Chapter 3. Review of Water Quality Studies of the Fox River Watershed

This chapter provides a review of various publications and studies concerning water quality issues in the Fox River watershed. A discussion of pollution sources and categories provides background information on typical pollution issues and a discussion of emerging issues identified in other watersheds provides additional background on urban watershed concerns.

3.1. Pollution Sources

Pollution sources to surface waters are typically divided into two major categories — point source (PS) and nonpoint source (NPS). A PS can be attributed to a specific physical location and has an identifiable, end-of-pipe point. The vast majority of PS discharges are from municipal and industrial wastewater treatment facilities. These pollution sources have relatively steady flows and chemical composition. The PS flows may constitute a significant portion of the river's base flow and control in-stream water quality at low-flow conditions. These sources are regulated under the National Pollution Discharge Elimination System (NPDES) program, which establishes permissible limits of pollutants to be discharged into surface waters. The NPDES facilities located in the Fox River watershed and violations of permitted limits since 1998 are posted by the U.S. Environmental Protection Agency (USEPA) on the EnviroFacts Web site (USEPA, 2003c, 2003e).

An NPS, in contrast, is a diffuse source that cannot be attributed to a clearly identifiable point of discharge. Examples are surface runoff from various land uses, such as agriculture and forests. Surface runoff carries pollutants from the land surface and discharges them into receiving waters. The magnitude and impacts of NPS are greatly governed by climatic conditions. The NPS tend to contribute dominant pollutant loads over PS during and shortly after large storm events. Factors such as land uses and management practices can have a great influence on NPS magnitude and duration. For example, the change from agricultural to urban land could result in higher total storm runoff and NPS loading from urban areas (Brun and Band, 2000; Miller et al., 2002). Quantities of fertilizers and pesticides applied to croplands and time of the application were found to affect loading of the pollutants and their distributions in receiving waters (Fallon et al., 2002).

Urban stormwater has a physical point of discharge and is regulated by NPDES permit. However, stormwater pollution is a function of land use and precipitation, and is diffuse in nature. Stormwater permitting is currently more focused on registration of dischargers and follows a land-use/best management practice approach with self-monitoring for regulation. Groundwater seepage, septic tanks, and atmospheric deposition are also NPS contributors to surface water. Groundwater discharge into surface streams may represent a potential source of pollutants to some streams. Nutrients and naturally occurring elements commonly found in aquifers often contribute to pollution in surface waters. Septic tank systems are generally a problem only if they become clogged or water-bound. Failure of septic systems often contributes to nutrient problems in surface waters (Kothandaraman et al., 1977).

Atmospheric deposition of pollutants occurs in both dry and wet forms. Dry deposition accounts for exchange of particulate and gaseous materials between the atmosphere and global surface (including surface waters). Wet deposition refers to washout of all forms of pollutants by rainwater. The National Atmospheric Deposition Program (NADP), a cooperative research support program, collects data on the chemistry of precipitation for monitoring geographical and temporal long-term trends. Figure 3.1 illustrates trends of annual precipitation-weighted mean concentrations and total annual wet deposition of inorganic nitrogen at Argonne, Illinois, DuPage County (NADP, 2003). Annual precipitation-weighted mean concentrations were calculated using concentrations of weekly samples. The total annual wet deposition data were calculated by multiplying precipitation-weighted mean concentrations by total rainfall in the corresponding year.

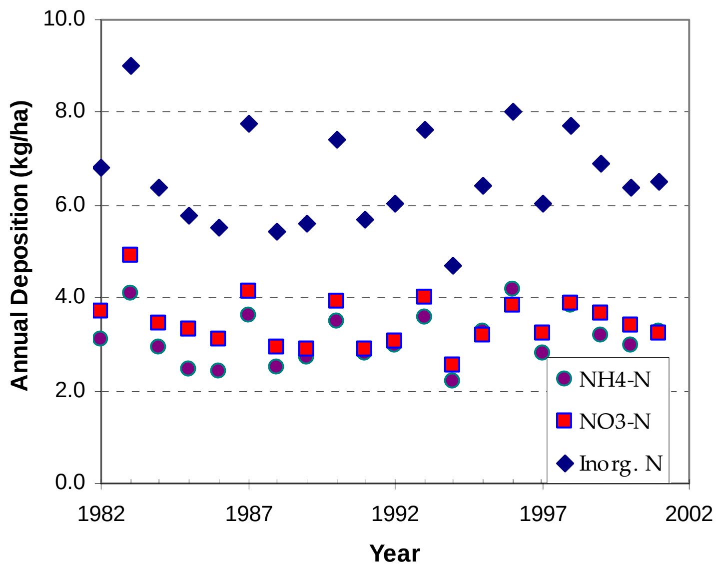
Kothandaraman et al. (1977) analyzed rainwater nutrient concentrations in the Fox River watershed at three locations in the Fox Chain of Lakes area during 1974–1975 (Table 3.1). The information allows for estimation of nutrient loads on the basis of concentrations in rainwater and assessment of the significance of atmospheric nutrients relative to surface and subsurface sources.

3.2. Use Impairment

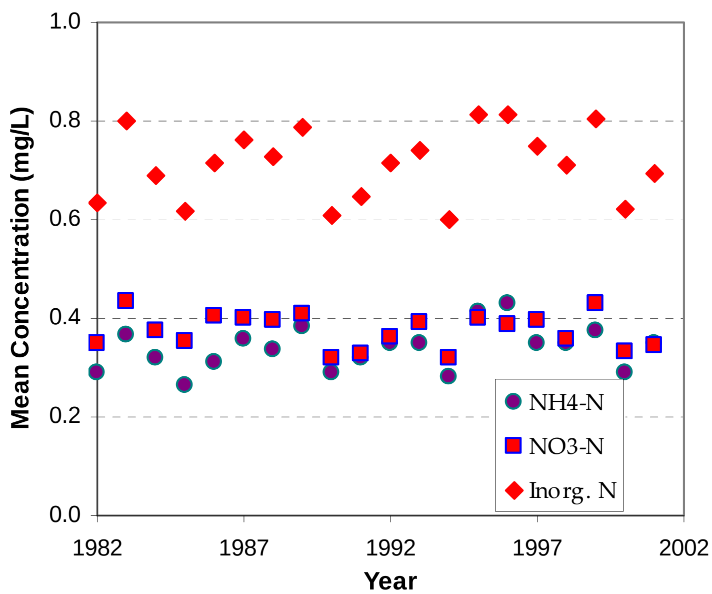
In a biennial summary, the USEPA reported that of the 19 percent of the streams assessed by U.S. states, territories, and tribes, 39 percent of the assessed stream miles were impaired for one or more designated water uses (USEPA, 2002). Leading causes for stream impairment are pathogens (35%), siltation (31%), and habitat alteration (22%). Other causes include oxygen-depleting substances, nutrients, thermal modifications, metals, and flow alteration. The Illinois Environmental Protection Agency (IEPA) assessed 18.3 percent of the total stream miles in the

Table 3.1. Rainwater Quality Characteristics in the Fox Chain of Lakes Area during 1974–1975 (Kothandaraman et al., 1977)

Location	*No. of samples*	*Range (mg/L)*	*Mean (mg/L)*
Antioch			
Nitrate N	11	0.26 – 2.90	0.77
Kjeldahl N	9	0.65 – 5.01	2.88
Ammonia N	11	0.38 – 4.78	2.22
Total Phosphorus	11	0.12 – 0.64	0.27
State Park			
Nitrate N	8	0.32 – 1.58	0.81
Kjeldahl N	3	1.81 – 11.1	5.45
Ammonia N	8	0.32 – 5.67	1.97
Total Phosphorus	8	0.00 – 0.70	0.32
Lake Villa			
Nitrate N	16	0.37 – 2.43	1.11
Kjeldahl N	9	0.85 – 6.03	2.53
Ammonia N	14	0.40 – 4.82	1.90
Total Phosphorus	14	0.03 – 2.09	0.56



(a) Total annual wet deposition



(b) Annual precipitation-weighted mean concentrations of nitrogen forms

Figure 3.1. Total annual wet deposition and annual precipitation-weighted mean concentrations of nitrogen forms, DuPage County, Argonne, IL, 1982-2001 (NADP, 2003)

state based on the most recent five-year monitoring data (e.g., 1996–2000 for the 2002 report). Nutrients, organic enrichment/low dissolved oxygen (DO), siltation, suspended solids, habitat alteration, pathogens, metals, and polychlorinated biphenyls (PCBs) were found to be potential causes for impaired streams and rivers in Illinois (IEPA, 2002a). Table 3.2 summarizes these statistics for the United States and Illinois.

Within the Fox River basin, leading causes for impairment to designated uses are similar to those found statewide except that flow alteration occurs more frequently in the Fox River basin than statewide (IEPA, 2002a). This is attributable to the many dam structures on the mainstem of the Fox River. These causes have led to degradation of ecological health and water quality in the Fox River basin. Biotic indices such as Index of Biotic Integrity (IBI) or Macroinvertebrate Biotic Index (MBI) are used to assess the level of aquatic life support (IEPA, 2002a).

Dreher (1997) conducted a regression analysis that showed a negative correlation between population density and the IBI in northeastern Illinois streams. Based on the assessment of more than 40 streams and rivers (including those in the Fox River watershed), nearly all streams in urban/suburban watersheds (population density > 300 persons/square mile) exhibited signs of considerable impairment of fish communities. Ecosystem monitoring for the Critical Trends Assessment Project found that the Fox and Des Plaines River watersheds (assessed as

Table 3.2. Leading Potential Causes of Use Impairment and Impaired Mileage of Streams and Rivers in the United States and Illinois in Year 2000 (USEPA, 2002; IEPA, 2002a, 2003)

	U.S.[a]		*Illinois*[a]		*Fox River watershed*[b]
Cause	*Impaired miles*	*Percent of total assessed*	*Impaired miles*	*Percent of total assessed*	*Impaired miles*[c]
Flow alterations	25,355	9.4	509	3.2	72.62
Habitat alteration	37,654	14	2,732	17.2	80.96
Metals	41,400	15.4	2,228	14	
Nutrients	3,234	19.6	3,082	19.3	42.52
Organic enrichment/low DO	55,398	20.6	2,962	18.6	56.4
Pathogens (fecal coliform)	93,431	34.7	2,318	14.6	92.04
PCBs			2,435	15.3	136.48
pH	20,193	7.5	685	4.3	28.43
Priority organics			743	4.7	34.37
Salinity/TDS/Chlorides	14,620	5.4	643	4	
Siltation	84,503	31.4	1,978	12.4	58.08
Suspended solids	14,077	5.2	1,728	10.9	54.49
Thermal modifications	44,962	16.7	9	0.06	
Excessive algal growth					3.59

Notes:
[a]Year 2002 listing.
[b]Year 2003 listing.
[c]Total number of miles, therefore percent of total miles assessed not available at this time.

watershed units) generally scored below the statewide average for most biological indicators, indicating below average health of ecosystems in both watersheds (IDNR, 2001).

The Max McGraw Wildlife Foundation recently conducted an intensive study to determine the effects of dams on fish and macroinvertebrate populations, aquatic habitat, and water quality in the Fox River during 2000–2001 (Santucci and Gephard, 2003). The study of approximately 100 miles of rivers and 15 mainstem dams between McHenry and Dayton provided a good assessment of the ecological communities in the river basin. Results showed higher quality fish communities in free-flowing portions of the river than impounded areas above dams based on IBI scores. The adverse effects of impoundment on nongame and sport fish communities extended well upstream of the dams. Similarly, free-flowing reaches supported more abundant and richer macroinvertebrate communities than impounded areas. In free-flowing reaches, there were a variety of water depths, current velocities, substrate types, and abundant cover for fish and invertebrates; good quality riffles and runs contributed to better habitat quality for fish and macroinvertebrates.

3.3. Water Quality

Pollutants were divided into seven categories to review water quality conditions in the Fox River basin. These categories include: nutrients, DO and pH, sediment and siltation, major and trace elements, pathogens, pesticides and synthetic organic compounds, and emerging water quality issues.

3.3.1. Nutrients

In an environmental context, nutrients typically refer to nitrogen (N) and phosphorus (P). The N exists in either dissolved or particulate forms, and in either inorganic or organic forms. These forms of nitrogen exhibit substantial differences in chemical properties. For example, NH_4^+ cations are strongly sorbed unto some mineral surfaces while anionic species such as NO_3^- are readily transported in water. Nitrite and organic N are unstable in aerated water and are considered to be an indication of pollution from sewage or organic waste at certain levels of concentration. These N forms are transformed via processes such as ammonification, nitrification, assimilation, and fixation. Environmental factors, such as nutrient concentration, DO concentration, solar energy, temperature, and flow, control the processes' kinetics and magnitudes to a great extent. Detailed information about the N cycle is available on the Illinois State Water Survey (ISWS) Web site (http://www.sws.site.uiuc.edu/nitro/).

The P concentrations in surface waters are generally much lower than N concentration. Phosphates are the most common forms of P found in natural waters and are not mobile in soil water because of their high affinity for soil particles. Attached P transported to water bodies by runoff poses a threat to the quality of receiving waters when released. Dissolved inorganic P is commonly known as orthophosphate or soluble reactive phosphorus, depending on methods used in chemical analyses.

Ammonia, nitrate, and phosphate are the main inorganic forms of dissolved nutrients present in surface water. They are biologically available and essential nutrients for algal growth. Excessive algal growth due to nutrient enrichment can degrade water quality in various ways: taste/odor of water supply, clogging of waterways, and low DO levels. Nutrient ratios such as total nitrogen to total phosphorus have been used to assess limiting nutrients for algal growth.

The ISWS has conducted water quality surveys in Illinois streams and rivers since the late 19th Century, which has helped portray water quality conditions in early years. Table 3.3 lists statistics of the monitoring results for several Fox River locations from comprehensive surveys throughout Illinois streams and rivers (Harmeson and Larson, 1969; Harmeson et al., 1973). There was an apparent decrease in nitrate concentrations at the Algonquin station from 1956–1961 to 1966–1971, based on the concentration distributions during the two time periods. Nitrate concentrations at the Dayton station were in general higher than at the Algonquin station during 1956–1961. Both nitrate and phosphate concentrations were higher at the Batavia station than at the Algonquin station during 1966–1971.

The Northeastern Illinois Planning Commission (NIPC) conducted a study to assess water quality conditions in the Fox River basin using the IEPA's 1958–1975 monitoring data (Elmore et al., 1977). The study covered 12 stations on the mainstem of the Fox River and 10 stations on its tributaries. The data showed that total P concentrations at all stations were constantly above the P standard of 0.05 milligrams per liter (mg/L) for lakes and reservoirs (no P standard for rivers and streams). The nitrate + nitrite N concentration was mainly in a range below 1 mg/L to 5 mg/L.

Table 3.3. Statistics of Nutrient Concentrations in the Fox River, 1956–1971 (Harmeson and Larson, 1969; Harmeson et al., 1973)

	Concentration (mg/L) not exceeded for indicated percentile		
	10	*50*	*90*
Nitrate			
Algonquin			
1956–1961	3.2	6.0	12.0
1966–1971	1.1	4.1	10.1
Batavia			
1966–1971	1.9	5.5	10.3
Dayton			
1956–1961	3.4	7.6	13.5
Phosphate (filtered)			
Algonquin			
1960–1961	0.11	0.45	1.09
1966–1971	0.40	0.90	2.30
Batavia			
1966–1971	0.80	1.85	2.90
Dayton			
1960–1961	0.40	0.90	2.30

Adams et al. (1989) monitored two tributaries of the Fox River from March 1987 to November 1988 twice a month, and Table 3.4 summarizes the results. The mean concentration of P in both Blackberry Creek and Ferson Creek showed that dissolved P was 50 percent or less of total P. Nitrate was the dominant chemical form of nitrogen at the monitoring sites.

Singh et al. (1995) analyzed IEPA's 1972–1992 monitoring data to study long-term trends and seasonal variation of water quality. In order to detect any improvement or worsening of a water quality parameter with respect to time, the data were divided into four time periods: 1972–1976, 1977–1981, 1982–1985, and 1987–1992. Data were segmented into four quarters to study seasonal variation: January–March, April–June, July–September, and October–December. Five stations along the mainstem of the Fox River with long records of monitoring data were selected for analysis: near Channel Lake, Algonquin, South Elgin, Montgomery, and Dayton. Nutrient conditions at these locations are summarized as below:

- *Nitrate + nitrite nitrogen (NO_3^- + NO_2^-):* Overall conditions (1972–1992) were better at Algonquin, followed in order by South Elgin, near Channel Lake, Montgomery, and Dayton. With the exception of Channel Lake, nitrate levels increased in the downstream direction. There were only isolated cases where the concentration exceeds the IEPA water supply standard of 10 mg/L. Trend analysis indicated practically no change at those stations. Seasonal variations showed lowest concentrations in July–September and highest concentrations in January–March.
- *Ammonia + ammonium nitrogen (NH_3 + NH_4^+):* Overall conditions were better near Channel Lake and Dayton, followed by Algonquin, Montgomery, and South Elgin. Trend analysis showed some decrease at all stations. Seasonal variations showed best conditions in April–June and July–September and worst conditions in January–March.

Table 3.4. Statistics of Nutrient Concentrations in Two Fox River Tributaries, 1987–1988 (Adams et al., 1989)

	Mean (mg/L)	*Max (mg/L)*	*Min (mg/L)*	*Standard deviation*
Blackberry Creek				
Total P	0.12	0.48	0.03	0.10
Total dissolved P	0.05	0.20	0.01	0.03
Kjeldahl N	0.86	1.87	0.24	0.36
Ammonia N	0.16	0.40	0.01	0.10
Nitrate N	3.10	7.25	0.93	1.54
Ferson Creek				
Total P	0.10	0.30	0.03	0.06
Total dissolved P	0.05	0.16	0.01	0.03
Kjeldahl N	0.90	2.82	0.24	0.43
Ammonia N	0.18	1.09	0.01	0.17
Nitrate N	2.85	5.57	0.65	1.26

- *Phosphorus (total):* Overall, concentrations were from the lowest to highest in the following order: near Channel Lake, Algonquin, South Elgin, Montgomery, and Dayton. There was a steady, significant improvement at all stations except Montgomery. Concentrations were lowest in January–March or October–December and highest in July – September.

On a regional scale, spatial distribution of nutrient concentrations was closely related to land cover in northeastern Illinois. Sullivan (2000) reported the following observations based on IEPA and USGS 1978–1997 monitoring data:

- Relatively large ratios of N to P and nitrate to ammonia are characteristics of agricultural drainage.
- Urban tributaries are characterized by smaller ratios of N to P and nitrate to ammonia.

Total ammonium concentrations in the Fox River basin are generally lower than those in urban areas of the Des Plaines River basin, and higher than those in the Kankakee River basin. Nitrate + nitrite N concentrations overall are lower in the Fox River basin than in the agriculturally dominated Kankakee and relatively urbanized Des Plaines River basins. Both dissolved and particulate forms of P are present, with municipal and industrial waste discharges being the major sources of dissolved P and agricultural land contributing mostly particulate P. In general, both total and dissolved P concentrations in the Fox River basin are comparable with respective P forms in the Kankakee River basin and lower than those in Des Plaines River basin (Sullivan, 2000).

Santucci and Gephard (2003) compared nutrient concentrations in the Fox River with the recommended nutrient guidelines for Midwestern rivers and streams (Robertson et al., 2001). These nutrient guidelines were derived based on the observed occurrence of concentration levels, ranked as exceedence percentiles within a selected ecoregion. In general, the Fox River is nutrient enriched and supports high algal biomass. Total P was near the recommended 0.11 mg/L guideline for P in Zone 4 Midwestern streams at Stratton Dam (Robertson et al., 2001), increased to the 90th percentile between Stratton and South Elgin (0.54 mg/L), and remained elevated at all downstream stations. There was a modest decrease in P from Yorkville to Dayton Dam, a river reach with more than 26 uninterrupted miles of free-flowing habitat. Total N followed a pattern similar to total P except that peak N concentrations were near the 50th percentile for N in Zone 2 Midwestern streams (4.0 mg/L), and the decrease in N at the southernmost stations was more substantial. Nutrient concentrations in impounded sediments were considered to range from low to moderate levels.

3.3.2. Dissolved Oxygen and pH

Dissolved oxygen (DO) is one of the most fundamental parameters indicative of aquatic ecosystem health. It is essential to support healthy aquatic biological communities. Although most anthropogenic water uses do not require high DO concentrations, the usefulness of water may be limited by low DO concentrations.

Major sources of DO in surface waters are gaseous oxygen in the atmosphere via dissolution and production from photosynthetic activities of aquatic organisms. Solubility of oxygen is governed by environmental factors such as barometric pressure, temperature, and chemical constituents in the water. It normally decreases with decreasing atmospheric pressure and with increasing temperature. The oxygen reaeration rate, which is governed largely by stream turbulence, increases with stream velocity (Bowie et al., 1985). Photosynthetic production of oxygen is typically highest during the daylight hours when sunlight is available and often results in supersaturation of DO in the water.

The DO is consumed from aquatic systems by biological respiration, decomposition of organic materials, and oxidation of inorganic waste. As a result, enrichment of organic and inorganic wastes [e.g., high biochemical oxygen demand (BOD) and ammonia levels] may lead to low DO concentrations in waters. Bacteria and plant respiration that reduce oxygen concentrations at night can cause temporary low DO levels. This diurnal variation can be dramatic with high algal biomass as a result of nutrition enrichment and sluggish hydraulic conditions. Butts and Evans (1978a) found significant DO swings in the impoundment area above the dams in northeastern Illinois streams. The dams aerate or deaerate water flowing over the structures depending on the upstream DO concentration.

Benthic organisms also consume DO from degrading organic compounds in underlying sediments. This sediment oxygen demand (SOD) could be significant in backwater lakes or in-stream pools where flow velocity and turbulence are greatly reduced. Butts and Evans (1978b) measured SOD in selected northeastern Illinois streams, and their results showed that rate of SOD ranged from 1.54 to 9.37 grams per square meter per day or $g/m^2/day$ (temperature-corrected at 25 ^oC). In the Fox River waters, the high SODs were found in Aurora and Elgin areas on the Fox River.

A side effect of high algal biomass is increased pH value due to consumption of carbon dioxide or bicarbonate by algae for production of cellular material. The magnitude of pH swing depends on water buffering capacity. The fluctuation of pH can change the balance between different forms of chemical elements (e.g., NH_3 and NH_4^+) and their fate in the environment. Brick and Moore (1996) showed diurnal variation of trace metal concentrations due to DO and pH effects on the solubility of the trace metals stored in streambeds and floodplains in the upper Clark Fork River, Montana. The results imply that daytime sampling may underestimate flux of the metals in the river.

Numerous studies and reports have summarized DO concentrations in the Fox River watershed based on regular and focused data monitoring over the years. During 1958–1975, DO concentrations in the Fox River basin (Elmore et al., 1977) occasionally fell below the water quality standards 6 mg/L (should not be less than 6 mg/L during at least 16 hours of any 24-hour period) and 5 mg/L (at no time). Values of pH sporadically exceeded IEPA's standard ($6.5 < pH < 9$) along the mainstem of the river.

Due to diurnal variation in DO, results are dependent on the monitoring methodology. The standard practice for ambient water quality monitoring by the IEPA is to sample during daylight hours, typically between 8 a.m. and 4 p.m. These data, representative of daylight DO conditions, do not represent the full spectrum of DO values. Specialized studies that provide continuous monitoring tend to show lower values of DO during night hours in streams with high algal biomass. Singh et al. (1995) summarized the IEPA's ambient water quality monitoring DO data from 1972–1992 at five stations on the mainstem of the Fox River. Overall concentrations did not vary significantly from station to station. Trend analysis revealed that DO had decreased slightly during the time period at the stations. Seasonal variations indicated October – December or January – March had the best DO conditions and July – September had the worst (lowest).

Terrio (1995) summarized monthly sampling data at eight fixed stations in the upper Illinois River basin (two in the Fox River basin) and from several synoptic surveys during 1987–1990. Results showed that median DO concentrations (measured during daylight hours) in the upper Illinois River basin were in the 3.4 – 12.2 mg/L range. During a low-flow synoptic sampling (measurements made prior to sunrise), all DO concentrations in the Fox River basin equaled or exceeded 5.0 mg/L. In comparison, median DO concentrations in the Fox River basin were substantially higher than those in Des Plaines and Kankakee River basins. Diurnal variation in DO concentration in the Fox River basin was the most significant of the three river basins. Adams et al. (1989) reported monitoring results for two tributaries of the Fox River during 1987–1988, which showed less variability in DO concentrations in the tributaries than in the mainstem of the Fox River reported by Terrio (1995). Table 3.5 presents a statistical summary of DO concentrations from both studies.

Singh et al. (1995) conducted continuous measurements of DO and pH in St. Charles Pool of the Fox River during 1993–1994 and reported violations of IEPA water quality standards for DO and pH as a result of the diurnal variations. Results also showed that mean DO concentrations and variability decreased as water depth increased. The time period of low DO (<5 mg/L) was longer at the bottom of the stream than near the surface. The SOD rate in the deep pool area near the dam was higher and became increasingly lower upstream near the free-flowing reach.

Table 3.5. Statistical Summary of Dissolved Oxygen Concentrations in Surface Water Samples Collected in the Fox River Basin, 1987–1990 (Terrio, 1995; Adams et al., 1989)

Station name	*Concentration (mg/L) not exceeded for indicated percentile*				
	10	*25*	*50*	*75*	*90*
Fox River					
Algonquin[1]	5.0	6.3	8.7	11.3	14.8
Dayton[1]	8.5	10.3	12.2	14.2	16.0
Blackberry Creek[2]	6.6	7.6	8.9	11.1	12.5
Ferson Creek[2]	6.7	7.8	9.0	11.0	12.5

Notes:
[1]USGS, April 1986–August 1990.
[2]ISWS, March 1987–November 1988.

Santucci and Gephard (2003) reported that the DO concentration fluctuated widely on a daily basis in impounded areas (2.5 mg/L – >20 mg/L), but not in free-flowing areas (5 mg/L – 10 mg/L). These wide fluctuations resulted in violations of the IEPA standards at nine of the 11impounded areas, but only two of the 11 free-flowing stations. Maximum pH values were at or above the upper IEPA standard at eight of the 11 impounded areas and four of the 11 free-flowing stations. Impounded areas were more susceptible to prolonged hours of low DO and high pH than free-flowing areas. Locations with significant prolonged duration, during a 24-hour period, of substandard DO level (<5 mg/L) included Algonquin (15 hours), Carpentersville (9.25 hours), Elgin (15.5 hours), North Batavia (8.25 hours), North Aurora (12.75 hours), and Stolp Island (13.5 hrs), based on continuous monitoring August 6–August 17, 2001.

3.3.3. Sedimentation/Siltation

Sedimentation embodies the processes of erosion, entrainment, transportation, deposition, and compaction of sediment (Gottschalk, 1977). Siltation is regarded as a simple change from large to small particles, or visually as a covering of original gravel and cobble substrates with silt and sand (Waters, 1995). The impact on aquatic ecosystems is turbidity, loss of benthic productivity, and loss of habitat. Anthropogenic sediments rarely act alone in their effects on the biological communities in streams. Other factors, such as loss of fish habitat, nutrient over-enrichment, and toxins, frequently accompany sedimentation and siltation. Common sources of sediment are streambank erosion, agriculture, forestry, mining, and urban development, among others. Any construction activity produces some of the greatest quantities of sediment (Waters, 1995).

In the Fox River watershed, sedimentation is a concern in the Fox Chain of Lakes and downstream reaches of the river (Bhownik and Demissie, 2002). Sullivan (2000) summarized IEPA and U.S. Geological Survey (USGS) 1978–1979 monitoring data for suspended solids (SS) for streams and rivers in the upper Illinois River basin. Monitoring sites in the Fox River watershed showed the largest variability in terms of median SS concentrations, which ranged from <10 mg/L (Poplar Creek) to >50 mg/L (Dayton) — the highest in the upper Illinois River basin. Most median SS concentrations in the Fox River fell in the 20–40 mg/L range. Seasonal variation indicated highest SS concentrations in the summer and lowest concentrations in the winter. The SS increase during the summer corresponded to higher streamflow due to increased runoff and transport of particles. Under low-flow conditions, increased phytoplankton growth in the summer months also contributes to higher SS concentrations.

Bhowmik et al. (1986) used weekly instantaneous data collected by the ISWS in 1981 and estimated sediment loads as 49,425 tons/year and 182,005 tons/year at Algonquin and Dayton, respectively. Another ISWS study estimated 5,400 tons/year in Ferson Creek near St. Charles using 1987–1988 sampling data (Adams et al., 1989). Sullivan (2000) estimated SS loads of 50,500, 46,400, and 331,000 tons/year carried by the Fox River at Algonquin, South Elgin, and Dayton, respectively. A recent USGS study estimated 29,400 tons/year of SS carried by the Fox River at Johnsburg (Schrader and Holmes, 2000). Table 3.6 lists stations and estimated sediment loads from these studies. A net deposit of sediment has been observed in the Fox River from Johnsburg to Dayton. Net deposition is deposition less scour. Santucci and

Table 3.6. Estimated Sediment loads in the Fox River watershed

Station	*Program/study*	*Data period (source)*	*SS load (tons/yr)*
Fox River			
Johnsburg	USGS (Schrader and Holmes, 2000)	1997 – 1999 (USGS)	29,400
Algonquin	NAWQA (Sullivan, 2000)	1979 – 1996 (IEPA)	50,500
	ISWS (Bhowmik et al., 1986)	1981 (ISWS)	49,425
S. Elgin	NAWQA (Sullivan, 2000)	1989 – 1996 (IEPA)	46,400
Dayton	NAWQA (Sullivan, 2000)	1978 – 1996 (IEPA)	331,000
	ISWS (Bhowmik et al., 1986)	1981 (ISWS)	182,005
Ferson Creek			
St. Charles	ISWS (Adams et al., 1989)	1987 – 1988 (ISWS)	5,400

Gephard (2003) recorded sediment depths at 544 probe locations in impounded habitat upstream of 12 Fox River dams and concluded that largest sediment deposits tended to occur downstream of islands and along impoundment margins above the dams. The main channel of several impoundments remained relatively free from sediment accumulation.

3.3.4. Major Elements and Trace Elements

Major elements are those normally present in water at concentrations greater than 1 mg/L (Hem, 1985). Some examples of major elements are aluminum, iron, and manganese. Elements normally present at concentrations less than 1 mg/L are considered as minor or trace elements. Most trace elements commonly found in surface waters are metals, such as copper, mercury, cadmium, chromium, and lead. However, these trace metals also may be present at concentrations greater than 1 mg/L as a result of various sources.

Sources of major and trace elements can be categorized as background and anthropogenic sources (Fitzpatrick et al., 1995). Background sources include runoff carrying eroded rocks and natural soils or groundwater from shallow aquifers. Extensive aquifers in the Ordovician and Silurian bedrock are known to contribute to the base flow of the Fox River in Kane County (Fitzpatrick et al., 1992). Anthropogenic sources may include PS discharges, atmospheric deposition, and surface runoff. Point discharges that originate from groundwater may contain elevated levels of some trace elements existing in bedrock and soil. In the Fox River watershed, some NPDES discharge facilities were found in violation of trace elements such as barium (USEPA, 2003c).

Toxicological effects on biota may occur due to uptake of the elements from water and sediment, or from consuming other organisms. Speciation and partitioning of the elements exert a great control on uptake processes. The elements, once in biota, can accumulate in certain tissues (bioaccumulation) and cause various toxic effects. In addition, trace elements in water and bottom material can biomaginify, or increase in concentration, at higher levels of organization in the food chain, even though they may have entered the aquatic system at subtoxic levels.

The ISWS conducted a survey of eight trace elements, (cadmium, chromium, copper, lead, lithium, nickel, strontium, and zinc) in samples collected from Illinois streams during 1966–1971 (Ackermann, 1971). Comparing the measured concentrations with USEPA freshwater quality criteria for chronic and acute effects (USEPA, 1986) indicated a few samples with concentrations in excess of the criteria at Algonquin and Batavia for the following elements: cadmium, chromium, copper, and zinc. The reporting limit of the analytical instrument used for lead was higher than its chronic criterion. Therefore, determination of exceedence for this element was not feasible.

Fitzpatrick et al. (1995) showed that metal concentrations reported in IEPA and USGS National Water-Quality Assessment (NAWQA) data collected during 1978–1986 exceeded USEPA freshwater chronic or acute criteria (Table 3.7).

Overall, total iron had the highest rate of exceeding the USEPA chronic criterion of 1 mg/L. However, the current IEPA standard of 1 mg/L is for dissolved not total iron. Occasional violations of chronic and acute criteria were found for the rest of the listed elements. In addition to the listed elements, relatively large concentrations of barium and strontium were found in stream water from the Fox River watershed compared to concentrations from other watersheds in the upper Illinois River basin. They appear to be linked with groundwater contributions and carbonate bedrock. Strontium may be leached from the carbonate particles in the Fox River watershed and be transported into the water column. Elevated barium levels were attributable to wastewater effluent originating from the Ordovician-Cambrian sandstone aquifer, where it is

Table 3.7. Element Concentrations that Exceeded USEPA Freshwater Chronic and Acute Criteria for Total Recoverable Concentrations, 1978–1986 (Fitzpatrick et al., 1995)

	Cd	*Cr*	*Cu*	*Fe*	*Pb*	*Hg*	*Ag*	*Zn*
Fox R. Channel Lake	48-1-0	97-2-1	48-5-3	61-16-na	---	86-10-1	48-5-0	48-2-2
Nippersink Cr. Spring Grove	42-2-0	65-4-2	42-3-1	65-18-na	42-1-0	---	42-6-0	---
Fox R. Burtons Bridge	37-1-0	54-2-2	---	52-5-na	---	---	37-2-0	---
Fox R. Algonquin	---	65-1-0	38-1-1	65-9-na	39-1-0	14-1-0	39-1-0	---
Poplar Cr. Elgin	---	85-5-1	---	94-31-na	55-17-0	10-6-0	22-0-2	---
Fox R. South Elgin	39-1-0	61-2-0	40-1-0	60-10-na	40-1-0	16-1-0	39-2-0	38-1-1
Fox R. Montgomery	46-2-0	90-4-3	46-3-3	61-24-na	---	86-4-0	45-2-0	45-1-1
Blackberry Cr. Yorkville	33-2-0	60-1-1	---	63-38-na	---	---	33-3-0	33-1-1
Somonauk Cr. Sheridan	38-1-0	50-1-1	---	50-12-na	---	---	38-5-0	36-2-1
Fox R. Dayton	48-3-0	95-5-2	48-4-3	94-35-na	---	93-8-0	48-2-0	47-1-1

Notes:
Format: number of observations – number of times chronic criterion exceeded – number of times acute criterion exceeded.
--- = No observation, na = no acute criterion, Cd = cadmium, Cr = chromium, Cu = copper, Fe = iron, Pb = lead, Hg = mercury, Ag = silver, and Zn = zinc.

present in a dissolved phase (Gilkeson et al., 1983). There were violations of the limit of barium concentration in NPDES discharges reported (USEPA, 2003c). However, these two elements were still within background concentrations found in rocks, soils, and surficial deposits (Fitzpartick et al., 1995).

Assessing concentrations found in tissues is difficult due to lack of complete screening criteria for tissue concentrations that cause adverse effects. However, contamination can be assessed by comparing the concentration in biota with those at other stations in the same region. During 1989–1990, the largest barium concentrations observed in biota in the upper Illinois River basin were 129 micrograms per gram (μg/g) in crayfish from Indian Creek in the Fox River watershed. Concentrations of cadmium in carp livers from the Fox River at Dayton and Big Rock Creek were elevated with respect to concentrations at other sites in the upper Illinois River basin. The largest concentration of copper in carp livers was observed in Big Rock Creek. Mercury concentrations in livers of common carp and white suckers indicated enrichment at Fox River tributaries (Blackberry Creek and Big Rock Creek), along with West and East Branches of the DuPage River and Iroquois River. Big Rock Creek was also one of the eight sites in the region with elevated selenium concentrations in carp livers. The Fox River at Dayton and Big Rock Creek had the highest zinc concentrations in carp livers. Blackberry Creek was one of the sites with elevated zinc concentrations in white suckers (Fitzpatrick et al., 1995).

Santucci and Gephard (2003) analyzed for heavy metal concentrations in sediment samples collected from impounded areas above 12 Fox River dams between Algonquin and Dayton. In general, sediment contaminant conditions were similar between core (bulk) and ponar (surface) sediment samples from impounded areas, and between impounded and free-flowing surface sediments. Core samples above Yorkville Dam had concentrations of heavy metals, particularly cadmium, mercury, and lead, that were more than double the probable effect concentration guidelines (MacDonald et al., 2000). However, the measured contaminants in ponar samples from the Yorkville impoundment were low.

3.3.5. Pathogens

Most microorganisms are beneficial and an essential part of the ecosystem. For example, microorganisms can facilitate decomposition of natural and synthetic organic compounds, serve as a food source, and play an essential role in cycling of chemical elements. However, a small subset of microorganisms is known to cause sickness or even death of animals and humans. As a group, these disease-causing microorganisms are known as pathogens. The most commonly known pathogens to cause waterborne diseases can be grouped into three general categories: bacteria, protozoans, and viruses (USEPA, 2001c). These pathogenic organisms are present in polluted waters with a wide variety of characteristics and types, and they are difficult to isolate and identify. As a result, scientists and public health officials have chosen some nonpathogenic bacteria as indicator organisms for assessing water quality. Indicator groups are normally associated with pathogens transmitted by fecal contamination and used to indicate the presence and abundance of pathogenic organisms. Large numbers of fecal coliform present in water presumably indicate a greater likelihood that pathogens are present (McMurray et al., 1998).

Types of fecal-indicator bacteria used for monitoring and regulatory purposes include several members of the coliform group: total coliforms, fecal coliform, *Escherichia coli* (*E. coli*), and streptococcal groups. Specific sources of these bacteria are wastewater treatment plant effluents; runoff from feedlots, rendering plants, and food processing facilities; and septic drainage and animal wastes. During and immediately after storms events, runoff carrying pathogens from lands can seriously deteriorate water quality in the receiving water. This has been a concern because the current water quality standards for fecal coliform were set at a constant level without addressing wet weather conditions (WEFTEC, 2002).

The IEPA's standard for fecal coliform for general-use waters is that the geometric mean of at least five samples within a 30-day period shall not exceed 200 colonies/100 milliliters (mL) during May–October, nor shall more than 10 percent of the samples during any 30-day period exceed 400 colonies/100 mL. For water supply use, the geometric mean of a minimum of five samples within a 30-day period shall not exceed 2000 colonies/100 mL. It is usually not feasible to determine compliance with the standards because most monitoring programs do not meet the requirement of at least five samples in 30 days. However, it is informative to compare results of individual samples with the standards.

Analysis of 1958–1971 IEPA data at 22 locations in the Fox River watershed showed fecal coliform counts varied widely with several orders of magnitude differences (Elmore et al., 1977), suggesting pathogen-related parameters were greatly affected by irregular sources such as surface runoff related to rain events. Singh et al. (1995) computed cumulative percent values for 1972–1992 fecal coliform data at five stations, and their results indicated better conditions (lower coliform levels) at Algonquin, near Channel Lake, Dayton, South Elgin, and Montgomery. Fecal coliform counts in individual samples at all five locations were occasionally above the IEPA's water supply standard and frequently above the general-use standards, with the exception of samples at Algonquin. Trend analysis showed almost no change near Channel Lake, some reduction at Algonquin and Dayton, and a steady reduction at South Elgin and Montgomery. Trend variations indicated higher fecal coliform counts in April–June and July–September. However, there was no consistent seasonal trend.

On a regional scale, Terrio (1995) reported funding bacteria densities larger than federal criteria and state standards in a higher percentage of samples collected at fixed stations in urban areas than those collected in agricultural areas. During 1987–1990, three of 54 samples collected at Algonquin exceeded the 200 colonies/100 mL standard and 10 of 52 samples collected at Dayton exceeded the standard. A 24-hour sampling took place in the Fox River at South Elgin downstream from a wastewater treatment plant discharge. The results showed variable *E. coli* densities in the streams, but the variability could not be related to either waste water treatment plant discharge or streamflow at the site. Significant downward trends in fecal coliform densities were found at Algonquin and Dayton during 1978–1990.

3.3.6. Pesticides/Synthetic Organic Compounds

Pesticides have provided important benefits by increasing food production and protecting humans from disease. These mostly synthetic organic compounds (SOCs) are used to control various target organisms. How a pesticide acts varies and is often highly complex, but toxicity usually takes effect by interfering with the biochemical processes of pest or target organisms (Baird, 1995). Other SOCs (e.g., PCBs) are used mainly in manufacturing. Their number approaches 60,000, with even more degradation products (Shackelford and Cline, 1986). Uses of these SOCs have become a major concern because of their potential hazard to the environment and human health.

Depending on their physicochemical properties, parent and degraded SOCs often exhibit varying toxicity and may be present in different environmental media. The impacts are greatly governed by fate and transport of the chemicals in the environment. Hazardous impacts include kill of aquatic species and wildlife, and human poisoning via pollution of surface and groundwater or air (Merrington et al., 2003).

Sources of pesticides and other SOCs fall into several general categories: point discharge of municipal and industrial wastewater, accidental spills, NPS runoff, groundwater discharges, and atmospheric deposition (Sullivan et al., 1998). As a result, distribution of SOCs in surface waters is governed by characteristics of their sources and chemical properties of the compound. Monitoring and analysis of the parent and degraded compounds can help to identify the sources and assess their impacts to the environment.

There are no existing standards for SOCs, but some national criteria have been developed as shown in Table 3.8.

Table 3.8. National Criteria for Selected Synthetic Organic Compounds in Water and Aquatic Biota

Compound	*For protection of human health*	*For protection of fish-eating birds and mammals (based on whole-fish samples)*	*For protection of human health (based on edible portions of fish)*	
	[a]USEPA primary drinking water standard: MCL (μg/L)	*[b]NAS recommended maximum tissue concentration (mg/kg)*	*[c]USFDA action level (mg/kg)*	*[d]USEPA fish tissue concentration (mg/kg)*
Alachlor	2			
Atrazine	3			
Chlordane		0.1	0.3	0.0083
p,p'-DDT		1.0	5.0	0.0316
Dieldrin		0.1	0.3	0.00067
PCBs			5.0	

Notes:
[a]USEPA (1992a).
[b]NAS (1972).
[c]U.S. FDA (1990, 1991a, 1991b, 1991c).
[d]USEPA (1992b).

As a pilot study of the NAWQA Program, Sullivan et al. (1998) investigated the distribution of pesticides and other SOCs in water, sediment, and biota in the upper Illinois River basin using data collected by various agencies during 1975–1990. Most of the compounds analyzed were in concentrations lower than detection limits of the analytical instruments used. Table 3.9 lists stations in the Fox River for which more than nine samples analyzed for SOCs had noticeable levels.

Sullivan et al. (1998) also reported that unsieved sediment samples collected from the Fox River watershed (1978 – 1988) had dieldrin levels primarily less than 1 microgram per kilogram (µg/kg) with two sites in the 1–2.4 µg/kg range. Most dichlorodiphenyltrichloroethane (DDT) concentrations fell in the 10–12.5 µg/kg range, with some in the 12.5–85.5 µg/kg range. The PCB concentrations were in the 10–30 µg/kg range, with some in the 30–205 µg/kg range. The clay/silt fraction had PCB concentrations primarily below 10 µg/kg, with one sample in the 10–11 µg/kg range. Concentrations of PCBs, DDT, and dieldrin in unsieved streambed sediments collected from Fox River basin were lower than those collected from the Chicago and Des Plaines River watersheds.

Total chlordane, total DDT, and total PCBs in fish tissues usually were detected at higher concentrations in the urban and more highly populated areas, and dieldrin usually was detected at higher concentrations away from the urban areas. The station at Burtons Bridge in the Fox River had among the highest of chlordane concentrations in whole carp fish (1978–1988). Elevated concentrations of PCBs in whole carp were found in the Fox River at Burtons Bridge and Montgomery (1978–1988). Dieldrin concentrations in whole carp were among the highest in the

Table 3.9. Statistics of Selected SOC Concentrations in Water Samples Collected from the Fox River Watershed, 1975–1990 (Sullivan et al., 1998)

Station		*Time period*	*No. of samples*	*Concentration µg/L at indicated percentile*				
				10	*25*	*50*	*75*	*90*
North Channel Lake								
	PCP[a]	1979–1988	18		< 0.01	< 0.01	0.015	
	PCP	1987–1990	10		< 0.01	< 0.01	< 0.01	
	T.P.C.[b]	1987–1990	32	2.1	2.8	3.7	5.0	6.7
Algonquin								
	T.P.C.	1987–1990	43	2.1	2.6	3.4	4.4	5.0
Montgomery								
	PCP	1979–1988	21		0.012	0.019	0.04	
	PCP	1987–1990	8		< 0.01	< 0.01	0.012	
	T.P.C.	1987–1990	32	2.4	3.0	3.6	4.5	5.0
Dayton								
	PCP	1979–1988	17		0.011	0.023	0.034	
	T.P.C.	1987–1990	48	1.7	2.3	3.2	4.4	5.0

Notes:
[a]PCP: Pentachlorophenol
[b]T.P.C.: Total Phenolic Compounds

upper Illinois River basin (1978–1988). Big Rock Creek had relatively high chlordane concentrations in whole fish samples based on 1989–1990 data. Dayton had relatively high PCB concentrations in whole fish samples.

Short and Henebry (2001) summarized results of stream surface water samples collected by IEPA between October 1985 and December 1998 and analyzed these for currently used pesticides. Atrazine, the most commonly detected herbicide, was present in 71.4 percent of the samples, followed by metolachlor (54.8%), cyanazine (49.5%), alachlor (44.4%), metribuzin (12.6%) and trifluralin (6.7%). Pesticide concentrations were generally low in the Fox River. Median concentrations of atrazine and alachlor at Algonquin were 0.05 and 0.02 μg/L, respectively, well below their corresponding drinking water standard, 3 and 2 μg/L, respectively.

Pesticides, polycyclic aromatic hydrocarbons (PAHs), and alkylphenols (endocrine disruptors) had low levels in sediment samples collected during 2000–2001 (Santucci and Gephard, 2003). All samples had undetectable levels of PCBs, which suggests low levels in sediments.

3.3.7. Emerging Water Quality Issues

A mounting pressure on the quality of water resources is continued population growth. There is a suite of chemicals used in households, pharmaceuticals, and other consumables, as well as biogenic hormones, released directly to the environment via wastewater treatment processes, overflow or leakage from storage structures, or land application (Halling-Sorensen et al., 1998). These chemicals are of concern because they were developed to have biological effects. Potential concerns include increased toxic effects, development of more harmful bacteria, and endocrine disturbances of human and animals (Jorgensen and Halling-Sorensen, 2000). The USGS conducted a nationwide study of pharmaceuticals, hormones, and other organic wastewater contaminants in 139 streams during 1999 and 2000 (Barnes et al., 2002). Nippersink Creek was the only Fox River watershed stream the study. The 30 most frequently detected compounds represent a wide variety of uses and origins, including residential, industrial, and agricultural sources. Only 5 percent of the concentrations for these compounds exceeded 1 μg/L. More than 60 percent of these higher concentrations were derived from cholesterol and three detergent metabolites (Kolpin et al., 2002).

3.4. Summary

Pollution sources in the Fox River watershed include those regulated under the NPDES program and (surface runoff, groundwater seepage, and atmospheric deposition). Municipal and industrial wastewater treatment discharges may constitute a significant portion of the river's base flow and dominate in-stream water quality at low-flow conditions. The NPS impacts are largely governed by rainfall, land uses, and land management practices. Designated uses of the Fox River are impaired due to various causes, including nutrients, organic enrichment/low DO, pathogens, SS, flow alteration, and habitat alteration. Ecosystem monitoring found that the Fox and Des Plaines River watersheds (assessed as a unit) generally scored below the statewide average for most biological indicators. Deteriorated biological integrity was found to correlate with urbanization and in-stream dam structures.

Water quality constituents were divided into seven categories to review previous studies of water quality conditions: nutrients, DO and pH, sedimentation/siltation, major and trace elements, pathogens, pesticides/synthetic organic compounds, and emerging water quality issues.

A trend analysis of 1972–1992 nutrient data at five locations on the mainstem of the Fox River indicated that nitrate/nitrite underwent no significant changes during the time period, with lowest concentrations in the warm season (July–September) and highest concentrations in the cold season (January–March). Ammonia nitrogen exhibited lowest levels during April–June and highest levels during January–March. Total phosphorus showed steady significant improvement (except at Montgomery) with lowest levels during January–March or October–December and highest levels during July–September.

On a regional scale, chemical forms and spatial distribution of nutrients are governed by land uses in the watershed. Agricultural drainage had relatively large N to P and nitrate to ammonia ratios. Urban tributaries had smaller ratios of N to P and nitrate to ammonia. The Fox River watershed has a lower ammonia level than the Des Plaines River watershed and lower nitrate concentrations than the Kankakee River watershed. Levels of P are comparable with those in the Kankakee River's watershed and lower than those in the Des Plaines River watershed. Most recent studies indicated nutrient-enriched high algal biomass in the Fox River during summer and fall seasons.

There was a decreasing DO trend during 1972–1992 based on IEPA's ambient monitoring program. Lowest DO levels were found during July–September. Tributaries of the Fox River exhibited less DO variability than the mainstem. Continuous monitoring showed a longer period of low DO in pool reaches than in free-flowing reaches, and near the river bottom rather than at the water surface. Similar diurnal variation was found in pH measurements, with high pH value corresponding to high DO concentration.

The Fox River watershed exhibited the largest variability in SS concentrations compared to neighboring watersheds in the upper Illinois River basin, within which Dayton had the highest concentration. In general, summer SS concentrations are highest in summer and lowest in winter. High concentrations in summer corresponded to runoff and algal biomass. The sediment load in the Fox River shows an increasing trend from upstream to downstream. Largest sediment deposition tended to occur downstream of islands and along impoundment margins above dams. The main channel of several impoundments remained relatively free of sediment accumulation.

Elements that exceeded USEPA freshwater chronic and acute criteria based on 1978–1986 sampling include: cadmium, chromium, copper, iron, lead, mercury, silver, and zinc. Overall, iron had the highest rate of exceeding its chronic criterion. Assessing concentrations found in biological tissues is difficult due to incomplete screening criteria for causing adverse effects. Contamination of metals was assessed by comparing concentrations in biota with those at other stations in the same region. Sediment contamination conditions due to metals were similar between core and ponar samples. Core samples above Yorkville Dam had concentrations of heavy metals, particularly cadmium, mercury, and lead, that were more than double probable effect concentration guidelines.

Fecal coliform counts varied widely with several orders of magnitude differences, suggesting pathogen-related parameters were greatly affected by irregular sources such as surface runoff related to rain events. On a regional scale, bacteria densities larger than the federal and state standards were found in higher percentages of samples collected in urban areas than agricultural lands. Continuous, 24-hour sampling at South Elgin downstream from a wastewater treatment plant discharge showed variable *E. coli* densities in streams, but the variability could not be related to either wastewater treatment plant discharge or streamflow at the site.

Concentrations of pesticides and SOCs in the Fox River watershed were lower than those in Chicago and Des Plaines River watersheds. Noticeable concentrations of PCPs and T.P.C.s were found in water samples based on 1975 – 1990 data. Total chlordane, total DDT, and total PCBs in fish tissues usually were detected at higher concentrations in the urban and more highly populated areas, and dieldrin usually was detected at higher concentrations away from the urban areas. Among the pesticides identified in sediment samples, atrazine was the most commonly detected herbicide, followed by metolachlor, cyanazine, alachlor, metribuzin, and trifluralin.

Emerging water quality issues are related to chemicals commonly used in households, pharmaceuticals, and other consumables, as well as biogenic hormones. Those chemicals are of concern because they were developed to have biological effects. Potential concerns include increased toxic effects, development of more harmful bacteria, and endocrine disturbances in humans and animals.