The Ohio River Oil Spill: A Case Study

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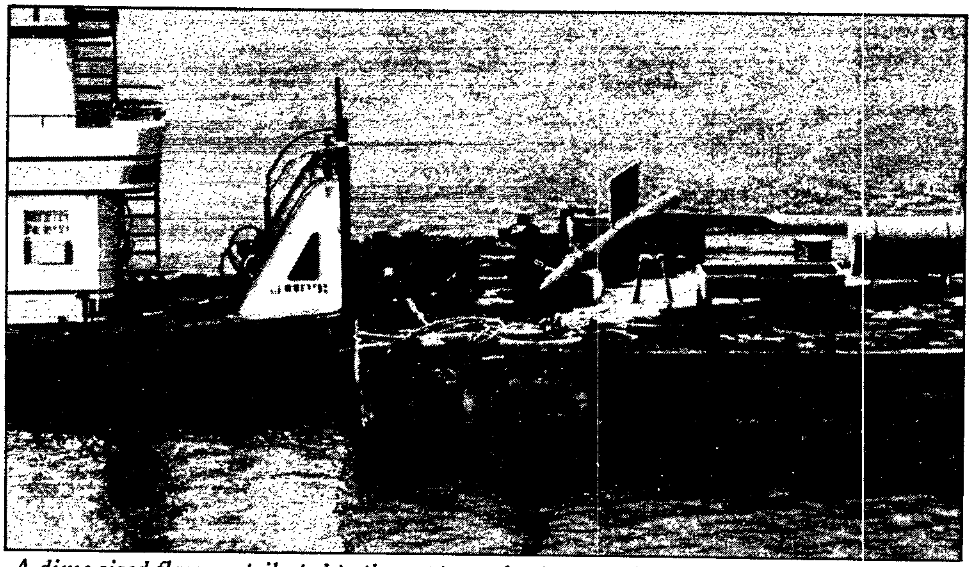

A dime-sized flaw contributed to the rupture of a 45-year-old diesel oil storage tank, releasing nearly 800,000 gal of oil into the Monongahela River.

The spill of diesel oil fuel in January 1988 raised a number of technical, legislative, and administrative issues—such as assessing long- and short-term environmental damage, evaluating regulations regarding oil tanks, and examining spill response procedures. An important research need is the development of computer models that can better predict the travel time and the concentration of contaminants should a spill occur.

Although industrial discharges from point sources are regulated by the National Pollutant Discharge Elimination System, some toxic pollutants are still detected in US surface waters. Pollutants may come from nonregulated or toxic substances allowed in low concentration in permitted discharges, accidental or deliberate spills, nonpoint sources, or stormwater runoff. Frequently, these same surface waters are major sources of drinking water. The National Organics Monitoring Survey (NOMS) conducted by the US Environmental Protection Agency (USEPA) examined 113 water systems and found 129 organic compounds—including carbon tetrachloride, benzene, trichloroethylene, vinyl chloride, styrene, and 1,2-dichloroethane—in drinking water.[1]

The Safe Drinking Water Act (SDWA) and its amendments have increased the number of maximum contaminant levels (MCLs) that drinking water utilities must meet.[2] In some cases, the target levels for MCLs are being lowered. The amendments and recent concern over toxic discharges from wastewater treatment plants have forced an increasing awareness of the impact of upstream discharges on drinking water quality. This awareness has led to a realization that drinking water utilities are highly vulnerable to upstream point and nonpoint sources of pollution. A water utility that finds one or more MCLs violated at its raw water intake may in the future seek to identify the upstream discharger and request that regulatory agencies force the discharger to install controls, rather than having the utility pay for expensive water treatment processes.[3]

A massive spill of diesel oil on the Monongahela River provided a striking example of this vulnerability. A storage tank containing more than 3.8 mil gal of diesel oil collapsed Jan. 2, 1988, near Pittsburgh, Pa. Nearly 800,000 gal of diesel fuel breached an earthen barrier surrounding the tank and entered the Monongahela River through storm sewers, 25 mi upstream from Pittsburgh. Normal procedures used to control oil spills were only partially successful, and the diesel fuel soon began to mix with the water. The spill also pushed through several locks and dams, causing the diesel oil to mix vertically in the water column. Approximately 30 percent of the spilled fuel entering the river was recovered with booms and vacuums. Figure 1 shows the Ohio River, including the Monongahela and Allegheny rivers, which meet to form the Ohio River at Pittsburgh.

As the slick moved slowly past Pittsburgh, then into the Ohio River, water plants prepared to close their water intakes. The first utilities affected were the West Penn Water Company, just downstream of Pittsburgh, and Westview Water Authority, just downstream of West Penn. By Monday, January 4, the slick was within 10 mi of the East Liverpool, Ohio, water plant at mile

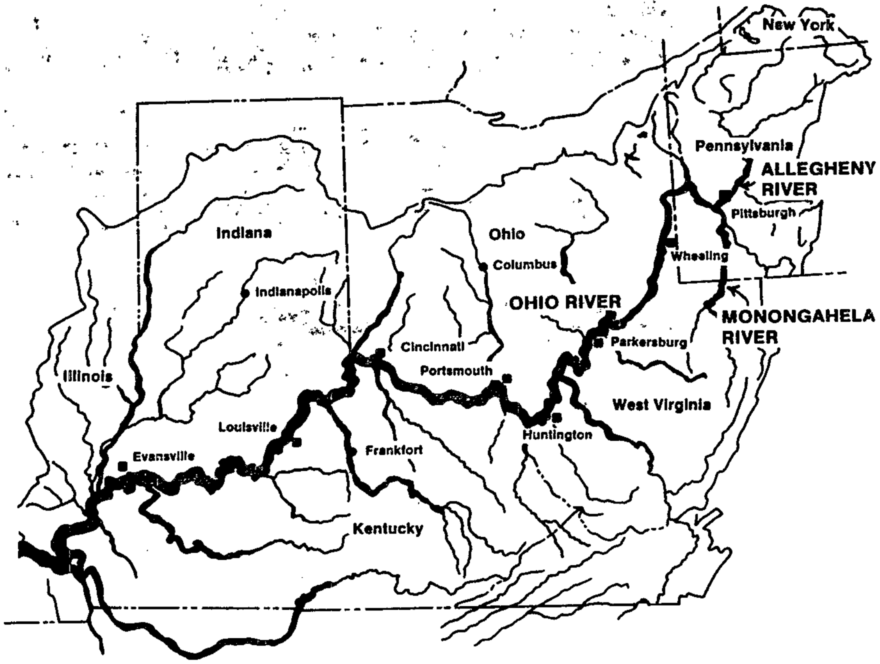

Figure 1. ORSANCO area of responsibility in the Ohio River Basin

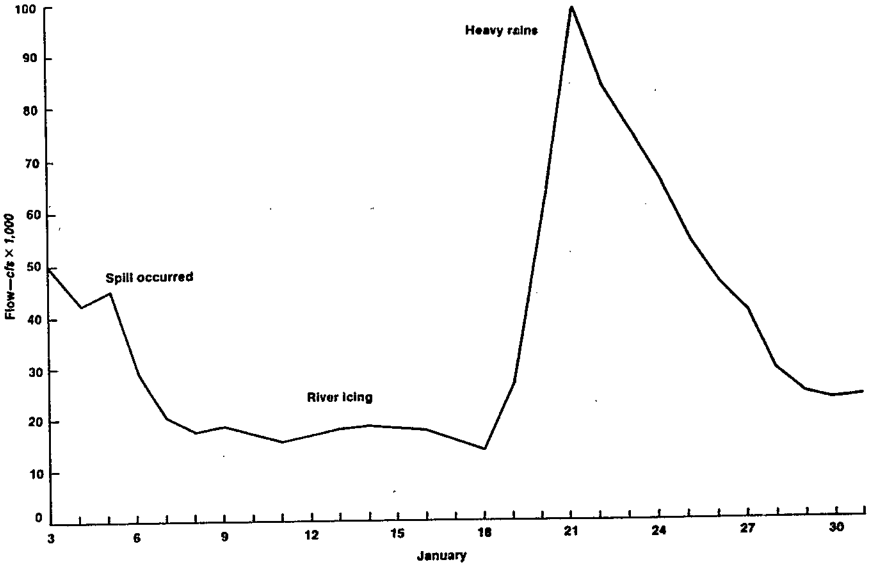

Figure 2. Daily flows at Wheeling, W. Va.

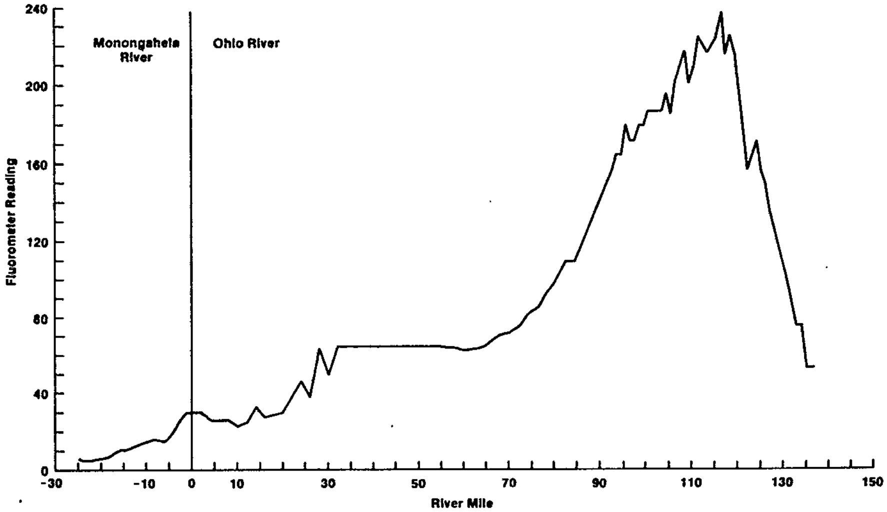

Figure 3. Oil concentration versus Ohio River mile on day 12

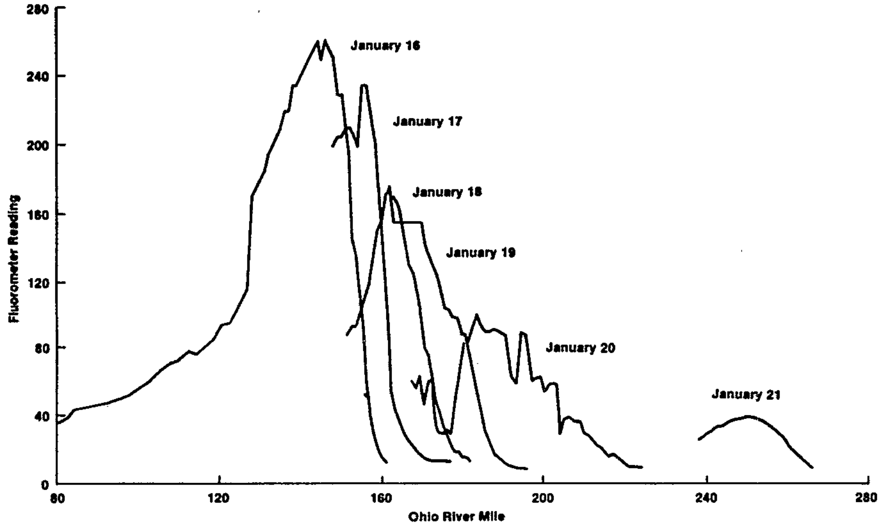

Figure 4. Travel distance and change in concentration of Ohio River spill from January 16 through January 21

TABLE 1

Municipal water intakes along the Ohio River

Location of Intake	Mile Point
West View, Pa.	4.5
Robinson Township, Pa.	8.6
Coraopolis, Pa.	10.2
Sewickley, Pa.	11.4
Moon Township, Pa.	11.7
Edgeworth, Pa.	12.8
Ambridge, Pa.	17.4
Aliquippa, Pa.	19.3
Baden, Pa.	20.1
Conway, Pa.	21.5
Freedom, Pa.	23.8
Monaca, Pa.	25.3
Beaver, Pa.	26.0
Midland, Pa.	36.3
East Liverpool, Ohio	40.2
Chester, W.Va.	42.1
Wellsville, Ohio	47.2
Toronto, Ohio	59.0
Steubenville, Ohio	65.2
Mingo Junction, Ohio	71.0
Wheeling, W.Va.	86.3
Martins Ferry, Ohio	88.6
New Martinsville, W.Va.	128.1
Sisterville, W.Va.	137.1
Gallipolis, Ohio	268.6
Huntington, W.Va.	304.2, 306.9
Ashland, Ky.	319.7
Ironton, Ohio	327.2
Greenup, Ky.	334.7, 336.2
Portsmouth, Ohio	350.8
Maysville, Ky.	408.5
Cincinnati, Ohio	462.8
Covington, Ky.	462.9
Newport, Ky.	463.5
Oldam County, Ky.	582.2
Louisville, Ky.	594.5, 600.6

TABLE 2

Comparison matrix for major water quality models

	Water Quality Model					
Parameter	TOXIWASP	WASP	EXAMS	HSPF	QUAL-II	DYNHYD-DYNQUAL
Applicable aquatic systems	Unlimited*	Unlimited*	Streams and rivers	Streams and wells, mixed	Streams and lakes	Unlimited*
Number of dimensions in aquatic system	2†	2†	1	1	1	2†
Applicable toxic pollutants	Most	Most	Most	Some	Some	Some
Kinetic representation	2nd order, process	2nd order, process	2nd order, process	1st order, gross	1st order, gross	1st order, gross
Dynamic pollutant loading	Yes	Limited	Limited	Yes	No	Yes
Integrated sediment or benthic nodules	Sediment, benthic	Benthic	Sediment, benthic	Sediment, benthic	Benthic	Benthic
Dynamic hydraulic transport	Yes	Yes	No	Yes	No	Yes
Integrated hydraulics	No‡	No‡	Yes	Yes	Yes	Yes

*Applicable for most stratified lakes and reservoirs, large rivers, estuaries, and coastal waters

†DYNID-DYNQUAL can only represent the horizontal and longitudinal dimensions; TOXIWASP and WASP can represent the longitudinal and the vertical or horizontal dimensions.

‡DYNHYD has been used for the hydraulic part of WASP and TOXIWASP.

point 30 (30 mi downstream from the origination of the Ohio River at Pittsburgh). The intake valves were temporarily shut down while samples were tested. On Tuesday, when the valves were closed, the slick was approximately 28 mi long, and oil was found as deep as 16 ft. East Liverpool had a three-day emergency water supply in reserve. By Wednesday, the valves were reopened and normal treatment was successfully initiated. Although other treatment plants along the Ohio dealt with the problem similarly, treatment varied because of the sudden changes in weather, including the river freezing and subsequent lack of movement of the water past the intakes, necessitating extended shutdown of some water intakes. By January 27 the spill had reached Louisville, Ky., 600 mi downstream, with diesel oil concentrations (based on fluorometric measurements) returning to background levels.

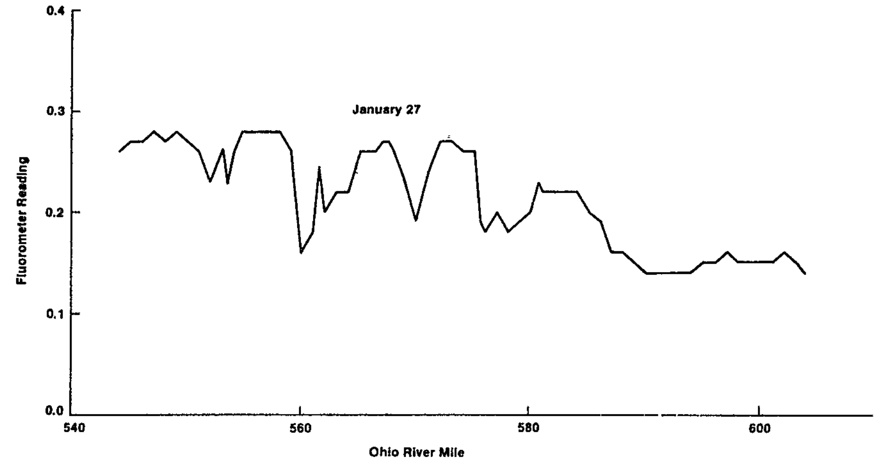

Figure 5. Travel distance and change in concentration of Ohio River spill January 27 at Louisville, Ky.

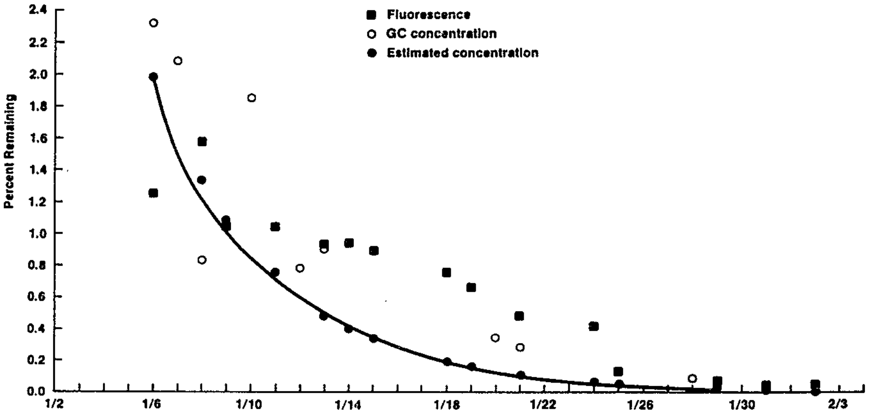

Figure 6. Estimate of reduction in peak concentration

The spill area

The Ohio River begins at the confluence of the Allegheny and Monongahela rivers just below Pittsburgh, Pa. (Figure 1). The Ohio River is nearly 1,000 mi long and flows through or borders six states. It carries the waters of a myriad of tributary streams that stretch into 13 states, and its drainage area covers more than 200,000 sq mi. Approximately 10 percent of the population of the United States lives in the Ohio River Valley, with approximately 3.5 million people depending on the Ohio River as a source of raw water supply. Table 1 lists the water intakes that are located along the river from Pittsburgh, Pa., to Louisville, Ky.

Flows in the Ohio River normally range from 35,000 to 220,000 cfs at Cincinnati. At the time of the spill, the flow in the Ohio River was 95,000 cfs. Several days after the diesel oil spill occurred, temperatures dropped into the single digits, causing freezing in the upper 100 mi of the Ohio River. River velocities were reduced to a rate of less than 0.5 mph, and river flow was reduced to 25,000 cfs. On January 19, however, the entire Ohio River Valley experienced heavy rainfall and an extended warm spell, increasing the river flows to more than 200,000 cfs and the river velocities to 3.1 mph. Figure 2 shows average daily flows at Wheeling, W. Va., during the spill period and illustrates one of the major problems in predicting the movement of the spill—the wide variation in flow rate.

Spill conditions

As stated earlier, the cause of the spill was the collapse of a 3.8-mil-gal diesel oil tank. A number of possibilities were investigated as to the cause of the tank failure. Shifting of the clay and limestone foundation was suspected as a possible cause of the tank collapse that fouled two rivers and triggered a drinking water crisis in three states. Specifications require a 3- to 4-ft-thick base of compacted clay, topped by 1 ft of crushed limestone. Before the tank was erected, the foundation was rolled and soft spots were filled and compacted. It was not known whether the stone and clay pad under the tank sank before the collapse or was eroded by escaping oil. Investigators began taking soil samples from the 120-ft-diameter foundation that supported the steel tank bottom. There was no visible settlement on the tank pad, but when the tank collapsed, the bottom ripped out and washed away a great deal of stone. Portions of the tank's foundation appeared to have sunk between 12 and 18 in.

Other possible causes of the failure were fatigue of the 45-year-old steel used for the tank, subfreezing temperatures on the day of the accident, or problems with vents in the tank.

A team of researchers ultimately discovered that a dime-sized flaw on the 45-year-old tank contributed to the rupture. A combination of factors aggravated the flaw and caused the tank to split. The tank was assembled in Cleveland in 1940 and rebuilt in 1986 at the company's terminal south of Pittsburgh. The original welds and those used during the reassembly made the tank's steel walls more brittle. Other contributing factors were the relative weakness of the World War II steel, pressure from the diesel fuel, and cold weather.

The flaw, which consisted of a small, rusting cavity about 0.125 in. deep, was caused by a torch and was in the steel before Ashland Oil personnel assembled the tank.

Institutional and monitoring conditions

Once the spill occurred, procedures for spill notification went into effect. An Ashland Oil representative notified the Pennsylvania Department of Environmental Resources, which, in turn, notified USEPA's Region III office in Philadelphia. From that point the proper procedures were followed to inform the other states, USEPA regional offices, other federal agencies, and water utilities that would potentially be involved in tracking and monitoring the spill. The Ohio River Valley Water and Sanitation Commission (ORSANCO) played a major role in coordinating the dissemination of information and emergency and remedial action.

The commission maintains an organics detection system and a spill response system. Both of these systems played a major role in monitoring and tracking of the spill.[4]

Organics detection system. The detection system consists of 13 laboratory stations operated in cooperation with 11 water utilities and 2 industries. River samples are collected daily and analyzed for 16 halogenated compounds. The identification and control of toxic substances is a high priority concern of ORSANCO.

Spill notification. An emergency response directory that provides information and telephone numbers concerning the reporting of spills to the appropriate agencies is issued twice a year. The commission also maintains an emergency response manual that details the response procedures for spills affecting the Ohio River and that lists the location of water intakes, discharges, locks and dams, and river terminals. The response manual lists specific responsibilities for each agency concerning notification, tracking the spill, monitoring water quality, treatment modification, interagency communication, and notification of the public. The manual is updated annually.

The commission keeps an electronic bulletin board for timely dissemination of spill information. River flow forecasts and information concerning spills are posted daily at ORSANCO headquarters. Water users and agency personnel can have instant access to the system by computer to learn the status of a spill. The electronic bulletin board supplements the 24-hour telephone service for receiving notification reports.

Monitoring the spill

A major problem in tracking a spill such as diesel fuel oil is measuring concentrations of the contaminant and its constituent parts. Diesel fuel is made up of a number of volatile and nonvolatile compounds, so that at any time the individual constituents and associated concentrations in the spill plume may change. For example, soon after a spill, the plume will have a much higher proportion of volatile compounds. This ratio changes the longer the plume is exposed to the atmosphere. In this case, the plume passed through three locks and dams within the first 50 mi on the upper Ohio, and the fuel oil was thoroughly mixed in the water column.

Because diesel fuel fluoresces, a fluorometer was obtained soon after the spill for most of the tracking, based on individual grab samples. The US Army Corps of Engineers later provided a flow-through fluorometer that proved to be more convenient.

Variables such as hydrologic conditions, ice, and the processes of dispersion, emulsification, microbial degradation, and volatilization made it difficult to predict the movement and fate of the spill. Figure 3 shows the fluorometer reading for Jan. 13, 1988 (day 12). As can be seen, the peak of the spill had passed Wheeling, W.Va. (mile point 87). The tail of the spill still showed measurable fluorometric readings all the way into the Monongahela.

Figure 4 shows a series of fluorometric peaks from January 16 through January 21. Several effects can be seen. The height of the peaks reduces fairly rapidly between January 16 and January 21. This is no doubt a result of several factors, including dilution as a result of increased stream flow, volatilization, and the confluence of several tributaries. Another interesting phenomenon is the rapid increase in velocity of the wave front resulting from increased stream flows. Figure 5 shows the concentration of the spill plume as it passed Louisville, Ky., and shows that the fluorescent measurements had almost returned to background levels.

There was a great deal of interest in predicting the propagation of the spill plume in the Ohio River. One approach was based on the following equation for peak concentration:[3,5]

$$\text{Peak} = 0.74 + 0.04236 \times \text{Init} \times e^{-K \times \text{TOT}} \quad (R^2 = 0.93) \tag{1}$$

in which Peak = peak concentration of contaminant (μg/L), Init = initial concentration of the spill (μg/L), K = decay rate of the contaminant (L/d), and TOT = time of travel of the contaminant to the utility in days. Equation 1 was developed from the results of extensive computer simulation runs based on an Ohio River Basin case study. The equation is intended to model concentration within a stream reach and is based on 296 runs of the model. Figure 6 shows the predicted peak concentrations of the spill as measured by fluorescence and gas chromatography.

The peak concentration may vary substantially if a large tributary enters at the beginning of a reach and is not accounted for. Equation 1 also assumes complete mixing of the contaminant in the river. To use Eq 1, spill and flow information, most of which may or may not be supplied by a regional authority, must be available to the utility manager. Although there is little empirical information regarding the fate of priority pollutants as they travel downstream, if the pollutant is known, it should be possible to know whether the pollutant is conservative, highly volatile, or subject to some other process affecting its disappearance rate. With this information the manager could perform several calculations incorporating a range of disappearance rates. In this way the utility manager would have a general idea as to when the spill will reach the utility and whether the level of concentration will require extra water treatment or closure of the intakes. Although the equation was derived from QUAL-II simulations for the Ohio River case-study area, similar analyses could be applied to other river basins.

Peak concentration is not the only measurement of interest; spill duration is important as well. A slow-moving spill, although it may be of lower peak height and lower average concentration than a more intense spill that passes quickly, may pose a major problem to a utility with limited storage capability.

Damage from the spill. At this time the ultimate damage of the spill is not known. Many water utilities were forced to alter their treatment and to close intakes as the spill passed. Many communities used bottled water as an emergency measure. Some obvious damage, such as the staining of concrete walls, occurred when the diesel oil passed through the locks and dams on the upper Ohio. One of the hardest hit water utilities was in Steubenville, Ohio. Icing conditions caused the spill to virtually halt over Steubenville's water intakes. The Ohio National Guard and two breweries delivered water to the residents. Commercial activity came to a virtual standstill.

A number of downstream water utilities have billed Ashland Oil for expenses incurred in dealing with the spill. Ohio and Pennsylvania officials estimated that 10,000 fish and 2,000 ducks were killed. Dead fish were found floating in the upper Ohio after the spill passed.

Ashland Oil Inc. has agreed to a long-term cleanup program and will reimburse the federal government $680,000 in connection with the spill, based on the terms of a proposed consent decree filed in the US District Court in Pittsburgh. The settlement requires Ashland Oil to clean up water and soil contamination. Ashland Oil will also be required to reimburse the government for its costs in carrying out emergency response work related to the initial cleanup efforts and for any future cleanup costs. Under the terms of the proposed settlement, the company is required to remove contamination from the soil or to excavate and dispose of all soil that is fouled. In addition, Ashland Oil must build and operate a system to pump and treat all contaminated groundwater to bring it up to federal drinking water standards. Ashland received about 4,000 other claims related to the spill. These claims, if all were determined to be valid, would total approximately $17 million.

Shortly after the spill, definition of the overall extent of damage to the Ohio River began according to the Natural Resource Damage Assessment (NRDA) procedure. This is a process made available by the Comprehensive Environmental Response, Compensation and Liability Act.[6] In addition, five technical committees, under the auspices of the US Department of Interior, were established to study various effects of the damage that occurred during the spill. The five workgroups were aquatic life–fish tissue residues, sediments, water users, terrestrial life, and water quality. The workgroups are no longer active because Ashland Oil has been reimbursing various states and agencies for their costs.

Institutional considerations

In general, the institutions designated to monitor and respond to the conditions of a spill worked relatively well. The state and federal governments and ORSANCO coordinated these activities during the crisis. One issue that was raised as a result of the spill is a need to develop aboveground storage tank legislation requiring inspection and certification as to tank integrity.

Research needs

The spill clearly illustrated the need to have better information regarding the time of passage versus discharge levels for various stages of Ohio River flow. Computer models should be developed that can better predict both travel time and concentration of contaminants. Improved ability to predict the arrival of a spill and to estimate the fate of a contaminant as it proceeds downstream would have immeasurable benefits for water resource managers. Spills and other emergencies require that public agencies be able to estimate the consequences quickly and use computer simulations of the events as they are unfolding. The prediction of the arrival and departure times of a spill such as the one that occurred on the Monongahela requires some type of computerized model, even if the spill is tracked en route. Modeling also can be used to estimate the fate of the spill as it travels downstream and can be used to perform postspill assessments on the regions where most of the contaminant may have entered sediments or food chains.

These computer models should be interactive. Unfortunately, many models are available and it may be difficult to select the appropriate ones. The USEPA has done some research on computer models both on the Ohio River and the lower Mississippi. Table 2 lists some of these models and their characteristics.[7]

Other needed research relates to such items as a better classification of the mixing and volatilization characteristics of the river and techniques for estimating sediment adsorption. There is a need for better damage assessment procedures, for information on treatment techniques, and for removing contaminants from source water. As illustrated by this spill, research needs to be conducted to develop emergency response plans for utilities and other involved agencies.

Summary and conclusions

A number of technical, legislative, and administrative issues were raised during the Monongahela spill. Both long- and short-term environmental damage assessments need to be made. These include quantifying damage to fish and wildlife and contamination of sediments and possibly groundwater. Correlation of fluorometric readings and gas chromatography-mass spectrometry data should also be undertaken. Legislative changes are being studied to assess the strengths and weaknesses of regulations regarding oil tanks. Spill response, coordination, and communication procedures are being reviewed by ORSANCO. Another issue identified during the spill is the need for an on-line water quality and quantity model to estimate travel times and concentrations not only for spills, but also for planning purposes in developing National Pollutant Discharge Elimination System permits. A great deal of information will have to be generated to calibrate a sophisticated model for the Ohio River. The river is difficult to model hydraulically because of numerous dams and tributaries and barge traffic. Data on volatilization, dispersion, and emulsion are also critical parameters that need clarification.

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