Improvements in Biosolids Quality Due to EPA's Pretreatment and Biosolids Programs

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Abstract

Publicly owned treatment works (POTWs) across the United States have realized a major reduction in the heavy metals in their influent and effluent, along with a substantial improvement in the quality of their biosolids, due to the development and promulgation, by the United States Environmental Protection Agency (EPA), of the following regulations:

1. General Pretreatment Regulations for Existing and New Sources of Pollution (40 CFR Part 403), and

2. Standards for the Use or Disposal of Biosolids (40 CFR Part 503).

While professionals in our industry are well versed in the positive impact that these regulations have had on human health and the environment, efforts to document and report these impacts to the general public have been minimal.

Keywords

Biosolids, 40 CFR Part 503, Pretreatment, 40 CFR Part 403, Heavy Metals

Introduction

The Northeast Ohio Regional Sewer District (District) provides wastewater conveyance and treatment services for 1.1 million residents and businesses in the Greater Cleveland area. Since its creation in 1972, the District has spent over $1.8 billion dollars to expand and upgrade its infrastructure.

The District's monitoring of industrial dischargers and enforcement of pretreatment regulations has effected a major reduction in heavy metals and other pollutants entering its three treatment facilities. These efforts, which have substantially reduced influent, effluent and biosolids metal concentrations, have been of value to the District's mission to protect public health and the environment.

National Pretreatment Standards

Pursuant to the Clean Water Act of 1977 and regulations enacted thereafter (specifically, 40 CFR Part 403), EPA established various responsibilities of Federal, State, and local governments, industry and the public to implement National Pretreatment Standards. Part 403 was enacted in January 1981, with the District obtaining approval for its pretreatment program on September 9, 1985.

One of the central objectives of the District's pretreatment program was the prevention of the introduction of pollutants into its three wastewater treatment plants (WWTPs) that interfere with the operation of its plants and the use or disposal of each plant's biosolids (i.e., sewage sludge).

History of the District's Pretreatment Programs

Several years prior to the promulgation of the National Pretreatment Standards, the District formed an Industrial Waste Section that ensured that the discharge of fats, oils, grease, acids and diesel fuels into Greater Cleveland's sewer system complied with the District's local limits.

Cyanide is a toxic pollutant that for many years was discharged without pretreatment. If concentrations of Cyanide reached certain levels in the POTW influent, it could cause inhibition of the treatment process. Elevated influent concentration may also pass through the treatment process and into the plant effluent. If toxic levels of Cyanide in the effluent were passed into the receiving stream, it would likely impact the viability of the organisms in the receiving water. Industrial Waste personnel reported that metal concentrations in the plants influent and biosolids substantially increased in the late 1970s due to the Cyanide destruction requirements. Up to that point in time, Cyanide used in industrial processes actually kept the heavy metals in solution. By requiring the industrial users to destroy Cyanide it allowed the metals to be suspended from solution and precipitated more readily at the POTW, increasing the metal concentrations in biosolids and reducing it in the final effluent.

The District pretreatment program was approved by USEPA in September 1985. The actual implementation of the program began in January 1984 under the authority of the District's Code of Regulations, Pretreatment Regulations. At that time, industrial dischargers falling under the existing or new categorical standards were inspected, sampled, and classified according to their applicable categories, and thereupon determined to be in or out of compliance.

The District then presented all industrial dischargers within its service area "administrative orders" to install the necessary pretreatment systems. The District typically monitors it industrial dischargers annually. Criteria for increased monitoring included past performance, citizen complaints, compliance status, potential for toxic discharges and the existence of any District enforcement judgments.

In addition to annual monitoring by District personnel, industrial dischargers were required to submit bi-annual self-monitoring reports, along with monthly samples of their waste.

Tracking-Down Illegal Dischargers

The District's pretreatment strategy between 1975 and 1982 was (i) to require good housekeeping, conservation, and source control for heavy metals and (ii) require pretreatment for acids and cyanides. A major effort was made to inform local industrial dischargers of upcoming federal pretreatment regulations. The Greater Cleveland area had a substantial number of electroplaters and other industries traditionally having high concentrations of metals in their discharges. These firms were notified that upcoming federal pretreatment regulations would be aggressively enforced by District personnel. As a result, most industrial dischargers were prepared when the order to pretreat was given. Affected industries, under pressure from District, changed their processes from a wasteful high-water, non-conservative operations to processes using counter-current rinses, source control, and recycle techniques. The decrease in effluent metal concentrations after 1984 is due primarily to the enforcement of the federal pretreatment standards.

Metal Influent Reductions - Case Studies

To assess the impact of the District's pretreatment program, the concentration trends for the certain metals were analyzed from 1980 to 2004. Only seven metals (cadmium, chromium, copper, lead, nickel, zinc and mercury) were consistently regulated under federal categorical discharge standards and local discharge limits, to have complete data. District influent data for mercury were available, however detection limits early in the pretreatment program were not as sensitive as they are today making it difficult to assess the effectiveness of the pretreatment program.

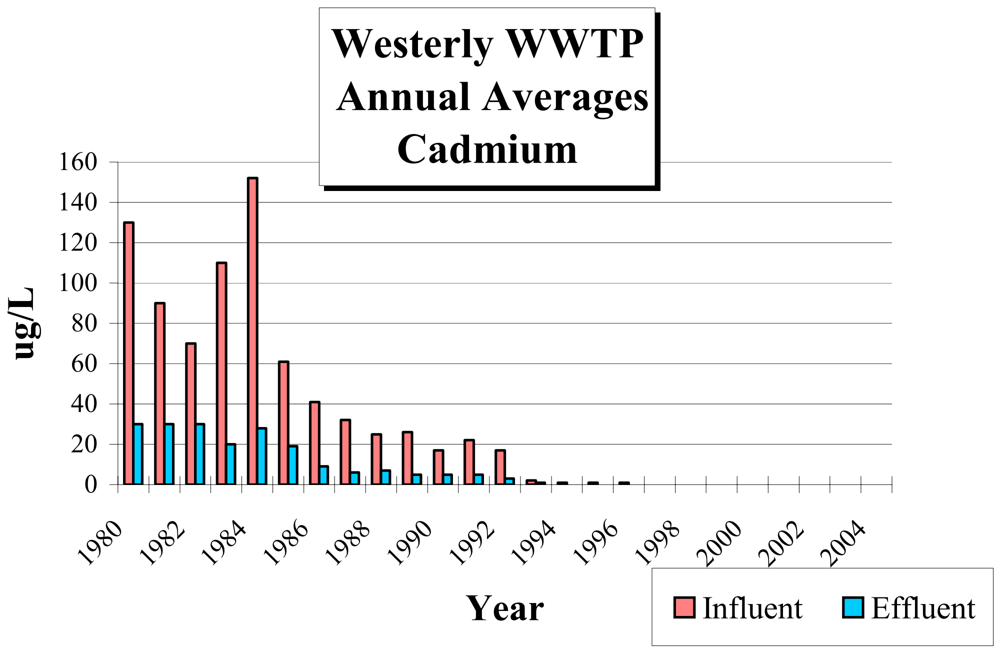
Cadmium

In 1981, the District implemented pretreatment requirements for the discharge of cadmium. This action resulted in a significant reduction in cadmium in the influent loadings at the District's three WWTPs. The cadmium concentrations continued to decrease after the approval of the District's federal pretreatment program. Many industries were willing to work at reducing their metal discharges in order to avoid administrative orders and litigation.

With the effectiveness of the District's pretreatment program, the Industrial Surveillance Section was able to identify industrial dischargers that were not in compliance. Many of these companies either had systematic problems with their pretreatment equipment or needed to implement a system.

In 1984, the District met with representatives of a plating operation located within the Westerly WWTP's service area after an analysis revealed that the company was out of compliance with Federal discharge limitations for cadmium. The outcome of the meeting resulted in the cadmium plating operation being eliminated. The company eventually installed a heavy metal removal system to prevent federal and local violations for other heavy metals. Figure 1 shows the 60% cadmium reduction between 1984 and 1985 in Westerly's influent, due to the elimination of one illegal discharger. A continued decline of cadmium concentrations was a result of the District's pretreatment program.

Figure 1. Westerly WWTP Influent and Effluent Cadmium Concentrations



Lead

In 1973, EPA initiated a "phase down" program designed to bring the levels of lead down in gasoline to 0.5 grams per gallon by 1980 in large refineries and by 1982 in small refineries. The standard allowed refineries to average their total (leaded and unleaded) output to reach the 0.5 standard.

In 1982, EPA changed the standard to 1.10 grams per leaded gallon but eliminated the provision that allowed averaging between unleaded and leaded gasoline. The new standard was projected to bring about a 34 percent reduction in the amount of lead being used by the refining industry as the demand for leaded gasoline declined.

Standards to phase out lead in gasoline came into effect in January 1986 and limit the lead content of gasoline to 0.10 grams per gallon. In January 1996, the Clean Air Act banned the sale of leaded fuel.

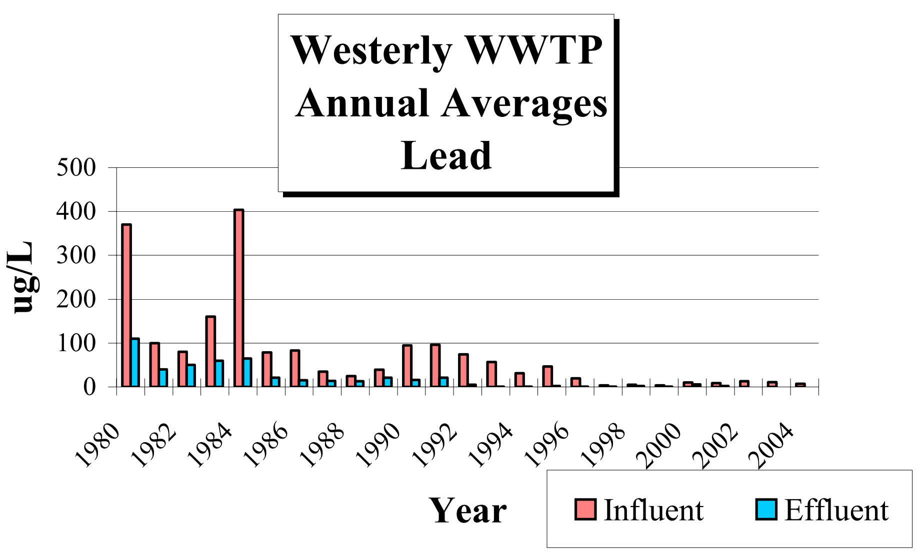
These rulings had a remarkable impact on lead concentrations coming into the District's three treatment plants. The monitoring and enforcement of the pretreatment program also helped reduce discharges.

In 1984, a plating firm located within the Westerly WWTP's service area was found to be discharging extremely high levels of lead. An inspection by District personnel revealed that the high lead concentrations were attributed to lead anodes and lead lined storage tanks. After the plating firm instituted a program to contain and haul the lead discharged to an approved waste treatment facility, Westerly's influent lead concentrations dropped by 77%.

Throughout the 1980's and early 1990's, lead was a major concern coming into the Westerly plant. The major contributor of lead was a smelting facility located along the west bank of the Cuyahoga River. Smelting is the process of reducing reclaimed lead compounds to elemental lead and lead alloys. The company would crack large batteries by lifting them into the air and dropping them onto the ground causing the battery to crack. Battery acid would spill onto the ground containing high levels of lead. Although the company was not directly discharging to the sewer system, during wet weather events, runoff from the site would enter into the combined sewer system that was tributary to Westerly. In 1993, the State of Ohio shut the facility down and in 1999, U.S. EPA began a final clean up.

Figure 2 shows lead concentrations coming into the Westerly plant from 1980 – 2004. years. The spike seen in 1984 was due to a single illegal discharger. Concentrations in the mid-1990's dropped due to the lead smelting facility ending operation.

Figure 2. Lead Influent and Effluent Concentrations at Westerly WWTP



Influent Loadings Reduction

Since the inception of the pre-treatment program at the District, metals have had a continued downward trend in treatment plant influents and effluents. From 1980- 2004, the District has seen a substantial reduction in metals entering its three-wastewater treatment plants. The following are a few examples of overall metal reductions in the plants' influent and effluent. Figures 3 through 5 show the reduction of heavy metal concentrations entering the three treatment plants in 2004 compared to 1980. These figures demonstrate the success of the District's pretreatment program. Table 1 shows the average influent and effluent reductions of the six metals evaluated in the paper over the last 24 years coming into the District's three treatment plants.

Figure 3. Easterly WWTP Heavy Metal Influent Concentrations and Percent Reduction

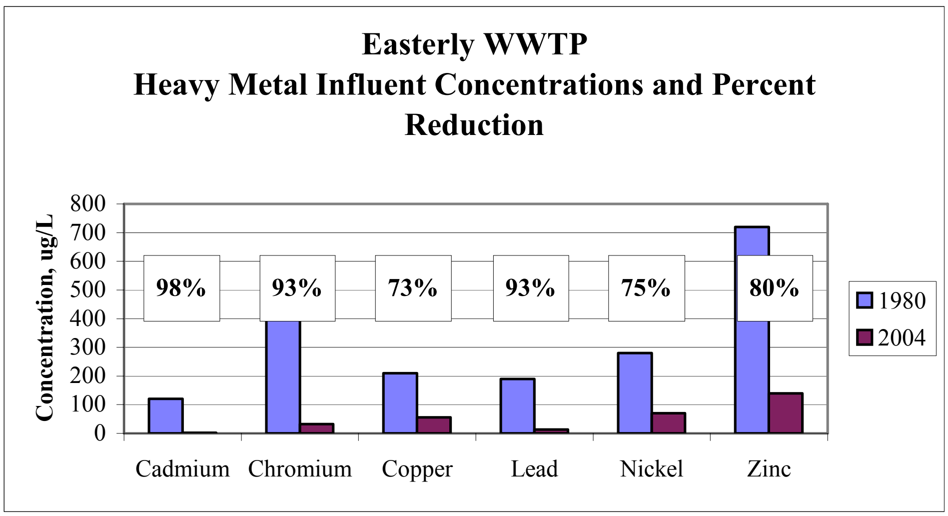


Figure 4. Southerly WWTC Heavy Metal Influent Concentrations and Percent Reduction

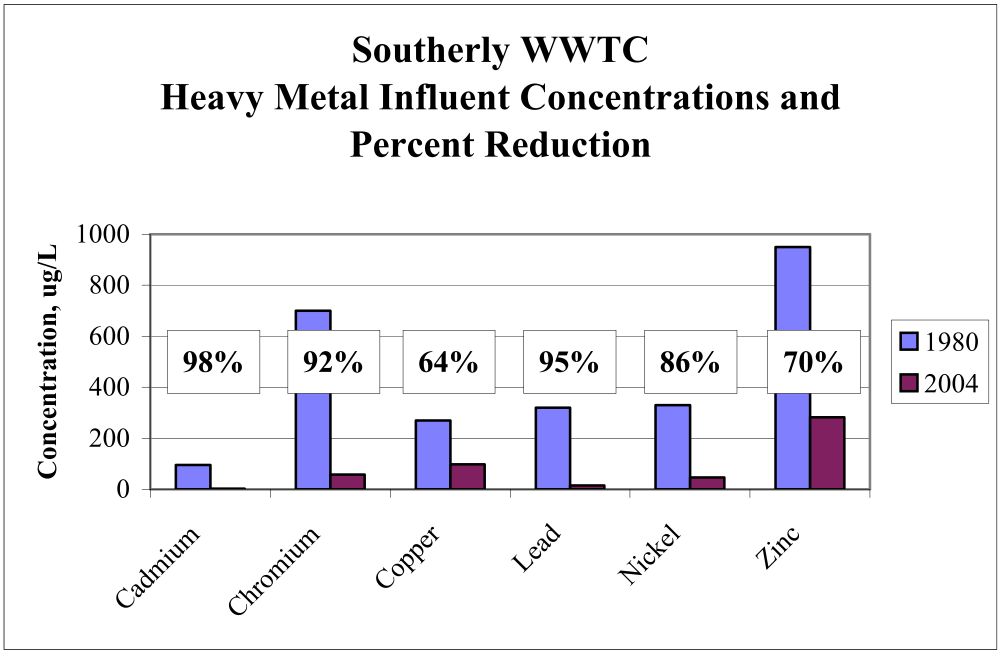


Figure 5. Westerly WWTP Heavy Metal Influent Concentrations and Percent Reduction

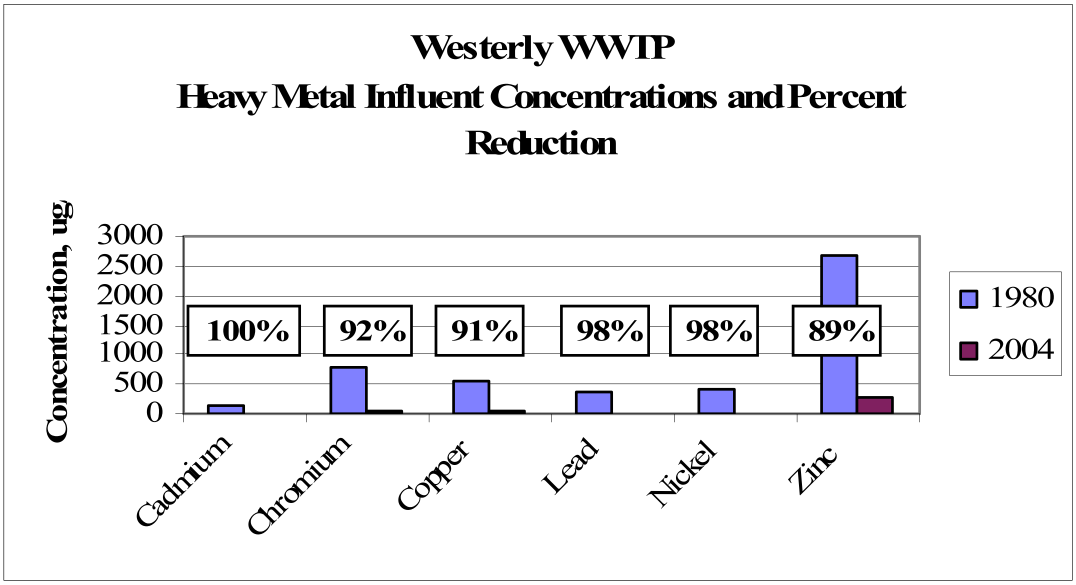


Table 1: Average Reductions in Selected Metals from 1980 – 2004 for NEORSD's Three WWTPs:

Metal	% Reduction in Influent	% Reduction in Effluent
Cadmium	99	99
Chromium	90	97
Copper	62	90
Lead	95	100
Nickel	89	90
Zinc	87	90

Industrial Changes in Greater Cleveland

A common inquiry regarding the reduction trends in heavy metals is whether or not the decrease in concentrations can also be attributed to the decline of heavy industry in Northeast Ohio. The following are the numbers of electroplaters monitored by the District for specified years:

- 1985-130
- 1990-143
- 1995-133
- 2000-121
- 2005-111

Today there are fewer electroplating companies compared to when the pretreatment program was implemented. However, the data listed above show that between 1985 and 1990 there was an increase in electroplaters. Heavy metal concentrations at the treatment plants declined during this timeframe. Appendix A of this paper contains figures showing the decline of heavy metal influent and effluent concentrations.

National Biosolids Regulation

In the early 1990's, the District started to update its Code of Regulations to integrate potential changes in federal and state regulations related to pretreatment. At this time, the District also began to evaluate how to reduce metal concentrations in its biosolids pending future biosolids regulations. As required by the Clean Water Act Amendments of 1987, USEPA developed a new regulation, 40 CFR Part 503, to protect human health and the environment from any reasonable anticipated adverse effects of certain pollutants that might be present in biosolids. Enacted in February 1993, Part 503 forced POTWs to carefully examine the metal concentrations in their biosolids and biosolids incinerator exit gases, and to find ways to reduce the metal concentrations and emissions. As a result of the Part 503 regulations, the District bolstered its pretreatment program to further decrease metal concentrations.

The District uses incineration to manage its biosolids. Solids from the Easterly WWTP are pumped through a 13-mile long force main to the Southerly WWTC for processing and disposal in Southerly's four multiple hearth incinerators (MHIs). Westerly's biosolids are burned in two MHIs located at Westerly.

Case Study - Cadmium

Prior to the promulgation of the Part 503 Regulation, the District undertook a program to ensure compliance with the proposed incineration related metal limits. One concern was with higher than normal cadmium concentrations being found in Southerly's biosolids. As previously mentioned, Southerly receives approximately 50% of its solids from the Easterly WWTP.

An in-house study was commissioned in 1993 to investigate higher than expected cadmium concentrations at the Easterly plant during the early 1990's. This was accomplished by sampling the tributary interceptors to the treatment plant. As a result of the pretreatment standards, industrial discharges were typically so void of heavy metals that the interceptor carrying the excessive loading was identified readily.

In 1994, a single plating firm in Easterly's service area was found to be bypassing pretreatment by discharging its waste during wet-weather events directly to its sewer. The company was issued a Cease and Desist Order and recommended for Show Cause Hearing. The company was fined over $20,000 and the owner was ordered to upgrade its pretreatment system to meet all applicable federal and local discharge limits prior to being allowed to discharge into the sanitary sewer system again.

In October 1998, a review of the monthly operating report by District personnel noted a marked increase of cadmium concentration in the biosolids at the Southerly WWTC. Samplers were deployed downstream of known cadmium sources. Within the laboratory turn around time, the source was identified and a Cease and Desist Order issued to the industrial user. The plating company was cooperative in rehabilitation of its pretreatment system and cessation of discharge during the period. A Show Cause Hearing was recommended for discharge violations and a settlement was reached

Figure 6 demonstrates the effectiveness of the District pretreatment program. A decrease in annual cadmium concentrations at the Southerly WWTC can be seen after the pretreatment programs was approved in 1985 and again after 1993 when the Part 503 programs were announced. Monthly peaks shown on the figure also show when companies were illegally discharging.

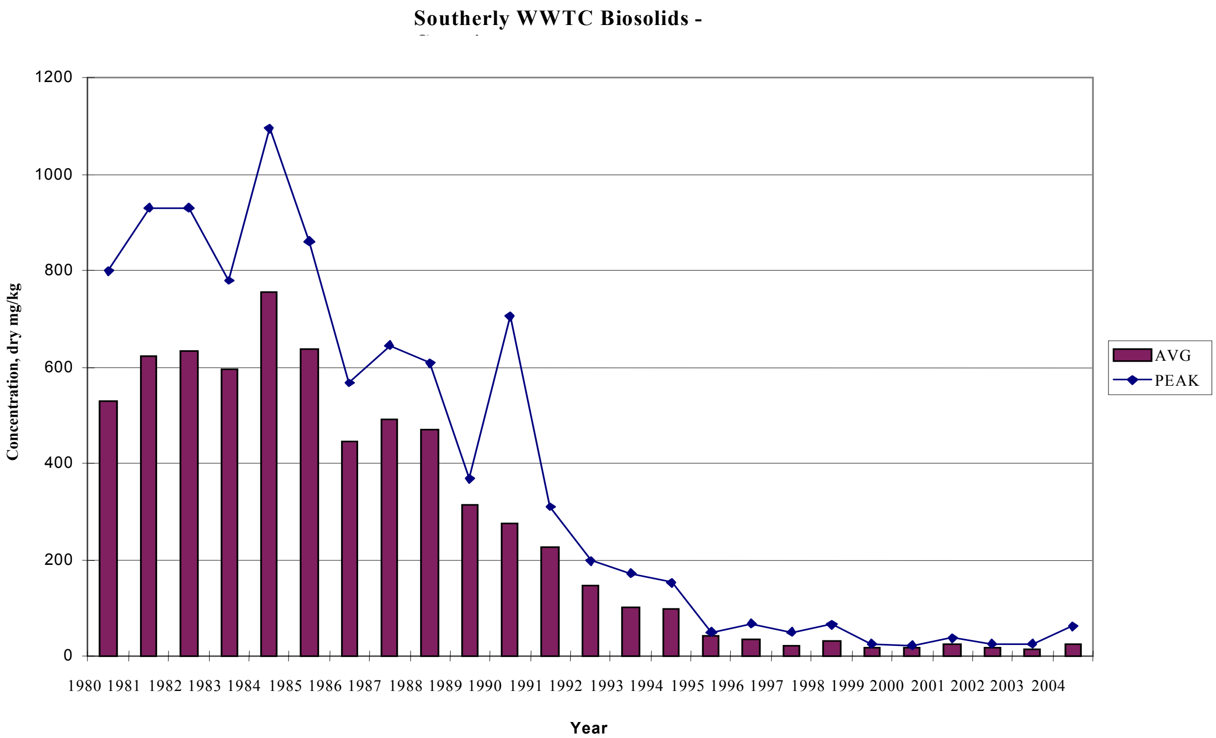


Figure 6. Cadmium Concentrations (dry weight basis) in Southerly Biosolids

In the late 1990s, given potentially more stringent regulatory requirements and rising operational and maintenance costs, the District decided to embark on a thorough investigation of potential residuals management options, through a residuals management study. One of the first actions taken was to determine how the quality of Southerly and Westerly's biosolids compared to the land application requirements contained in the Part 503 Regulation. Columns 1 and 2 contain the Part 503 Pollutant concentration limits for biosolids that are land applied, while Columns 3 and 4 show Southerly and Westerly actual biosolids concentrations. Table 2 clearly demonstrates that Southerly and Westerly's biosolids metal concentrations are substantially below the Part 503 land application metal limits.

Table 2: Part 503 Land Application Limits vs. Actual 2004 Concentrations

Pollutant	***Column 1*** Ceiling Concentrations (mg/dry kg)	***Column 2*** Pollutant Concentrations (mg/dry kg)	***Column 3*** Southerly WWTP Highest 2004 Monthly Average Concentrations (mg/dry kg)	***Column 4*** Westerly WWTP Highest 2004 60-day Average Concentrations (mg/dry kg)
Arsenic	75	41	10	13
Cadmium	85	39	62	18
Chromium	Deleted in 1995	Deleted in 1995	441	435
Copper	4300	1500	529	489
Lead	840	300	185	227
Mercury	57	17	3	1
Molybdenum	75	Deleted in 1994	20	25
Nickel	420	420	119	72
Selenium	100	100	15	2
Zinc	7500	2800	1486	2123
	All biosolids that are land applied	Bulk and bagged biosolids		

Table 3 shows Southerly and Westerly's site specific Part 503 Limits and the maximum concentrations.

Table 3: Part 503 Site Specific Incineration Limits vs. Actual 2004 Concentrations

Notes:

Pollutant	Southerly WWTP Part 503 Limit (mg/dry kg)	Southerly WWTP Highest 2004 Monthly Avg. Concentration (mg/dry kg)		Westerly WWTP Part 503 Limit (mg/dry kg)	Westerly WWTP Highest 2004 60-day Avg. Concentration (mg/dry kg)
Arsenic	292	10		511	13
Cadmium	272	62		450	18
Chromium	18,071	441		50,473	435
Lead	12,508	185		2,678	227
Nickel	379,429	119		168,995	72

Site specific limits are based on the quantities of biosolids incinerated and air pollution control devices' actual control efficiencies for arsenic, cadmium, chromium, lead and nickel.

Table 3 clearly demonstrates that Southerly and Westerly's biosolids metal concentrations and resulting air emissions are substantially below the Part 503 site specific incineration limits.

From 1980 to 2004, NEORSD has seen a substantial reduction in metals in its biosolids. The following are a few examples of overall metal reductions in the plants' biosolids:

Figure 7. Southerly WWTC Heavy Metal Biosolids Concentrations (dry weight basis) and Percent Reduction

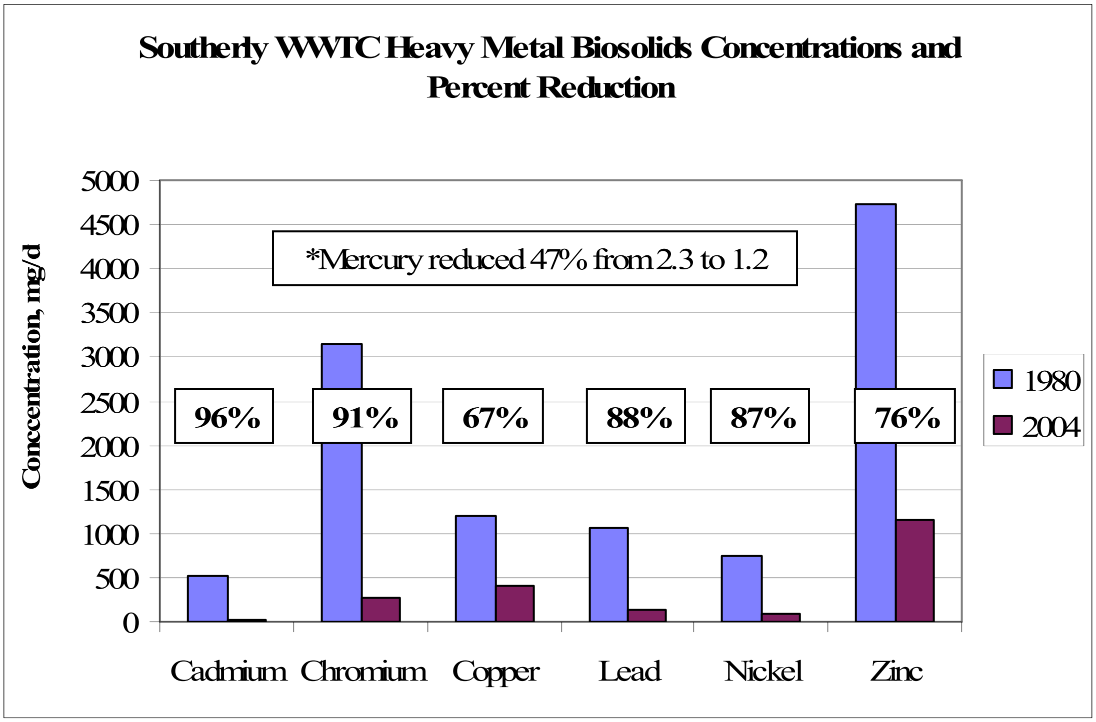


Figure 8. Westerly WWTP Heavy Metal Biosolids Concentrations (dry weight basis) and Percent Reduction

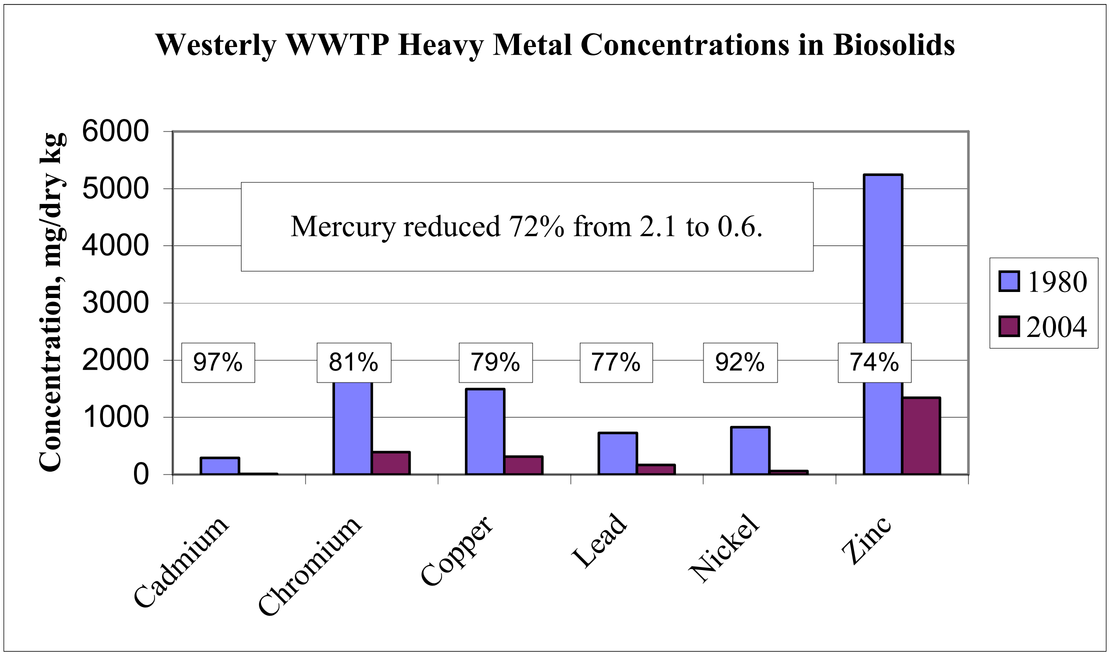


Table 4: Average Reductions in Selected Metals from 1980 – 2004:

Metal	% Reduction in Biosolids
Cadmium	96
Chromium	86
Copper	73
Lead	82
Nickel	96
Zinc	81
Mercury	60

Lessons Learned

Since the Industrial Waste Section was created in 1974, the District's knowledge base has improved markedly. The department, now called Water Quality and Industrial Surveillance (WQIS) has learned the key to a successful program includes employee safety, working with other enforcement agencies and maintaining a thorough database of all industrial users.

The District leverages its strong relationships with other enforcement agencies to track down illegal or accidental discharges. The Superintendent of Environmental Services is on a local pollution control task force. The District also works with local fire departments, hazardous material units and emergency planning committees to keep communication present. The WQIS department only has limited sets of eyes to watch over a large service area, therefore it is essential to work with other agencies and keep them on the lookout for illicit discharges.

The most useful tool in tracking down illegal discharges is a well-maintained and complete database of industrial customers. When the pretreatment program was implemented, the District maintained a list of industries including contact names, water usage and what they discharge (e.g., cadmium) in an Access database. Today, the department is taking advantage of more current technologies to manage pretreatment information and is using these tools to streamline its work.

Using a pretreatment information management system (PIMS), the pretreatment program is able to integrate its laboratory data, currently in a system called LABlynx, with its pretreatment data. This allows WQIS to ensure industries are in compliance from annual monitoring samples, assess surcharge costs for treatment, and provide a warehouse for documentation and inspection reports.

The District has also implemented an industrial user monitoring system, which is similar to a residential home security system. The system notifies the Control Authority of an event at an Industrial User, such as abnormal pH or a discharge valve being opened or closed. The system is currently being upgraded to deliver data about the event rather than simply an occurrence.

The last information management system being employed includes an industrial discharger's digit dialer. This system automatically calls a dedicated phone line at an industrial discharger delivering a message to cease or resume discharging to the sewer system. The system makes the calls based on flow conditions in the combined sewer system or capacity at the tributary POTW. The tool was developed to reduce concentrations of pollutants typically associated with industrial discharges during combined sewer overflows. In cases where an industrial discharger is required to be on both the monitoring system and the dialer, data compiled can be compared to ensure that the industrial user complies with the stop discharge order and closes the discharge valve in a timely manner.

Currently, the District is developing a Geographic Information System (GIS) tool to integrate the sewer system infrastructure with the LABLynx PIMS. The GIS tool will help spatially locate industrial users on a service area map and allow PIMS data to be shared throughout the organization through a user friendly interface. Users can view this data without the risk of making any changes to the data.

Combining these two information systems connects industrial users to the collection system and will allow network tracing upstream or downstream of a particular point. In the future, when a location has been found to have high levels of a particular contaminant, the GIS and PIMS tool will be able to identify users with this contaminant upstream of the location.

Conclusions

Due to the implementation of the Federal Pretreatment Standards along with Federal Standards for the Use or Disposal of Biosolids, the District has seen a substantial reduction in metal concentrations in its influent, effluent, biosolids and biosolids incinerator exhaust gases. Normally spikes in metal concentrations in influent and biosolids can be attributed to a single illegal discharger. Care must be taken to know the locations of your industrial dischargers, their operations, and the metals that they are normally discharging to the sewer system.

The implementation of these programs by the Northeast Ohio Regional Sewer District has resulted in the protection of human health and the environment.

Acknowledgements
The authors would like to acknowledge the assistance of the following individuals for their invaluable assistance in the preparation of this paper.

Scott Broski
Richard Connelly
Lowell Eisnaugle
Keith Linn
David McNeeley
Terry Meister
Timothy Tigue
James Weber
Ray Weeden

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Long-Term Residuals Management Options for the Northeast Ohio Regional Sewer District, Lori Stone and Bob Dominak, Presented at WEFTEC 2003

Monthly NPDES Reports - Easterly, Southerly and Westerly (1980 – 2004)

Annual Part 503 Reports - Southerly and Westerly (1993 – 2004)

Appendices

Appendix A : Easterly WWTP Influent and Effluent Heavy Metal Concentrations

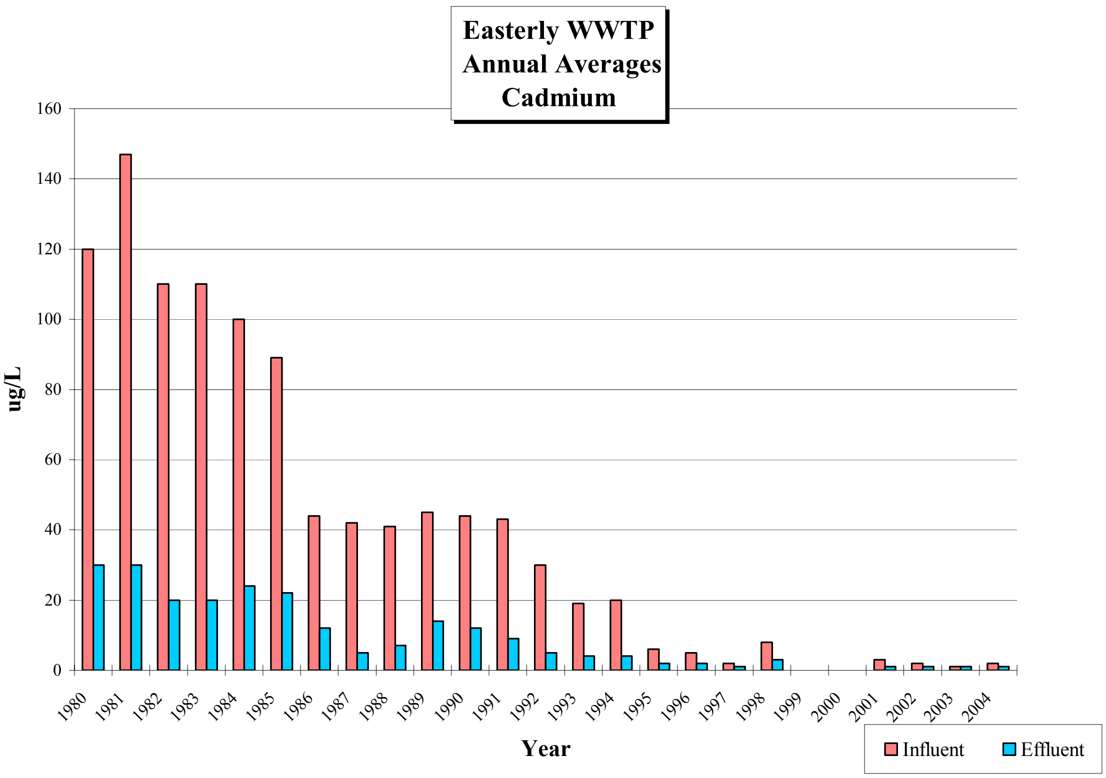
Appendix B: Southerly WWTC Influent and Effluent Annual Average Heavy Metal Concentrations

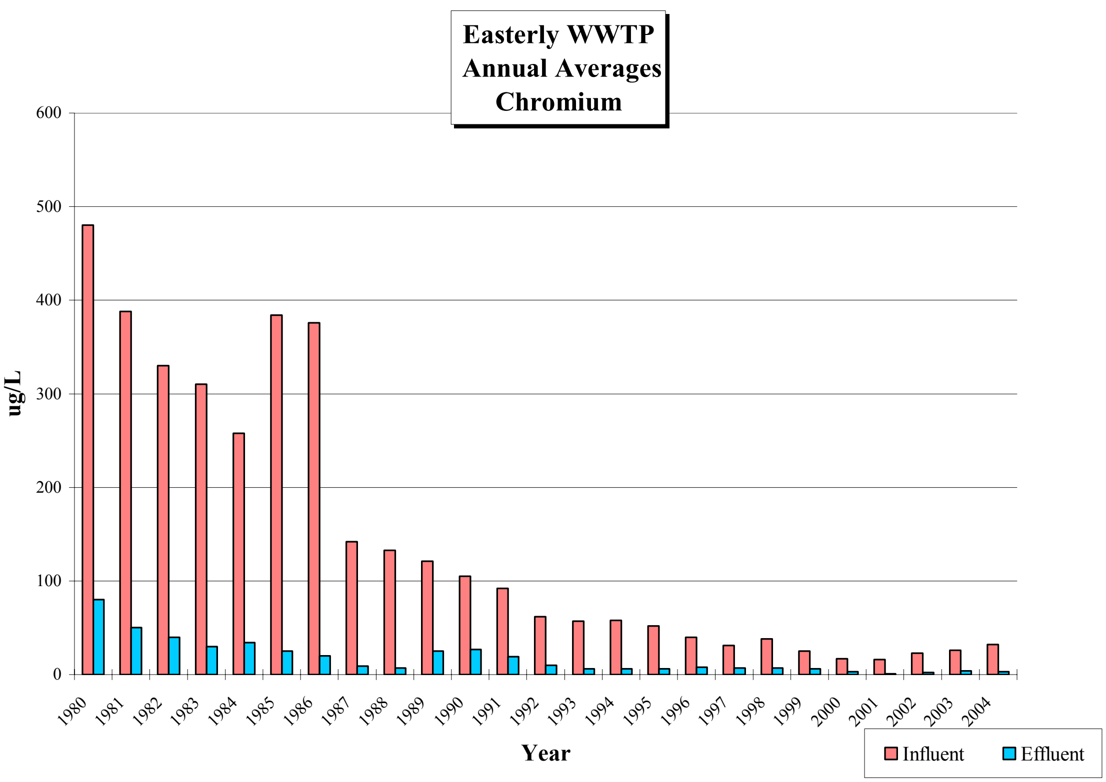
Appendix C: Westerly WWTP Influent and Effluent Annual Average Heavy Metal Concentrations

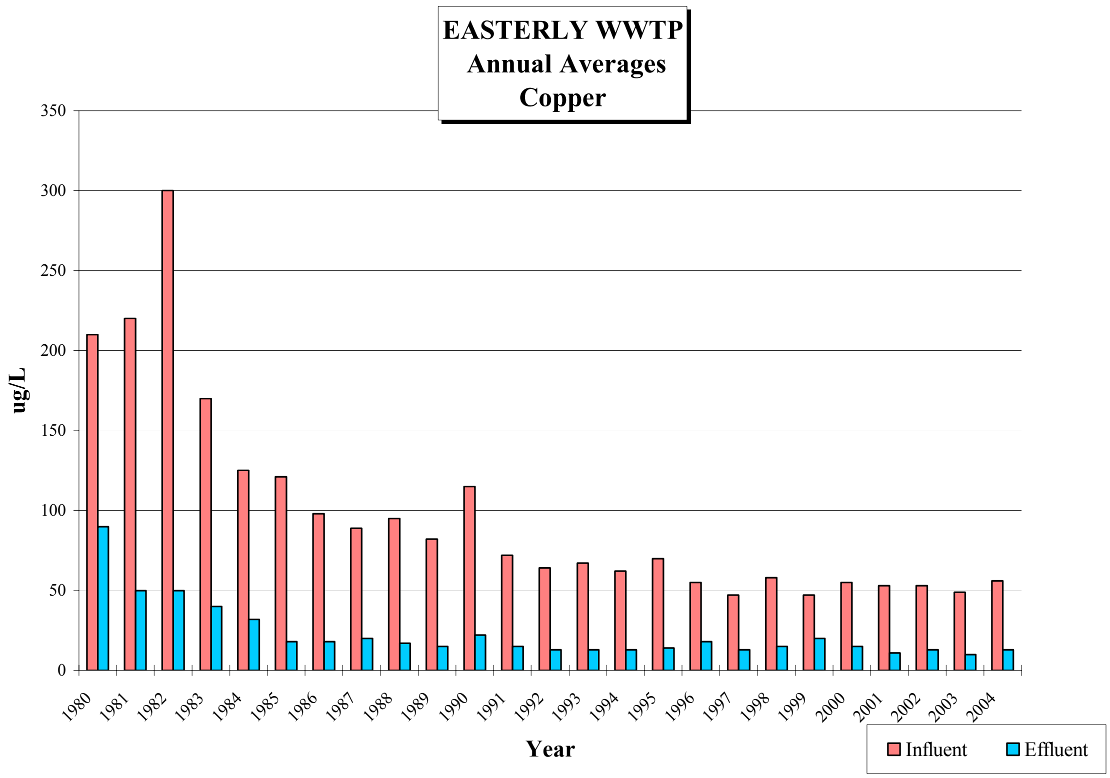
Appendix D: Southerly WWTC Heavy Metal Biosolids Concentrations (dry weight basis) – Annual Average and Monthly Peaks

Appendix E: Westerly WWTP Heavy Metal Biosolids Concentrations (dry weight basis) – Annual Average and Monthly Peaks

Appendix A: Easterly WWTP Influent and Effluent Annual Average Heavy Metal Concentrations



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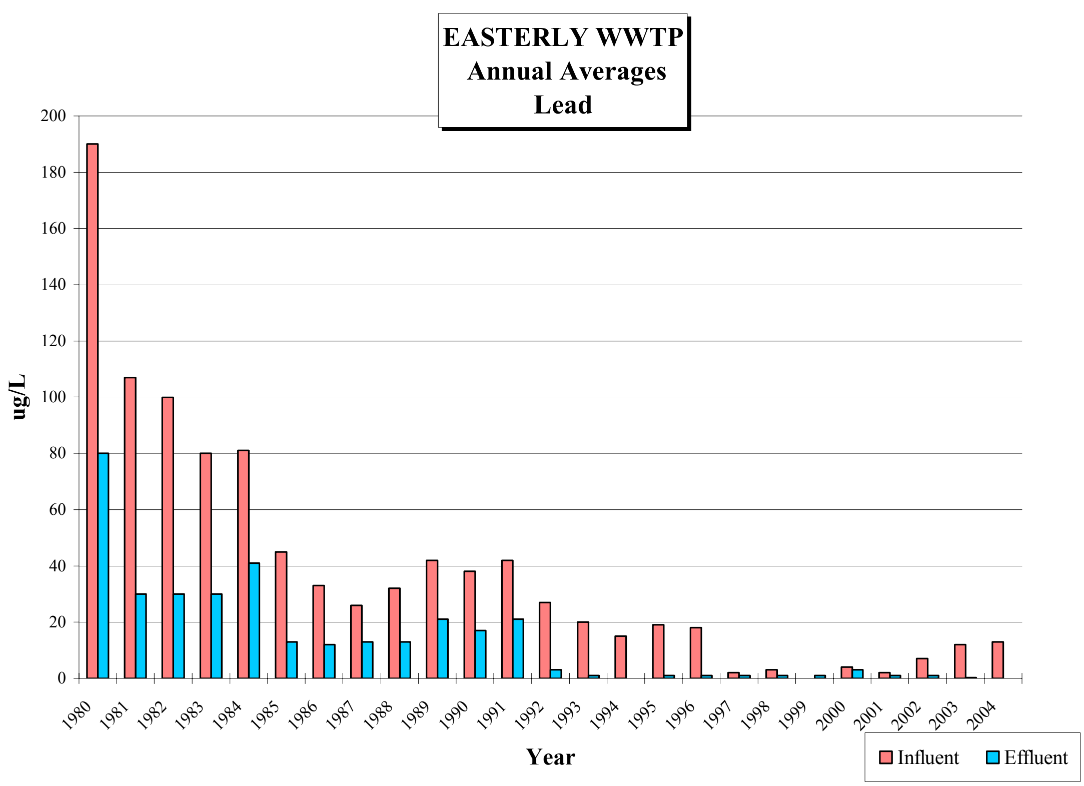
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Annual Averages
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ug/L
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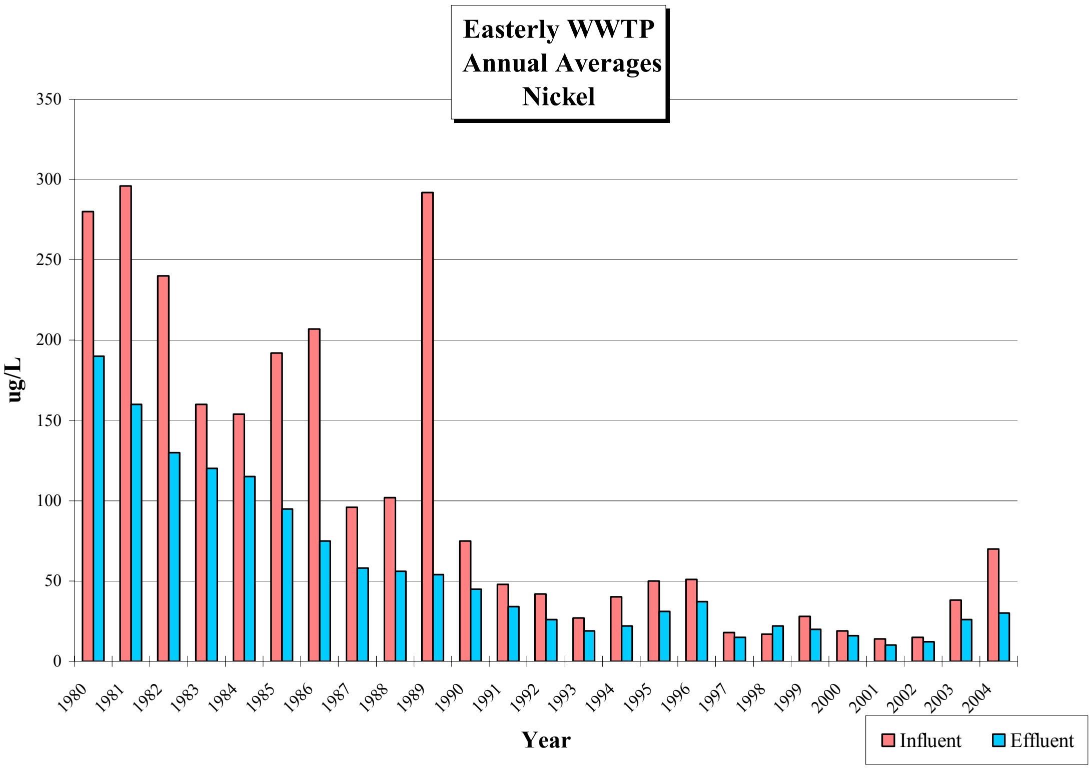
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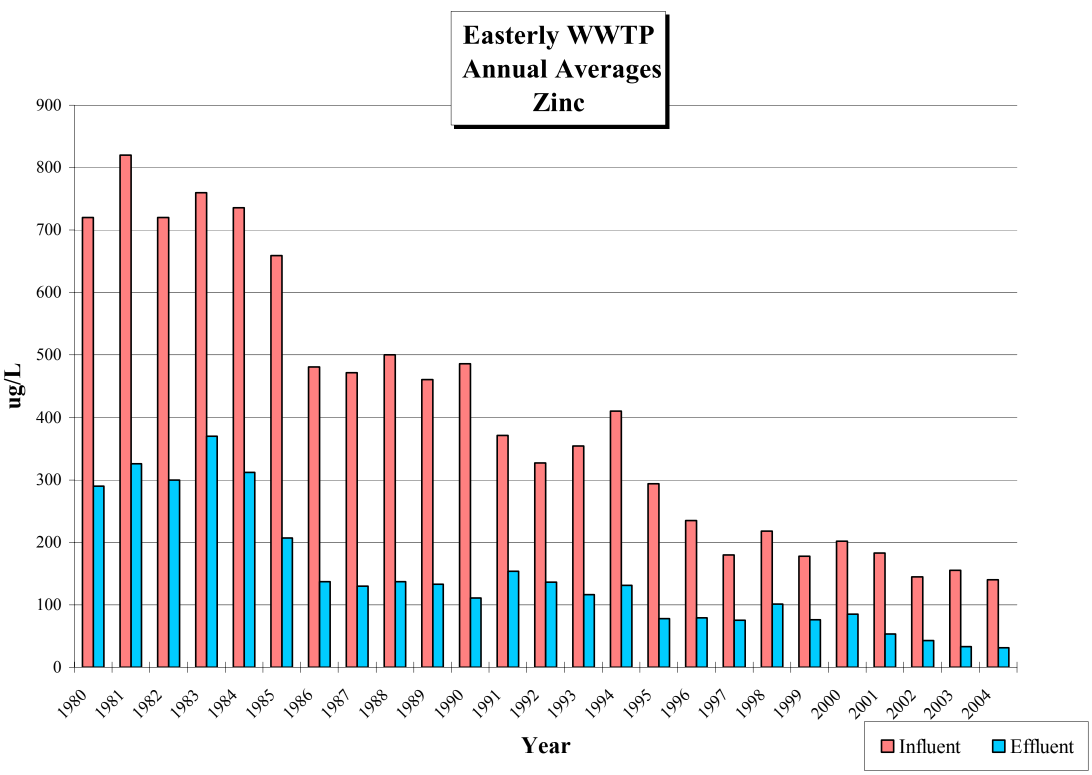
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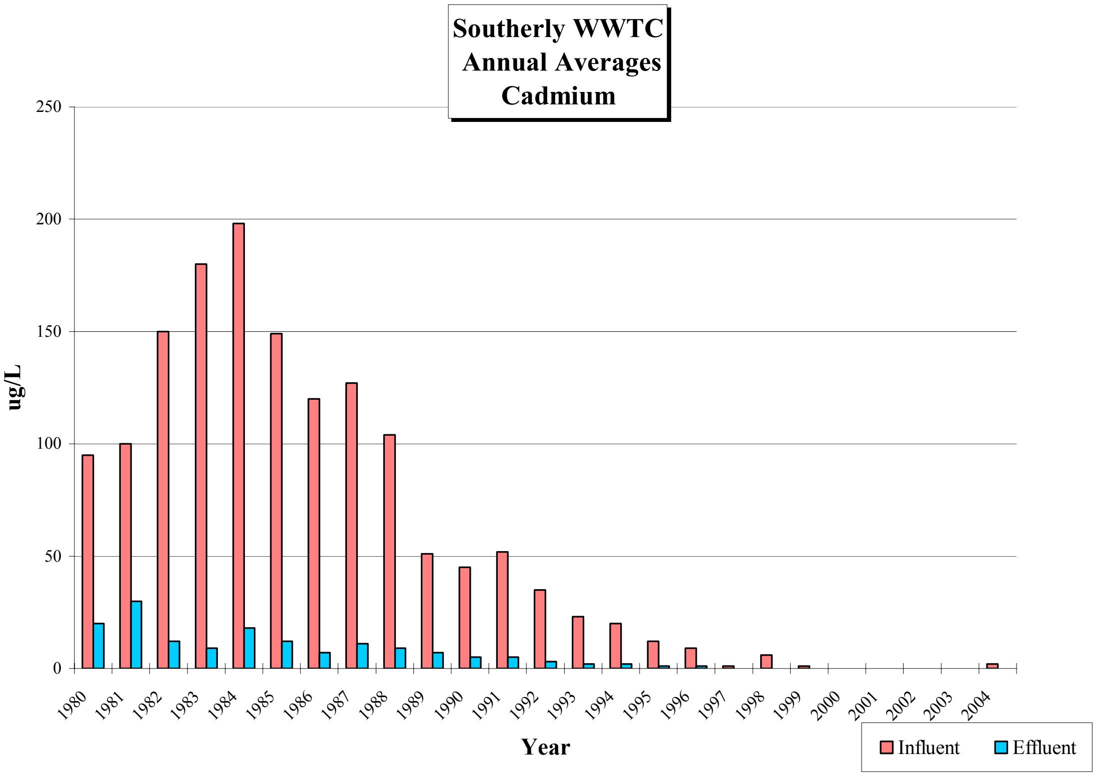
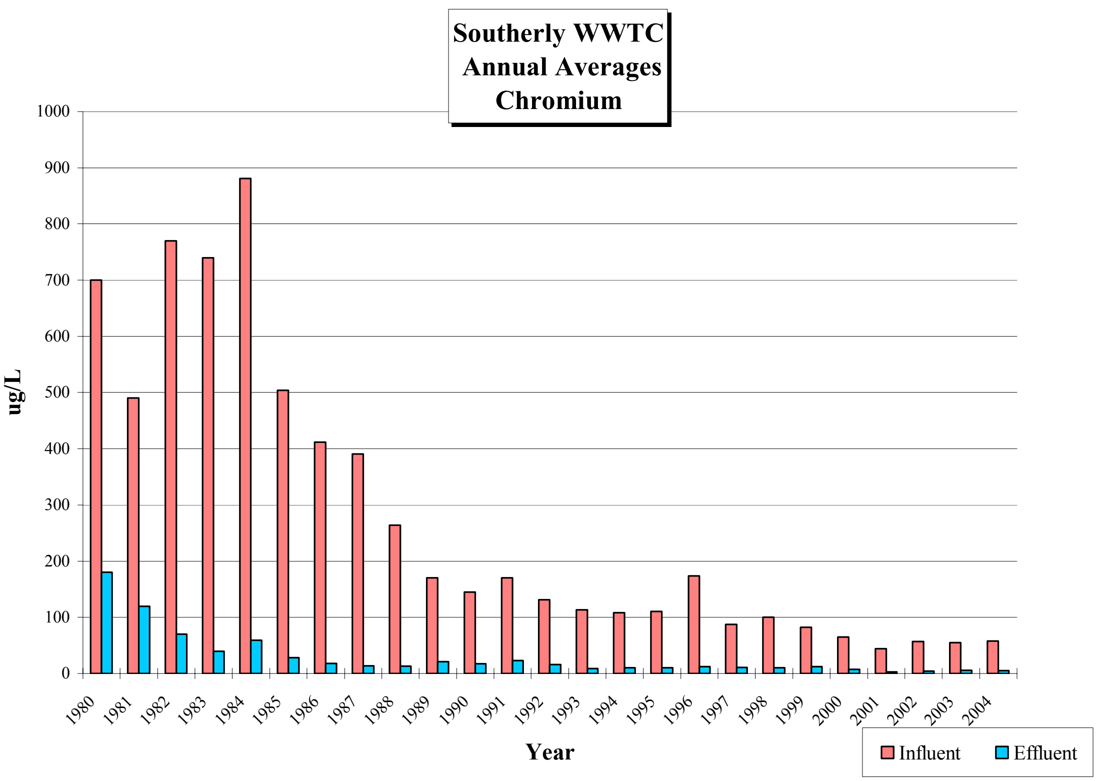
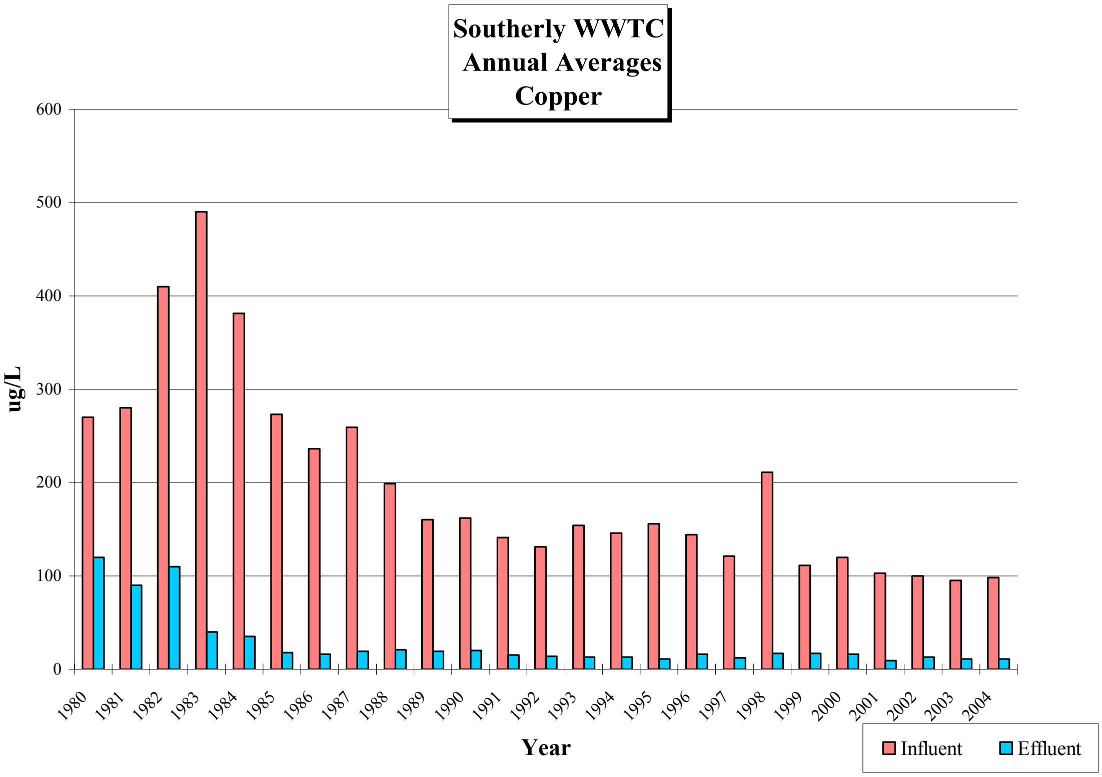
Appendix B: Southerly WWTC Influent and Effluent Annual Average Heavy Metal Concentrations



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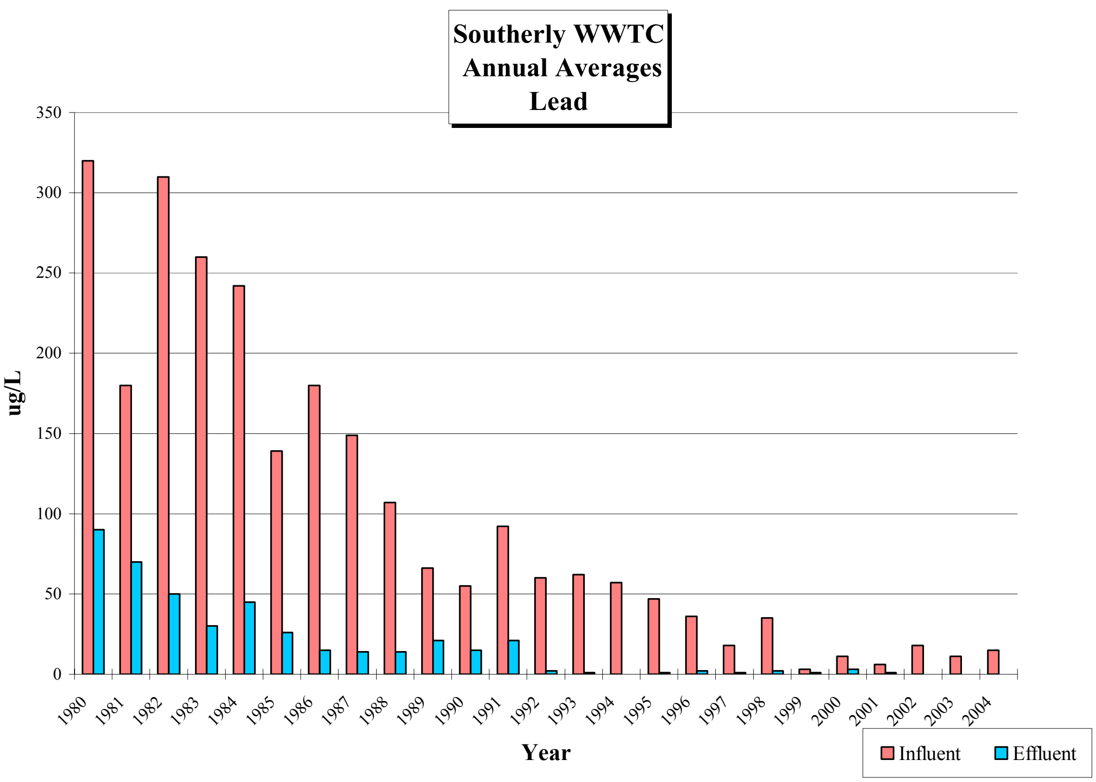
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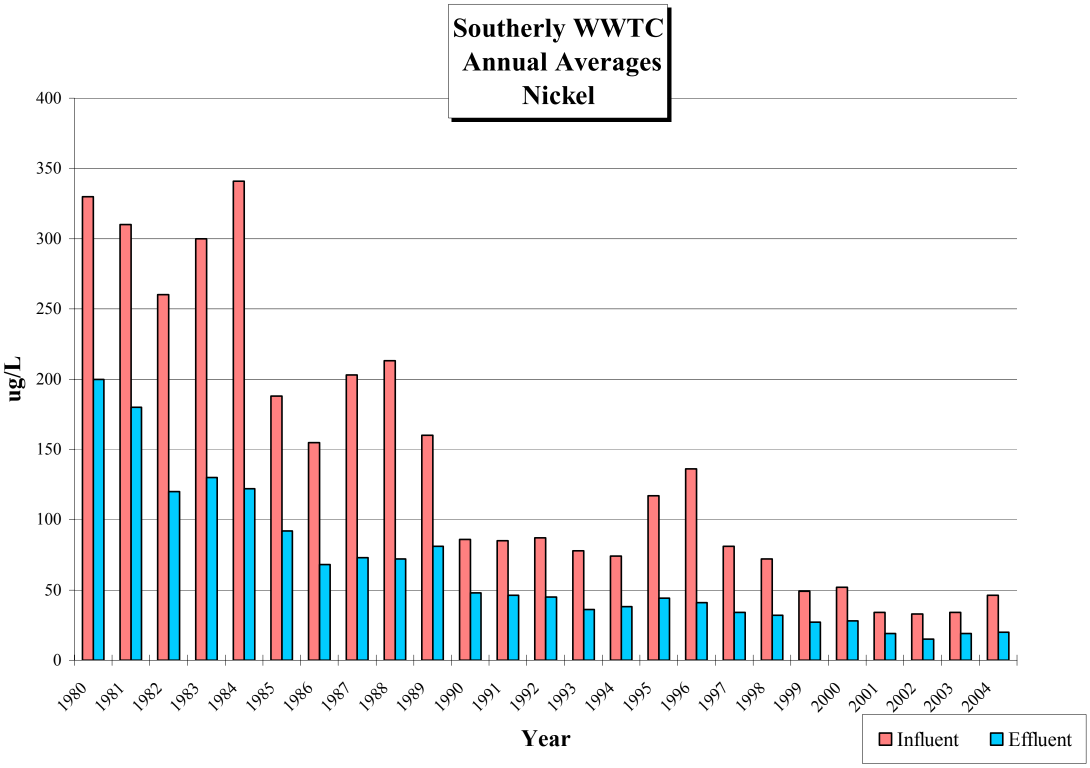
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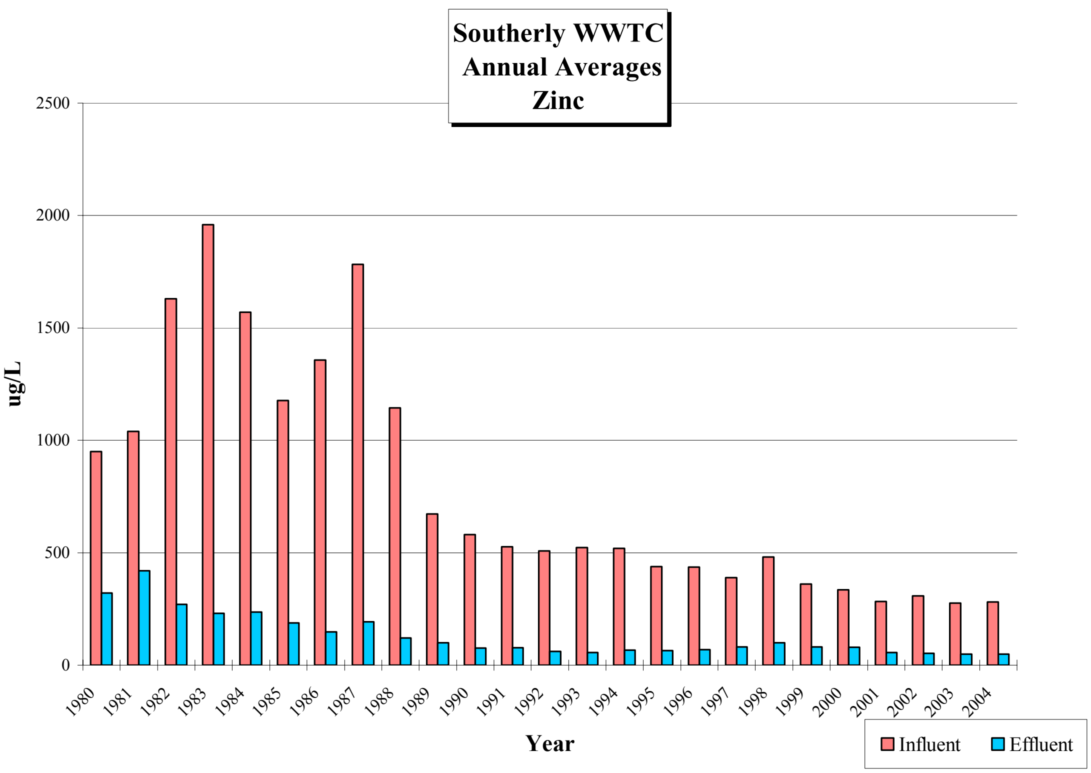
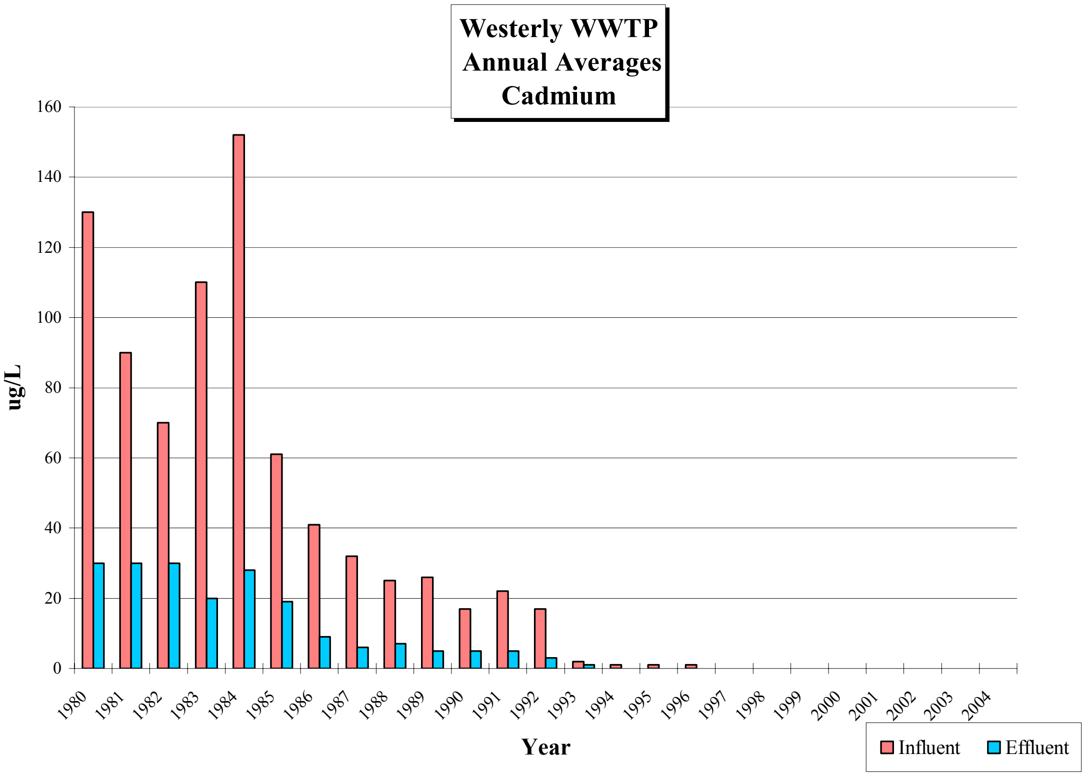
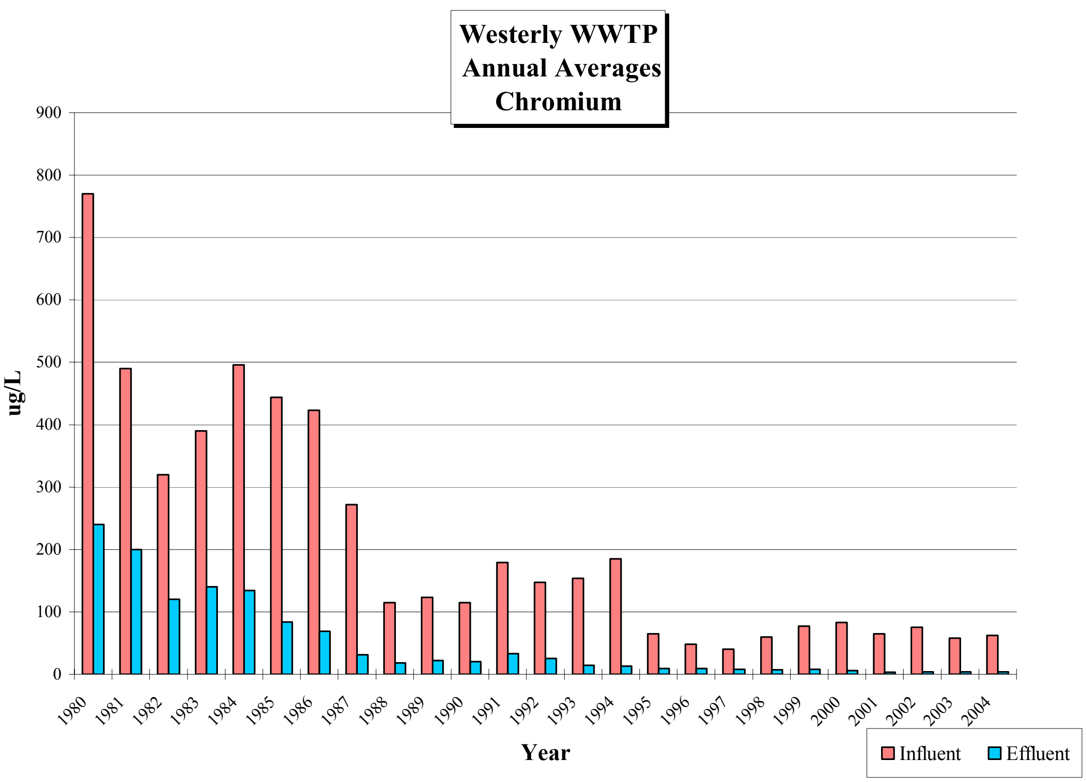
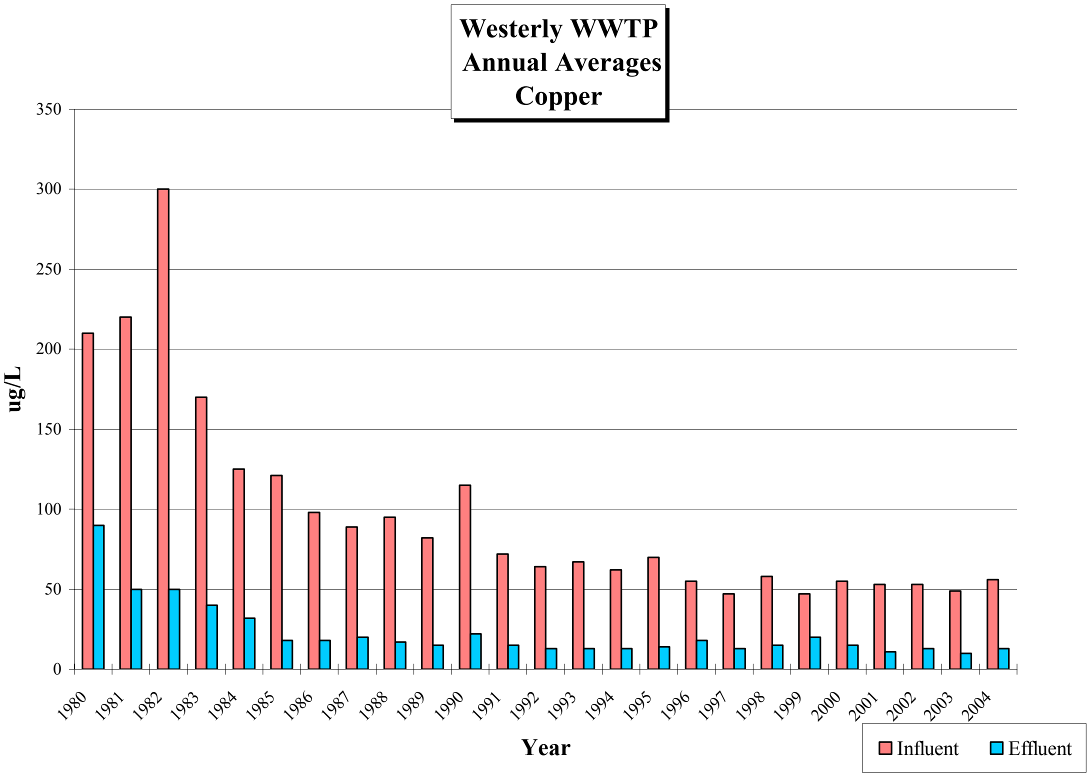
100
50
0
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
Year
Influent
Effluent

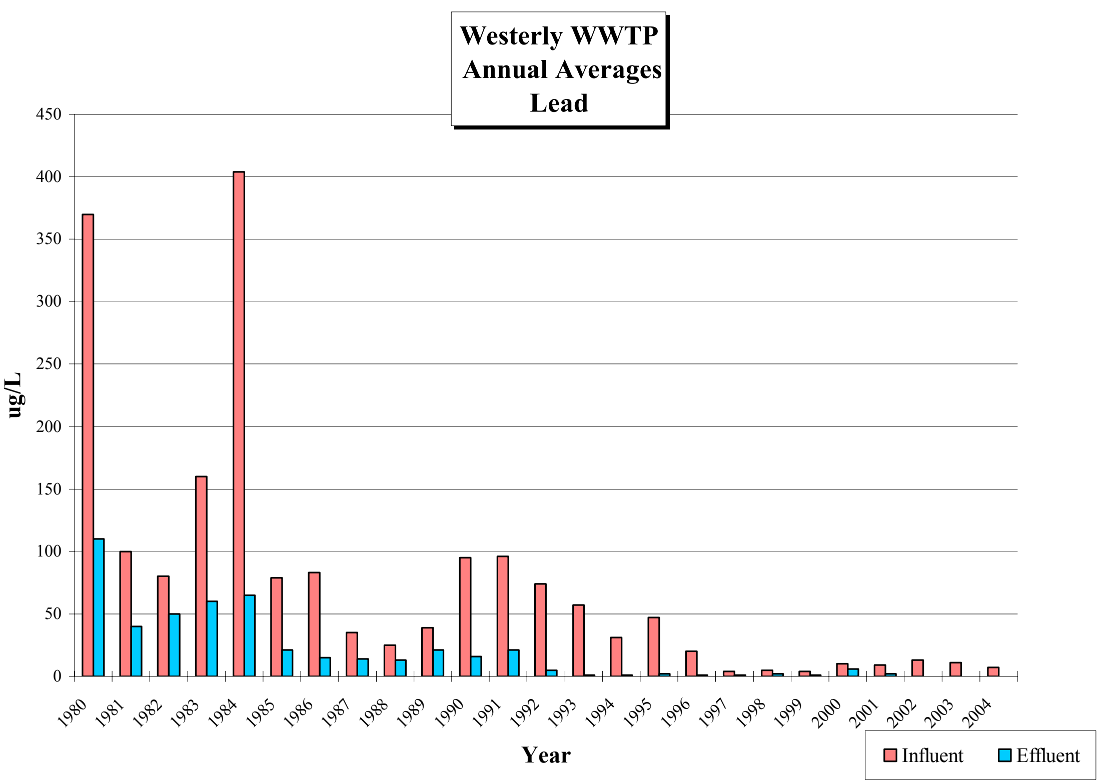

Southerly WWTC
Annual Averages
Zinc
ug/L
2500
2000
1500
1000
500
0
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
Year
Influent
Effluent

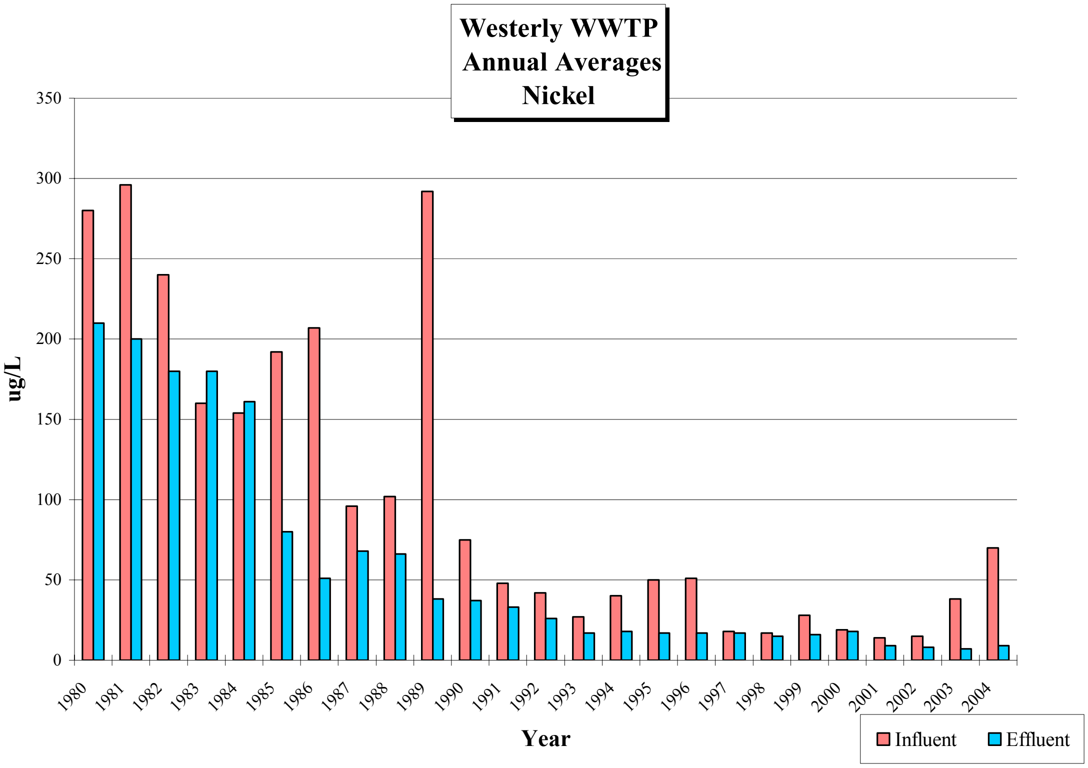
Appendix C: Westerly WWTP Influent and Effluent Annual Average Heavy Metal Concentrations

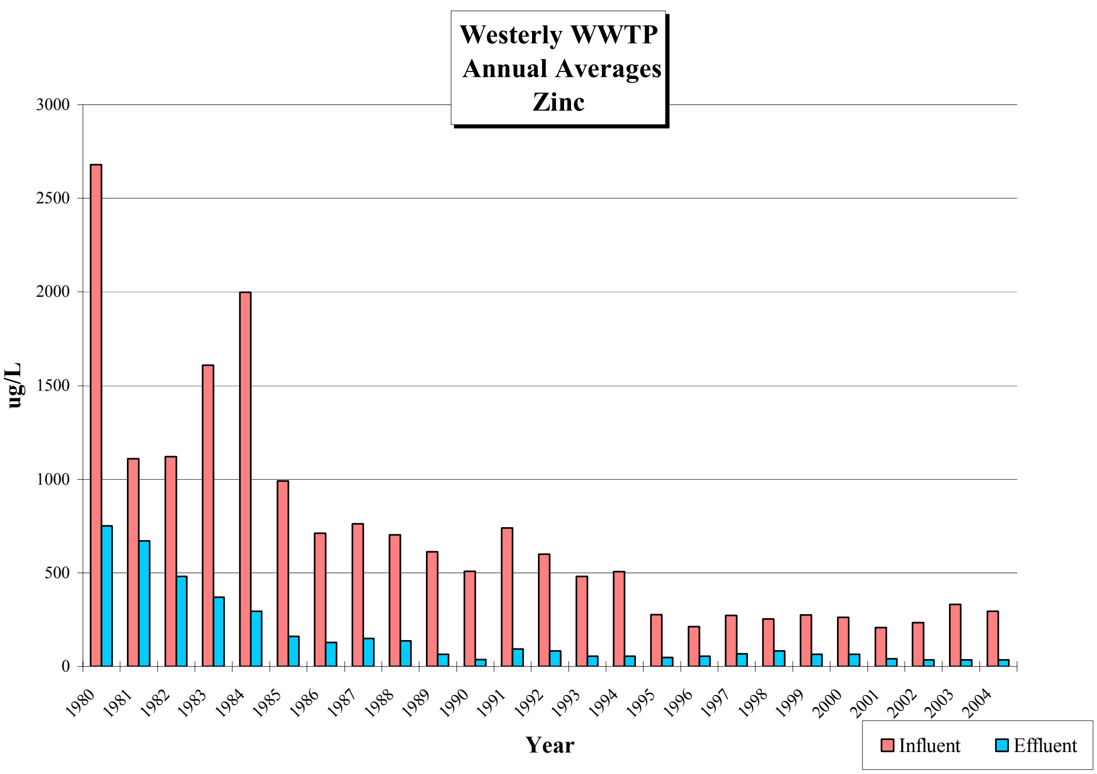




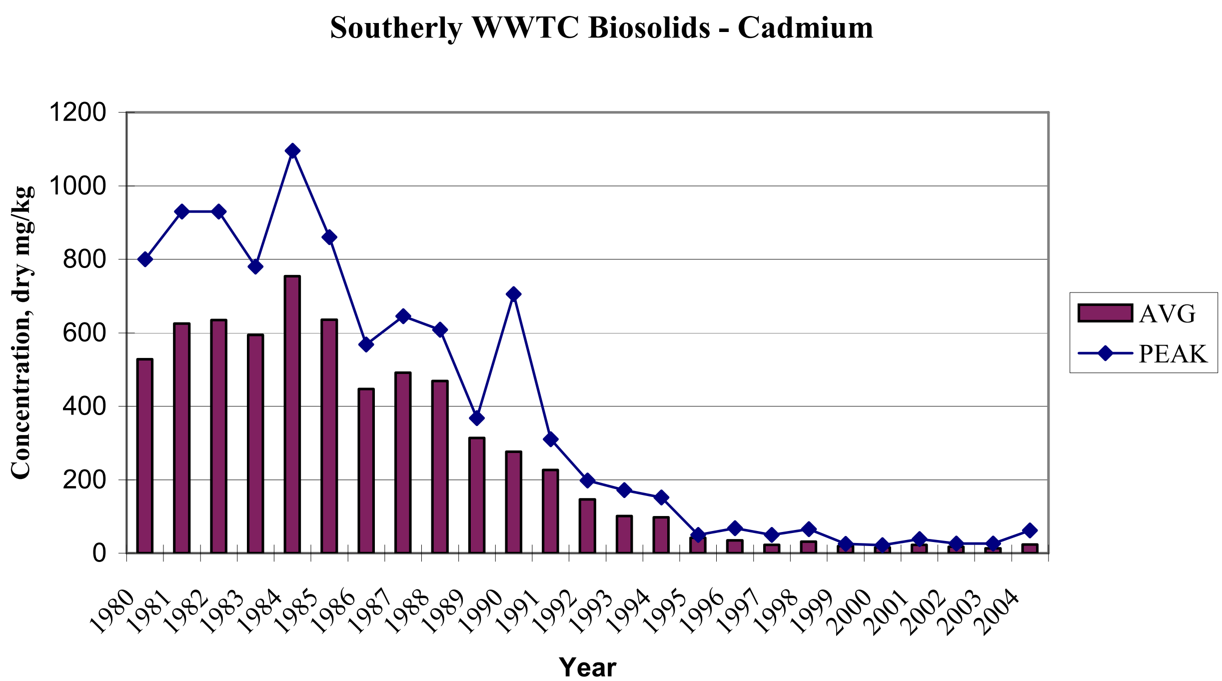

Westerly WWTP
Annual Averages
Copper
ug/L
350
300
250
200
150
100
50
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year
Influent
Effluent

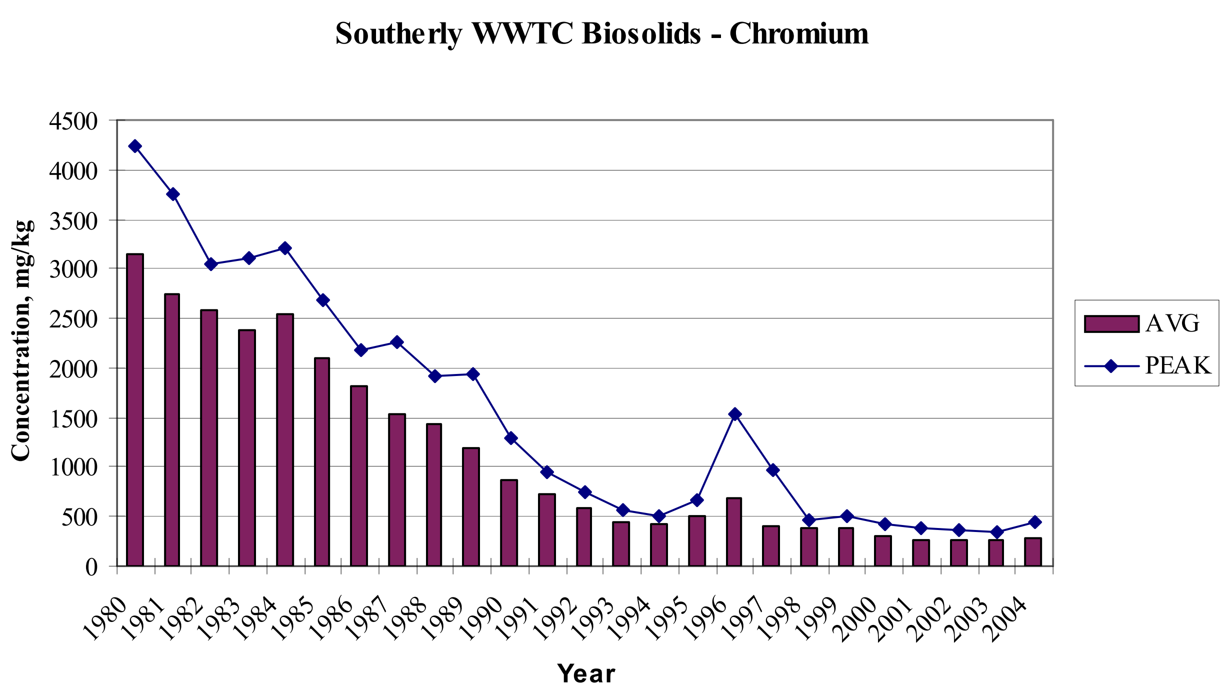

Westerly WWTP
Annual Averages
Lead
ug/L
450
400
350
300
250
200
150
100
50
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year
Influent
Effluent

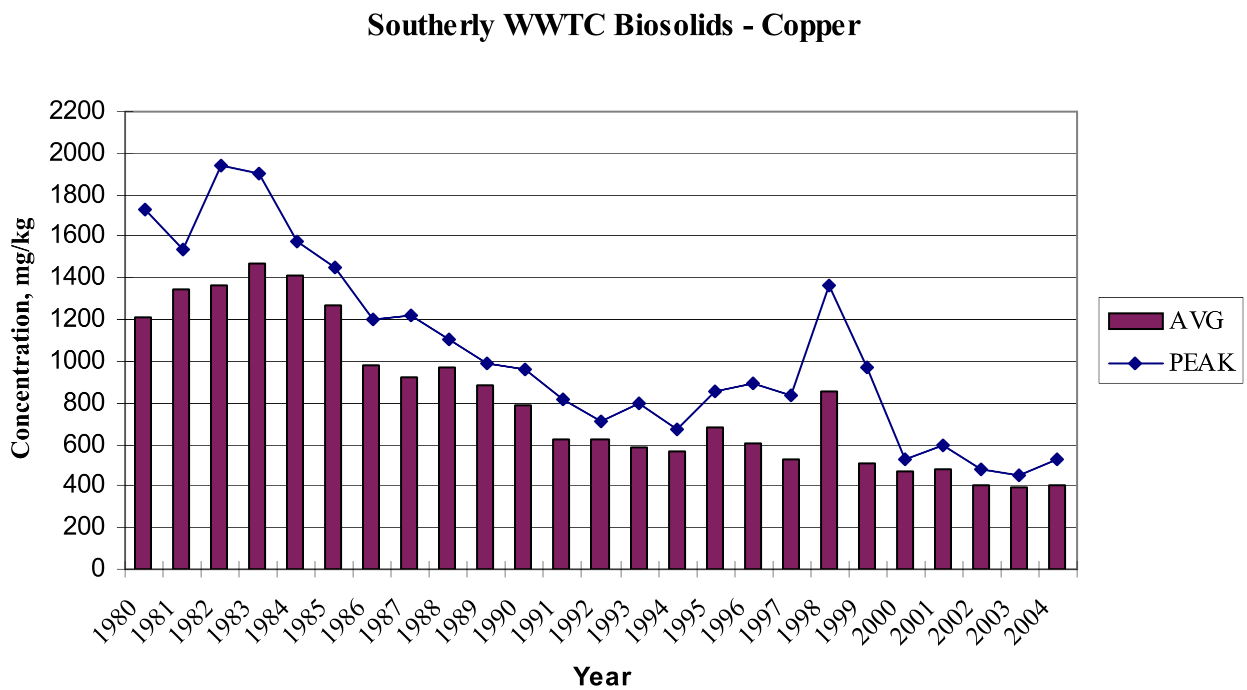

Westerly WWTP
Annual Averages
Nickel
ug/L
Year
Influent
Effluent
0
50
100
150
200
250
300
350
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004

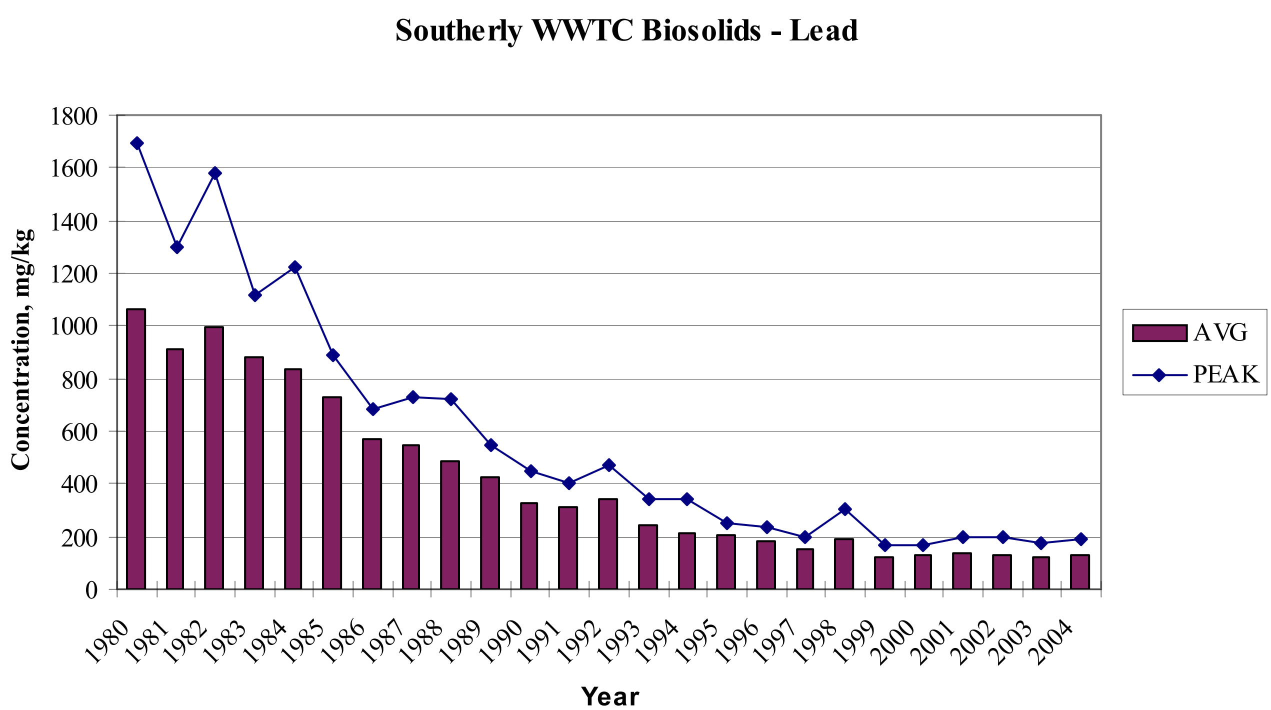

Westerly WWTP
Annual Averages
Zinc
ug/L
Year
Influent
Effluent
0
500
1000
1500
2000
2500
3000
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004

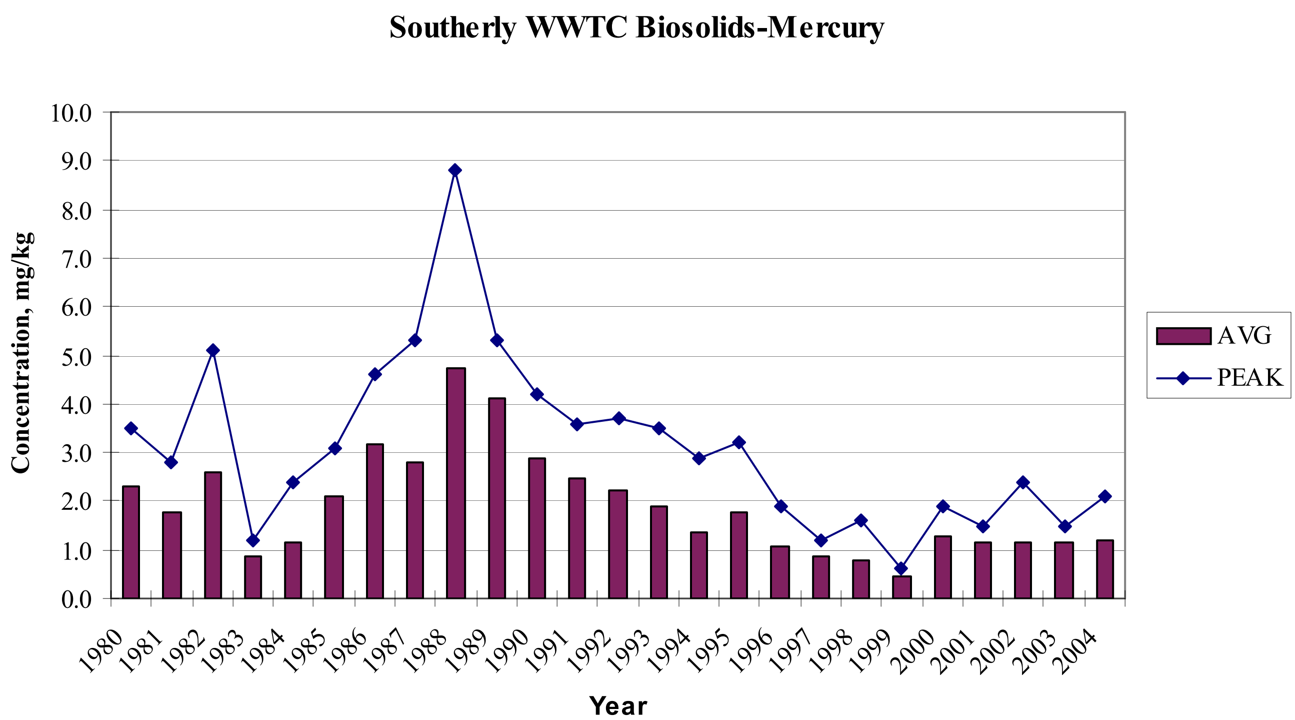
Appendix D: Southerly WWTC Heavy Metal Concentrations (dry weight basis) – Annual Averages and Monthly Peaks

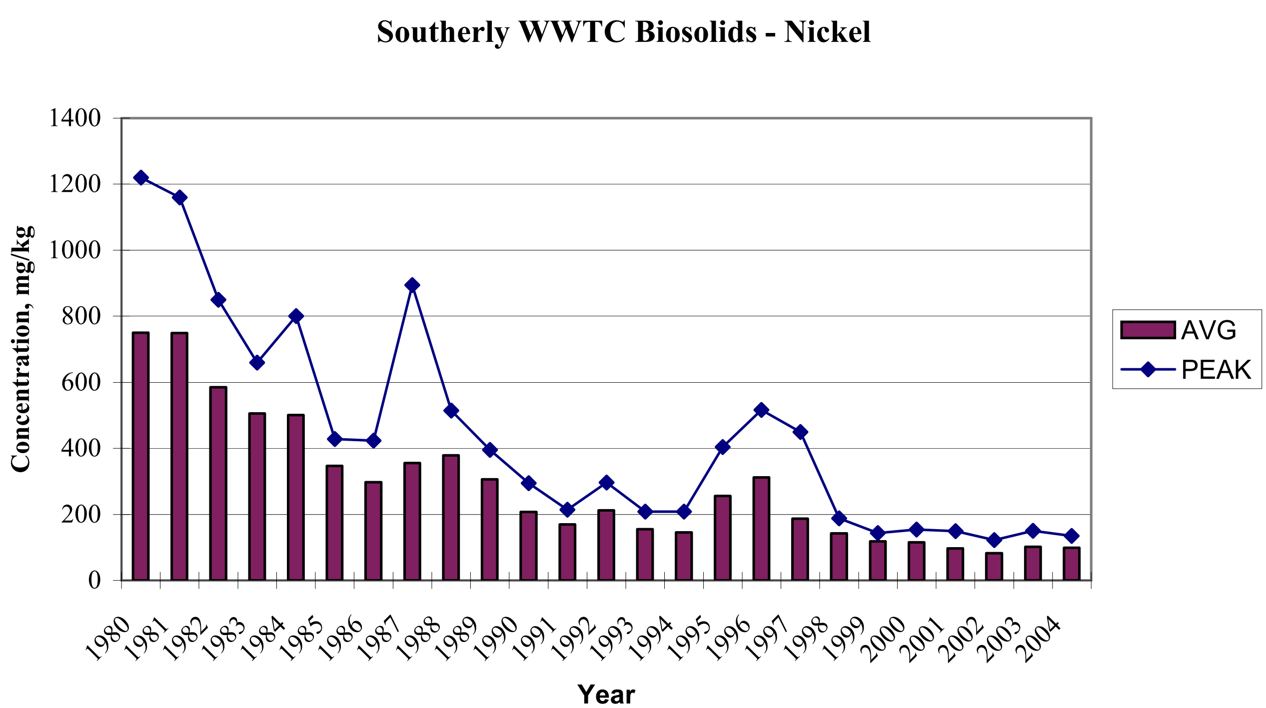


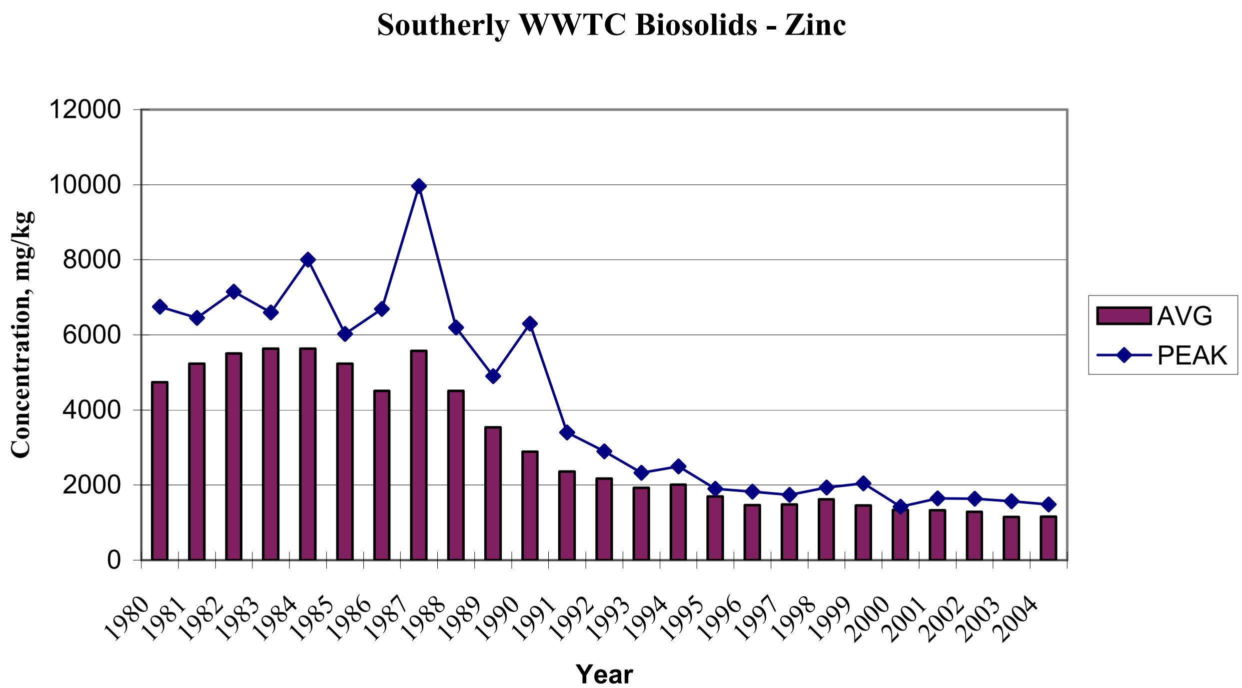



Southerly WWTC Biosolids - Copper
Concentration, mg/kg
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
Year
AVG
PEAK

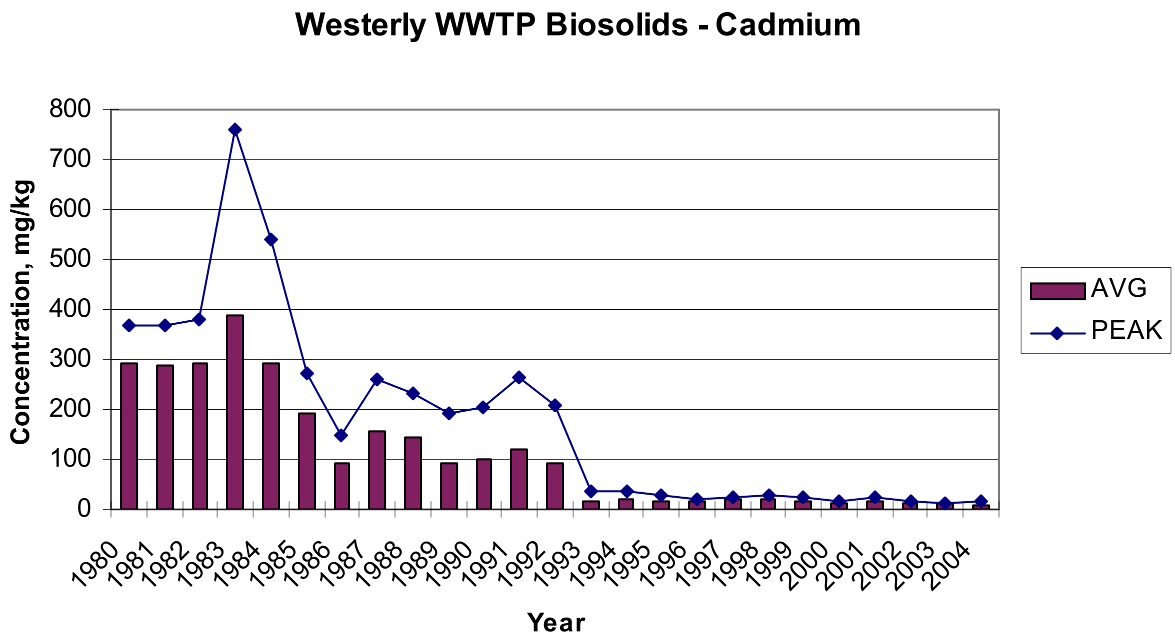

Southerly WWTC Biosolids - Lead
Concentration, mg/kg
0
200
400
600
800
1000
1200
1400
1600
1800
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
Year
AVG
PEAK

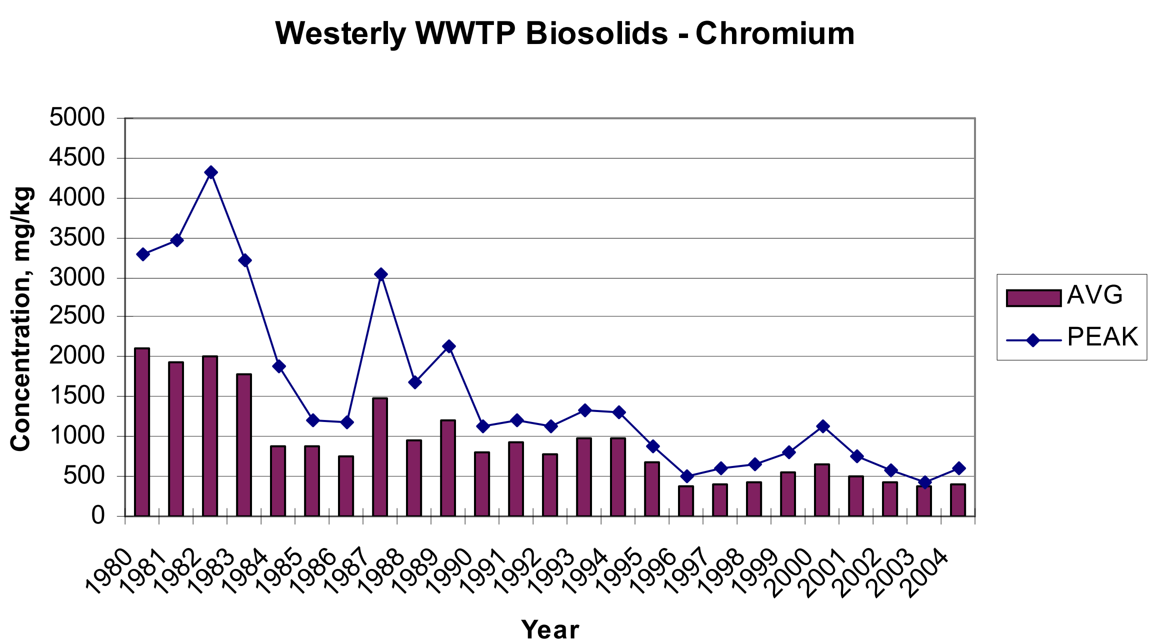

Southerly WWTC Biosolids-Mercury
Concentration, mg/kg
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year
AVG
PEAK

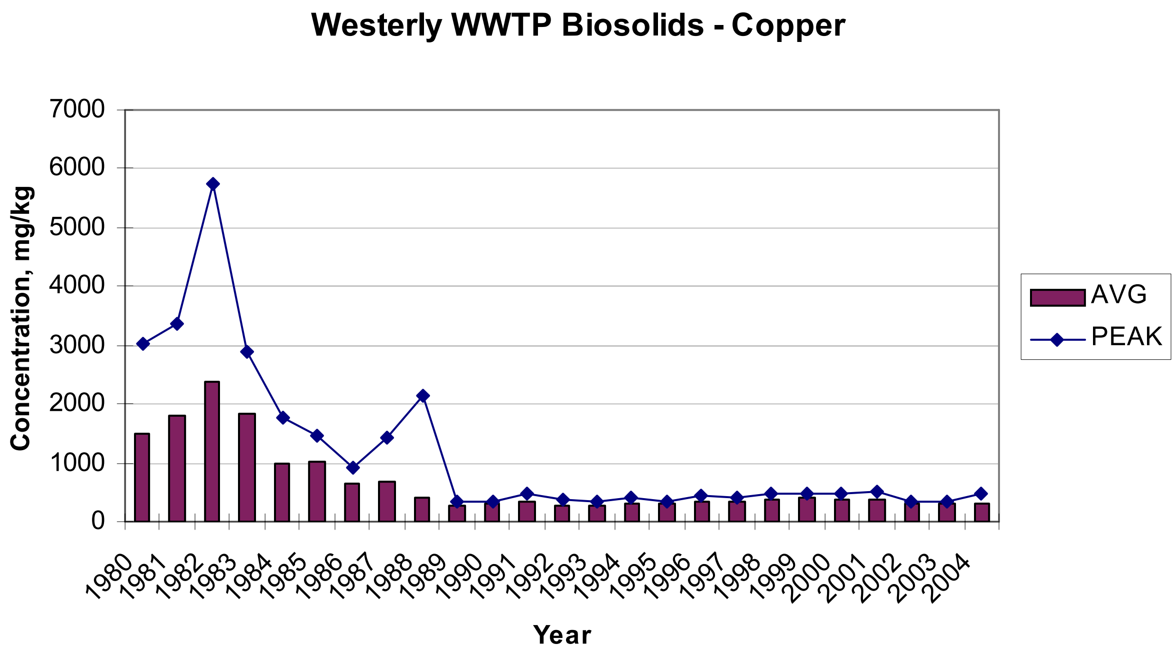

Southerly WWTC Biosolids - Nickel
Concentration, mg/kg
1400
1200
1000
800
600
400
200
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year
AVG
PEAK

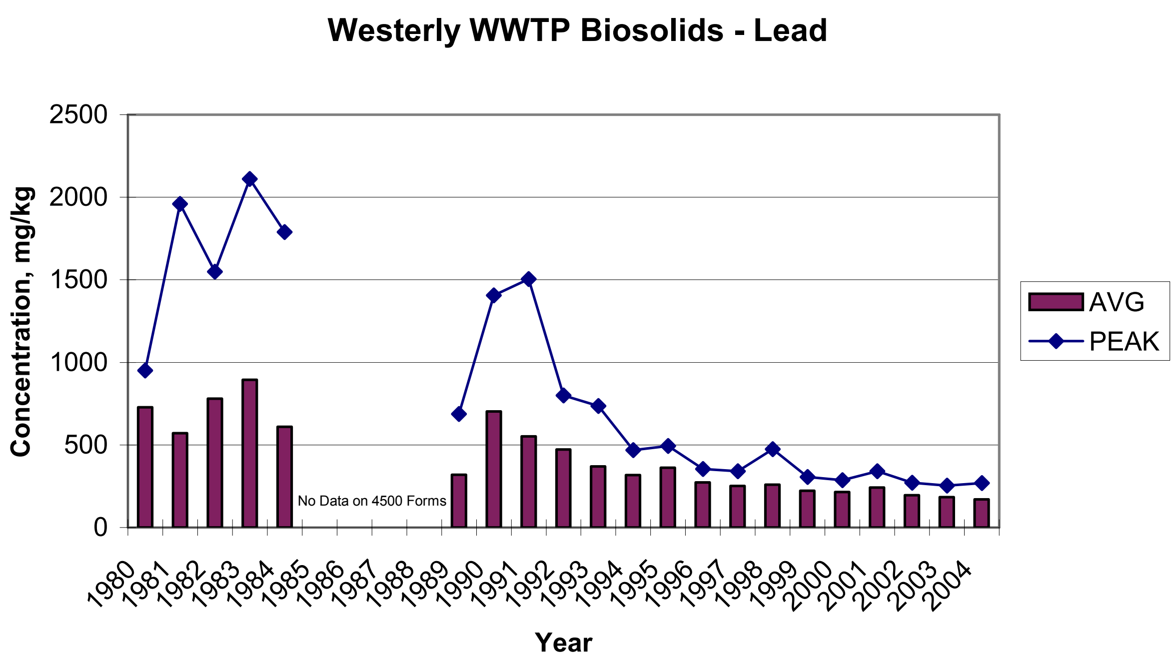

Southerly WWTC Biosolids - Zinc
Concentration, mg/kg
12000
10000
8000
6000
4000
2000
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year
AVG
PEAK

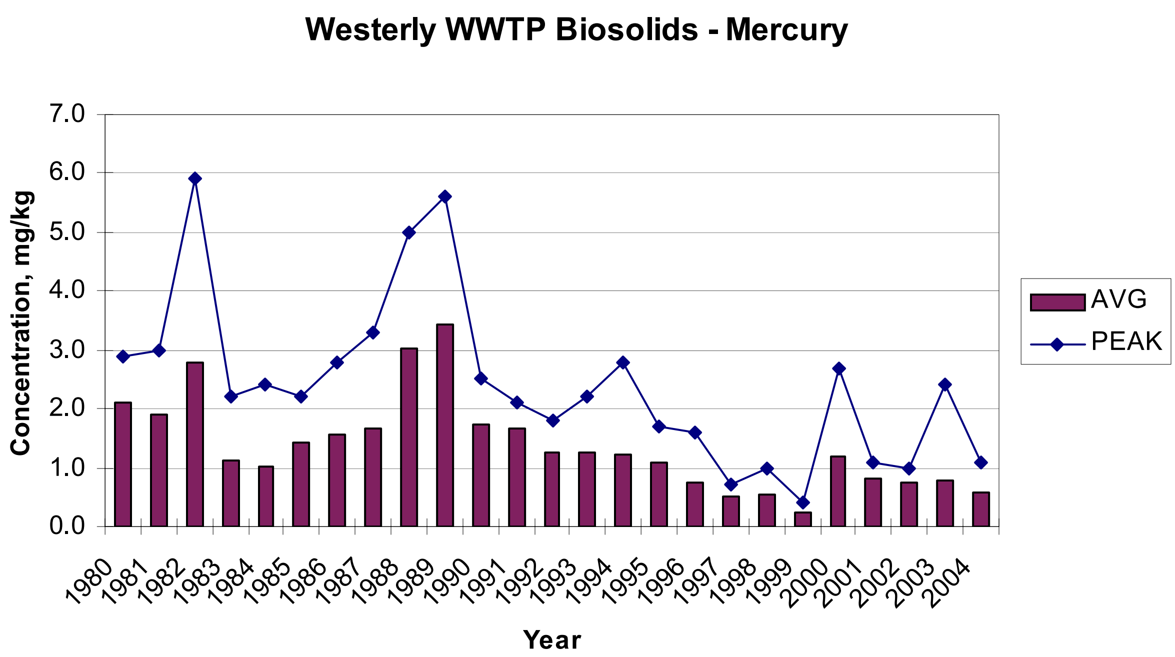
Appendix E: Westerly WWTC Heavy Metal Concentrations (dry weight basis) – Annual Averages and Monthly Peaks

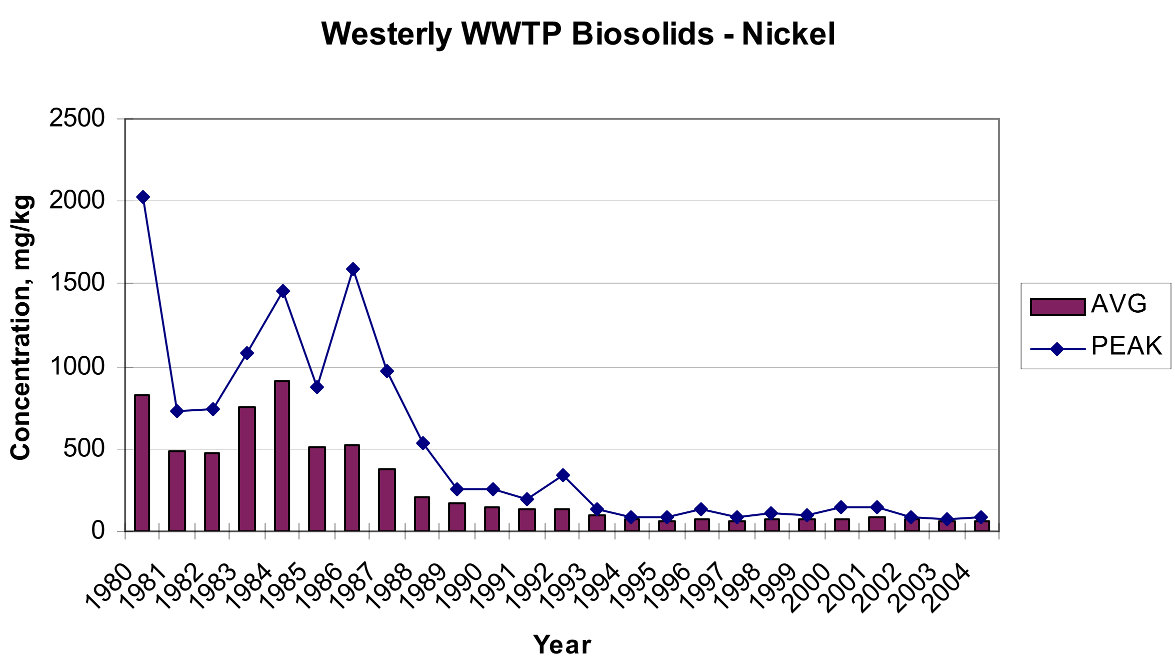


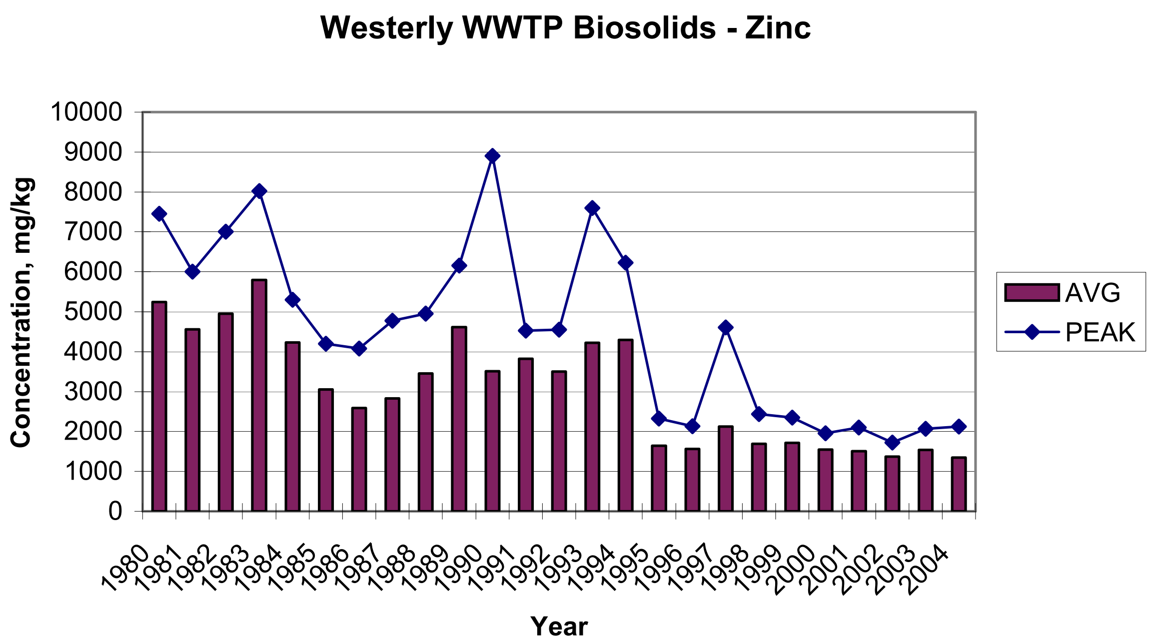



Westerly WWTP Biosolids - Copper
Concentration, mg/kg
7000
6000
5000
4000
3000
2000
1000
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year
AVG
PEAK


Westerly WWTP Biosolids - Lead
Concentration, mg/kg
2500
2000
1500
1000
500
0
No Data on 4500 Forms
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year
AVG
PEAK


Westerly WWTP Biosolids - Mercury
Concentration, mg/kg
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
Year
AVG
PEAK


Westerly WWTP Biosolids - Nickel
Concentration, mg/kg
2500
2000
1500
1000
500
0
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
Year
AVG
PEAK


Westerly WWTP Biosolids - Zinc
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Concentration, mg/kg
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year
AVG
PEAK