0.0298 mg/l (*Source:* Montgomery Watson 1994)

> Residential wastewater samples were collected from residential trunk lines located in Palo Alto. Palo Alto receives essentially all its water from the San Francisco Water System. Cu concentrations in San Francisco tap water are assumed to be representative of combined water supply and corrosion concentrations. The tap water concentration is estimated on the basis of 188 concentration measurements of first and full flush samples of hot and cold water. Copper was detected in all samples. The detection limit was 0.001 mg/l.

Water Supply and Corrosion Load in Residential Waste =
0.0298 mg/l x 8.346×10^{-6} l-lb/mg-gal = 2.487×10^{-7} lb/gal
2.487×10^{-7} lb/gal x 14.7×10^6 gal/day x 365 days/yr = 1,334 lb/yr

Net Residential Waste Load

Net Residential Waste Load =
Total Residential Waste Load - Water Supply and Corrosion Load =
1,534 lb/yr - 1,334 lb/yr = **200 lb/yr**

Residential Waste Other than Human Waste

Residential Waste Other than Human Waste =
Net Residential Waste Load - Residential Human Waste Load =
200 lb/yr - 175 lb/yr = **25 lb/yr**

IDENTIFIED COMMERCIAL FACILITIES
Vehicle Service Facilities (Including Car Washes) and Machine Shops

Total Identified Commercial Facilities Cu Load = 34.4 lb/yr
(*Source*: RWQCP data, "industrycuload.xls")

Water Supply and Corrosion Correction

Identified Commercial Facilities Flow = 0.041 x 10^6 gal/yr
(*Source:* RWQCP data, "industrycuload.xls")

Cu Concentration in Tap Water = 0.0298 mg/l (*Source:* Montgomery Watson 1994)

> Identified commercial sources within the RWQCP service area receive essentially all their water from the San Francisco Water System. Therefore, Cu concentrations in San Francisco tap water are assumed to be representative of combined water supply and corrosion concentrations. The tap water concentration is estimated on the basis of 188 concentration measurements of first and full flush samples of hot and cold water. Copper was detected in all samples. The detection limit was 0.001 mg/l.

Water Supply and Corrosion Load in Identified Commercial Waste =
0.0298 mg/l x 8.346 x 10^{-6} l-lb/mg-gal = 2.487 x 10^{-7} lb/gal
2.487 x 10^{-7} lb/gal x 0.041 x 10^6 gal/yr = 0.01 lb/yr

Net Identified Commercial Facilities Waste Load

Net Identified Commercial Facilities Waste Load =
Total Identified Commercial Facilities Load - Water Supply and Corrosion Load =
34.4 lb/yr - 0.01 lb/yr = **34.4 lb/yr**

STANFORD UNIVERSITY

Stanford Trunk Line Flow = 433 x 10^6 gal/yr (*Source:* EIP Associates 1999a)

Average Stanford Trunk Line Cu Concentration = 0.07042 mg/l
(*Source:* RWQCP data, "stanford_98.xls")

> The average concentration is based on 26 samples collected by RWQCP staff. Cu was detected in all the samples. The detection limit was 0.0006 mg/l.

Total Stanford Trunk Line Load =
0.07042 mg/l x 8.346 x 10^{-6} l-lb/mg-gal = 5.877 x 10^{-7} lb/gal
5.877 x 10^{-7} lb/gal x 433 x 10^6 gal/yr = 254 lb/yr

Residential Load Correction

Residential Flow in Stanford Trunk Line = 290 x 10^6 gal/yr
(*Source:* EIP Associates 1999a)

> The residential flow in the Stanford trunk line is estimated on the basis of the approximate population of the residential areas served by the Stanford trunk line compared to the total population of the RWQCP service area. The population of the residential areas served by the Stanford trunk line is about 12,234 (Wong 1999), which represents about 5.4% of the RWQCP service area population of 226,300. The total residential flow in the service area is about 14.7 x 10^6 gal/day or 5,370 x 10^6 gal/yr; therefore, the residential flow in the Stanford trunk line is about 290 x 10^6 gal/yr (i.e., Stanford trunk line residential load = 5,370 x 10^6 gal/yr x 5.4% = 290 x 10^6 gal/yr). The remaining institutional flow in the Stanford trunk line is the difference, 143 x 10^6 gal/yr (i.e., remaining institutional flow = 433 x 10^6 gal/yr - 290 x 10^6 gal/yr = 143 x 10^6 gal/yr).

Average Residential Cu Concentration = 0.03425 mg/l
(*Source:* RWQCP data, "residential_98.xls")

Total Residential Load in Stanford Trunk Line =
0.03425 mg/l x 8.346 x 10^{-6} l-lb/mg-gal = 2.859 x 10^{-7} lb/gal
2.859 x 10^{-7} lb/gal x 290 x 10^6 gal/yr = 82.9 lb/yr

Remaining Institutional Load for Stanford University =
Total Stanford Trunk Line Load - Residential Load in Stanford Trunk Line =
254 lb/yr - 82.9 lb/yr = 171 lb/yr

Water Supply and Corrosion Correction

Cu Concentration in Tap Water = 0.0298 mg/l (*Source:* Montgomery Watson 1994)

> Stanford University receives essentially all its water from the San Francisco Water System. Cu concentrations in San Francisco tap water are assumed to be representative of combined water supply and corrosion concentrations. The tap water concentration is estimated on the basis of 188 concentration measurements of first and full flush samples of hot and cold water. Copper was detected in all samples. The detection limit was 0.001 mg/l.

Net Stanford University Flow =
Stanford Trunk Line Flow - Residential Flow in Stanford Trunk Line =
433 x 10^6 gal/yr - 290 x 10^6 gal/yr = 143 x 10^6 gal/yr

Water Supply and Corrosion Load in Stanford University Waste =
0.0298 mg/l x 8.346 x 10^{-6} l-lb/mg-gal = 2.487 x 10^{-7} lb/gal
2.487 x 10^{-7} lb/gal x 143 x 10^6 gal/yr = 35.6 lb/yr

Net Stanford University Waste Load

Net Stanford University Waste Load =
Remaining Institutional Load - Water Supply and Corrosion Load =
171 lb/yr - 35.6 lb/yr = **135 lb/yr**

STORM WATER

Infiltration and Inflow = 3.2×10^6 gal/day (*Source:* EIP Associates 1999a)
Approximate Storm Water Inflow = Infiltration and Inflow x 50% =
3.2×10^6 gal/day x 50% = 1.6×10^6 gal/day

Storm water inflow is assumed to be about half infiltration and inflow combined.

Average Cu Concentration = 0.04394 mg/l
(*Source:* Santa Clara Valley Runoff Pollution Prevention Program 1996)

Calculation is based on 88 concentration data points. Of these measurements, one resulted in a "non-detect." One half of the 0.001 mg/l detection limit was used to estimate this sample concentration.

Total Storm Water Inflow Load =
0.04394 mg/l x 8.346×10^{-6} l-lb/mg-gal = 3.667×10^{-7} lb/gal
3.667×10^{-7} lb/gal x 1.6×10^6 gal/day x 365 days/yr = **214 lb/yr**

INFILTRATION AND GROUNDWATER

Groundwater Flow (purposeful discharges) = 1.4×10^6 gal/day
(*Source:* EIP Associates 1999a)

Infiltration and Inflow = 3.2×10^6 gal/day (*Source:* EIP Associates 1999a)
Approximate Groundwater Infiltration = Infiltration and Inflow x 50% =
3.2×10^6 gal/day x 50% = 1.6×10^6 gal/day

Groundwater infiltration is assumed to be about half infiltration and inflow combined.

Total Infiltration and Groundwater Flow =
Approximate Infiltration + Groundwater Flow =
1.6×10^6 gal/day + 1.4×10^6 gal/day = 3.0×10^6 gal/day

Groundwater Cu Concentration = 0.02628 mg/l
(*Source:* RWQCP data, "groundwater_98.xls")

The Cu concentration of infiltrating groundwater is assumed equal to the Cu concentration of groundwater purposefully discharged to the RWQCP. The average concentration is based on 12 samples collected by RWQCP staff or permitted dischargers. Cu was not detected in 4 of the samples. Their concentrations were assumed to be half the detection limit of 0.02 mg/l. Another data point was about 15 times the next highest value, and all the other measurements were within a more narrow range. On the basis of the "Q-test," a statistical method for identifying outliers in data sets, the result for this was discarded because it did not appear representative of the data as a whole.

Total Infiltration and Groundwater Load =
0.02628 mg/l x 8.346×10^{-6} l-lb/mg-gal = 2.193×10^{-7} lb/gal
2.193×10^{-7} lb/gal x 3.0×10^6 gal/day x 365 days/yr = **240 lb/yr**

SEPTAGE

Septage Flow = 1,884 gal/day (*Source:* Michailidis 1997)

Average Cu Concentration = 6.36 mg/l (*Source:* Michailidis 1997)

Total Septage Load =
6.36 mg/l x 8.346 x 10^{-6} l-lb/mg-gal = 5.308 x 10^{-5} lb/gal
5.308 x 10^{-5} lb/gal x 1,884 gal/day x 250 days/yr = **25.0 lb/yr**

ABBREVIATIONS, SYMBOLS, AND CONVERSION FACTORS

RWQCP, Palo Alto Regional Water Quality Control Plant
Cu, copper

gal, gallons
g, grams
mg, milligrams
ug, micrograms
l, liters
lb, pounds
%, percent

0.001 g/mg
0.002205 lb/g
3.785 l/gal

8.346×10^{-6} l-lb/mg-gal
1.198×10^{5} mg-gal/l-lb