Monitor Cooling Towers for Environmental Compliance

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Photo courtesy of Westlake Group.

Establish an effective monitoring program by following these recommended practices.

During recent years, the use of water for cooling has come under increasing scrutiny and, as a result, cooling-water use patterns are changing and will continue to do so.

Many systems pass cooling water through the plant system only once and return it to the watershed. This creates a high water-withdrawal rate and adds heat to the receiving stream. On the other hand, cooling towers permit reusing water to such a large extent that most modern evaporative cooling systems reduce stream withdrawal rates by over 90% compared to once-through cooling. This substantially decreases the heat input to the water streams, but not to the environment, since the heat is transferred to the air.

The particulates from the drift loss, blowdown from the cooling towers, and the volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) that leak from the heat exchangers into the cooling water systems and are then emitted to the adjacent areas all need to be controlled. Especially in environmentally sensitive areas, the leakage of VOCs and HAPs into cooling water systems has caused a great concern, and regulatory agencies may require hydrocarbon leakage monitoring.

This article offers some guidance on monitoring cooling towers to ensure environmental compliance.

Inherent environmental problems

Most evaporative cooling water systems consist of cooling towers and heat exchangers. The most common environmental problem is leakage of hydrocarbons into the cooling water from aging heat exchangers, which subsequently causes high biological oxygen demand (BOD) and chemical oxygen demand (COD) levels in the blowdown. Other problems include: possible leaching of lumber treatment chemicals; particulates from the total dissolved solids (TDS) carryover in the drift loss; uncontrolled pH; high discharge temperature; and TDS and residual chlorine in the blowdown.

Hydrocarbon leakage could be due to the failure of tube sheets or the rupture of tubes caused by corrosion or poor materials of construction. Depending on its size, the leak is normally not noticed by operations and maintenance personnel and the plant continues to operate until the next planned turnaround. Should the cooling water system leak, the light hydrocarbons usually exit the cooling tower exhausts by means of air stripping, which may result in air-pollution problems (*i.e.,* VOC or HAP emissions). Heavier hydrocarbons can escape via the cooling tower blowdown and, if discharged into the public water streams, can cause water pollution problems (*i.e.,* high BOD, COD, and priority pollutant concentrations at the outfall).

In most of the refineries and plants that usually handle heavier hydrocarbons and have multiple units, the cooling tower blowdown is typically collected and treated with other wastewater streams before being discharged to the outfall. Fugitive VOC emissions sometimes are unavoidable due to an unexpected heat exchanger leak, and they may find their way out via the cooling tower exhausts. Chemical plants handling lighter chemicals are usually considered cleaner and often discharge their cooling tower blowdown directly into the outfall without treatment.

Particulates resulting from the TDS in the drift, once dried in the ambient air, will become very fine particulates (usually smaller than 10 micron). They could affect sensitive areas with impacts on the local vegetation, soil contamination, and hazards to personnel, automobiles, and plant equipment. Visible steam plumes from the cooling-tower exhaust stacks, if not controlled, may also impact visibility.

Other cooling tower problems are free oil and grease (O&G) leaked from exchangers handling hydrocarbons, which need to be skimmed off in the cooling tower basin. Sludge buildup from the suspended solids in the makeup raw water, ambient air scrubbing, algae, and piping corrosion products could be contaminated by leaking hydrocarbons and free O&G and accumulate in the bottom of the cooling tower basin and pump sump. Such contaminated oily sludge may become hazardous and must be collected and disposed of in an environmentally sound manner.

Changes in environmental rules have forced plant management and design engineers to change the old way of using treatment chemicals, engineering concepts, disposal methods, and testing and monitoring programs.

During cooling tower operation, the pH of the cooling water over time will increase due to the addition of water treatment chemicals, the increased alkalinity while operating at higher cycles, and the addition of CO_2 from air scrubbing. Therefore, in most cases, acid is added to the tower basin to reduce the pH of the blowdown to between 6 and 9, an acceptable level for discharge. Residual halogens can be a problem due to the use of the nonoxidizing and oxidizing biocides for microbial controls. Most permits have a residual halogen limit.

The temperature of the cooling tower blowdown is also an environmental concern because of its effects on aquatic life in the receiving body of water. The discharge temperature limit at the mixing zone is usually set in the wastewater permit. Therefore, most cooling water systems discharge their blowdown from the cold supply side. Water plume dispersion may be necessary to evaluate the mixing zone temperature at the cooling tower blowdown discharge.

In some countries, TDS concentration is also limited at the wastewater discharge. This may restrict the number of cooling-tower operating cycles, depending on the TDS concentration in the makeup water.

Regulations and cooling tower monitoring

Air emissions from cooling towers are regulated under several federal laws, which have resulted in regulations that may require certain monitoring, air-pollution controls, work practice standards, and permitting conditions. Some of these regulatory requirements are discussed below.

Prevention of Significant Deterioration (PSD) permits. This program applies to large new, modified, or reconstructed sources in “clean air” areas (areas that are in compliance with National Ambient Air Quality Standards [NAAQS]). It is intended to protect the air quality in these areas, while allowing some industrial growth and expansion. Affected sources must evaluate the emissions from all sources, including cooling towers. Cooling towers emit particulates and VOCs (or HAPs). If included in a PSD review, sources of these emissions would be required to install best available control technology (BACT) and to assess the impact (with air dispersion modeling) on the appropriate NAAQS. Generally, monitoring, recordkeeping, and reporting requirements are established in the PSD permit.

New Source Review (NSR) permits. This program applies to large new, modified, or reconstructed sources in nonattainment, or “dirty air,” areas (areas that are not in compliance with NAAQS) and is intended to improve the air quality. Affected sources must evaluate the emissions from all sources, including cooling towers. Sources of particulates and VOCs, if included in a NSR permit review, would have to install control equipment to achieve the lowest achievable emission rates (LAER) and to obtain offset credits for the emissions increases associated with the project. Monitoring, recordkeeping, and reporting requirements are generally established in the NSR permit.

Title V operating permits. A Title V operating permit is required for all “major” sources of air pollution. It identifies emissions limits, regulatory requirements, monitoring and recordkeeping provisions, and reporting requirements.

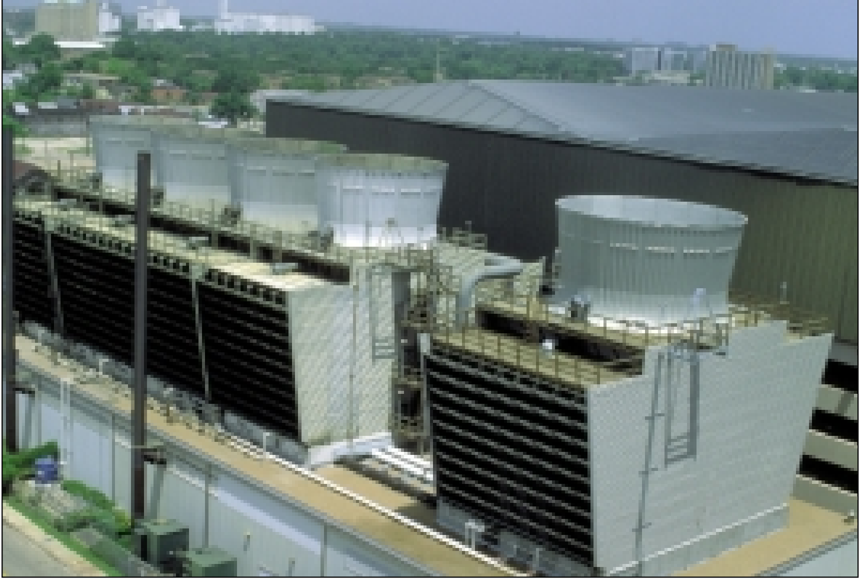

Photo courtesy of Marley Cooling Tower.

If a major source includes a cooling tower, the emissions associated with the cooling tower must be assessed and included in the Title V operating permit. Monitoring, recordkeeping, and reporting requirements are established in the Title V operating permit.

National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulations. One important NESHAP regulation is the Hazardous Organic NESHAP (HON), which requires the installation of maximum achievable control technology (MACT) at all affected organic chemical manufacturing facilities. The HON contains specific requirements for cooling towers, including monitoring, recordkeeping, and reporting provisions.

Toxic Release Inventory (TRI) reports. The TRI rules include a list of chemicals and classes of chemicals for which releases to the environment must be reported to the Environmental Protection Agency (EPA). Many of these may be present in cooling water systems. Affected facilities must monitor and assess cooling tower emissions.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) release reports. CERCLA requires a facility to immediately report any release of a hazardous substance greater than its reportable quantity to the National Response Center. The CERCLA rules include a list of chemicals and classes of chemicals that must be reported, many of which may be present in cooling water systems. Affected facilities must monitor and assess cooling tower emissions.

Enforcement provisions. The Clean Air Act Amendments of 1990 include new, enhanced enforcement provisions. These include civil penalties of up to $25,000 per day per violation and criminal penalties of up to 5 years in jail for knowingly violating a provision of the Act.

Present monitoring

Due to increasing environmental concerns and the impacts of the inherent cooling tower problems, air and water discharge permits have become more stringent. More online and *in situ* continuous monitoring and sampling systems to reduce potential hydrocarbon leakage, pH upset, excessive residual chlorine, temperature, and organic discharge may be required.

As an example, consider an air permit for a new petrochemical plant in a nonattainment area issued recently by the Texas Natural Resource Conservation Commission (TNRCC). This permit required the plant to monitor its cooling water system for benzene and total organic carbon (TOC) concentrations in the return cooling water. The operator committed in the permit application that all exchangers containing cooling water and hydrocarbons would use welded tube-sheet construction (rather than bolted flanges) to minimize possible leakage. This additional heat-exchanger design requirement thus became one of the special conditions and requirements in the approved permit.

Additionally, the operator is required to perform sampling of the cooling tower using air stripping and other testing as necessary to establish the rate (in lb/h) of VOC being emitted into the atmosphere from the cooling tower. The sample must be collected in a polyvinylfluoride (Tedlar) sample bag and analyzed by gas chromatography within 24 h of collection. The permit has set a minimum detection level for the testing system that is equivalent to 0.015 ppmw concentration in water.

The VOC concentration (in ppmv) in the exhaust from the air stripping (or equivalent) testing system and the corresponding amount of strippable VOC per gallon of cooling water must be reported. This information will be used to determine the level (either in ppmv or lb VOC/gal) at which a leak into cooling water will be assumed. The appropriate equipment must be maintained so as to minimize fugitive VOC emissions from the cooling tower. The results of the monitoring and maintenance efforts must be recorded, and these records must be kept for two years. Any leak must be repaired as soon as practical, but no more than 45 days after it is detected.

In addition, the operator has to take daily liquid samples on each cooling water return and analyze (using gas chromatography) for benzene at a 0.013 ppmw detection limit. If a benzene concentration greater than 0.013 ppmw is detected, the analyzer must be used to help determine the area from which the leak into the cooling water system occurred. A sampled benzene concentration of greater than 0.013 ppmw on five consecutive days is considered a leak.

These special hydrocarbon-leakage sampling and detection requirements are not found in any federal or state regulations. But, they can be imposed by the state authority on a case-by-case basis during the permit evaluation and approval stages, especially in ozone nonattainment areas.

As a good engineering practice and to ensure that the hydrocarbon leakage can be detected early, a plant may install an online TOC analyzer in the common cooling-water return header and provide sample connections at different return subheaders for easy leak identification. The TOC analyzer detection limit must be set based on the TOC concentration in the raw makeup water to the cooling tower. For example, if the TOC in the makeup water is 10 ppm, with 7 tower cycles operation, the maximum background TOC in the recirculating cooling water should be about 70 ppm or less for a new nonleaking cooling-water system, which must be verified during system startup. Any substantial increase in TOC concentration could be due to hydrocarbon leakage from process equipment.

In addition to a TOC analyzer, an online pH analyzer and a conductivity meter may be installed at the cooling-water return header to monitor the tower operating cycles. The pH meter is used to control acid injection into the tower not only for operation, but also to ensure that the blowdown can be discharged within the allowable pH range of 6 to 9. Also, temperature, flow rate, and residual chlorine are normally monitored at the cooling tower blowdown line before discharge to the outfall for permit reporting purposes.

The online residual chlorine analyzer can be used to control the addition of dechlorination chemicals. This will help ensure that the residual chlorine at the blowdown does not exceed the permitted limit at the outfall.

A Canadian refinery has installed an online process gas chromatograph to continuously monitor the cooling water discharge for benzene, toluene, xylene, and ethyl benzene. The ability to rapidly identify even trace amounts of hydrocarbons means that corrective actions can be taken immediately. Current state-of-the art gas chromatographs can easily detect hydrocarbons in the ppb range.

Westlake's light hydrocarbon plant currently discharges its cooling tower blowdown to the outfall. At all of the company's plants, the cooling tower blowdown is sampled four times a day for pH, chlorine residual, temperature, and conductivity. In addition, at the newest plant, the cooling tower blowdown is continuously monitored for TOC, pH, and temperature. Each individual plant's discharge and the combined outfall is sampled weekly for BOD, TSS, VOCs, and residual chlorine (Table 1).

Table 1. Typical monitoring data for cooling tower.

Weekly Analytical Data for Outfall

BOD	TSS	TOC	VOC	Residual Chlorine	pH
6.72 mg/L	5.47 mg	54.21 mg/L	ND	0.138 mg/L	7.35

Daily Analytical Data for Cooling Tower Blowdown

TOC	VOC	Residual Chlorine	pH
70 – 80 mg/L	ND	0.2–0.4 ppm	7.2–7.8

ND = Not Detectable

Current regulations

It is not feasible to assess air emissions impacts from cooling towers using standard EPA protocols. The EPA test methods analyze emissions across a traverse in a stack or duct at a minimum distance from any disturbance such as a fan. This is not possible with a cooling tower, where the air discharge to the atmosphere is generally immediately after the fan.

Monitoring of cooling tower performance to assess air emissions impacts can be accomplished in several different ways. Some monitoring may be required by a source's air operating permit, an air-pollution regulation, or the source's water discharge permit. Other monitoring may be needed to ensure compliance with other laws or regulations, which would be determined by site-specific issues and the propensity for cooling tower emissions or releases. Some of the types of monitoring that may be required for a cooling tower are outlined below.

Total dissolved solids. The TDS of the cooling water is a surrogate parameter for particulate (PM10) emissions from cooling towers. The EPA's AP-42 Emission Factor Manual *(1)* identifies emission factors for most industrial sources. For PM10 emissions from cooling towers, the emission factor is a function of the circulation rate and the TDS of the cooling water. PM10 emissions from cooling towers could be assessed based on the TDS of the cooling water.

The TNRCC has developed technical guidance for cooling tower monitoring of VOC and design of the tower to reduce drift. To reduce PM10 emissions, it is sometimes necessary to install a high performance mist eliminator to reduce drift losses to as low as 0.0005%. This increases the cost and operating horsepower of the cooling tower — a tradeoff to reduce potential future environmental impacts.

Organic loading of the cooling water. The cooling water's organic loading can be determined by various tests, including total HAPs, total VOCs, speciated HAPs, TOC, or COD. These tests will identify the total organic loading or the specific chemical loading of the cooling water. During operation of the cooling tower, many of these organic compounds will be volatilized and emitted to the atmosphere.

In the absence of any acceptable actual test data, VOC emissions from a cooling tower are calculated using the AP-42 emission factor for refinery industries of 0.7 lb/MMgal of recirculating cooling water.

Lower explosive limit (LEL) monitoring. LEL monitors can be placed in the vicinity of the cooling tower to check for episodic releases of combustible organic compounds. The LEL monitors would provide a near-real-time indication of a release from the cooling tower.

Material balance. A material balance around a facility's operation can be used as an indicator of large ongoing or episodic releases. The material balance can indicate a significant loss in the facility, which may be a result of cooling tower emissions. The material balance method can only be used for large losses due to its inherent inefficiencies.

Future possible regulations

It is likely that environmental regulations requiring the monitoring of cooling tower performance will be enhanced in the future. This will be facilitated by the development of new technology. The technologies discussed here are currently being implemented at sites in the U.S. Although not specific to cooling tower monitoring, these technologies may assist in the monitoring of cooling tower performance in the future.

Open-path monitoring. Open-path monitoring utilizing either Fourier transform infrared (FTIR) or ultraviolet (UV) technology can provide real-time ambient air monitoring along an open-air path (or fence line).

The open-path FTIR monitor transmits infrared (IR) light along the monitoring path to a retro-reflector mirror, which returns the IR beam back to the FTIR detector. Likewise, the open-path UV monitor transmits UV light along the monitoring path to a retro-reflector mirror, which returns the UV beam back to the detector. Gaseous compounds present in the beam absorb the IR or UV energy at characteristic wavelengths in amounts directly proportional to their concentrations.

These systems could serve as an indicator of the cooling tower's performance by monitoring and detecting releases and emissions to the atmosphere along a specific path or at the property line.

Multipoint species-specific monitoring of VOCs. Continuous multipoint species-specific monitoring of VOCs in ambient air can simultaneously analyze a large number of discrete sampling points (up to 64) for a complete mixture of identified VOCs. These online instruments are based on mass spectrometry and can analyze a multicomponent VOC mixture in seconds, thus enabling an almost immediate detection of a leak or release. This system could monitor and detect releases and emissions to the atmosphere from the entire complex, including areas around the cooling towers.

Concluding thoughts

The objectives of sampling and monitoring are to demonstrate regulatory compliance, to verify effluent limitations, and to aid in identification and correction of operational problems. With increasing awareness of the environmental concerns due to hydrocarbons in cooling water systems, regardless of the frequency, sampling and monitoring accuracy will need to be enhanced.

Regulatory permits require recordkeeping and reporting to document compliance. Plant operators want an easy-to-use monitoring and reporting program. The design engineers will have to provide accurate online monitoring and sampling systems using state-of-the-art instruments to notify operators when hydrocarbons are present in the cooling tower so that emissions can be minimized. Manual sampling seems simple and inexpensive, but requires extensive labor and around-the-clock preparation and recording to produce reasonably accurate and representative samples. While online monitoring seems expensive at first, in the long run it could cost less because it generally eliminates guesswork, reduces safety hazards, lowers labor costs, and produces accurate results. CEP

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