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INTRODUCTION

Since its beginning in 1952, the Lawrence Livermore National Laboratory (LLNL), has supported an environmental surveillance program to determine its impact, if any, on the local environment. LLNL, located in the city of Livermore which is 65 km east of San Francisco, is involved in widely varied research and development programs for the U.S. Department of Energy (DOE). The main efforts are in nuclear and nonnuclear weapons, magnetic and laser fusion energy, biomedical research, and nonnuclear energy technologies, such as geothermal power and fossil-fuel utilization. These programs and their support groups generate waste products that could have a negative impact on the environment if improperly managed.

LLNL's sanitary sewer system is a possible route for the escape of toxic materials. Liquid effluents are released to Livermore's sanitary sewer system and the effluent is treated at the Livermore Water Reclamation Plant (LWRP). The plant is a secondary-treatment operation that returns most of the water to the San Francisco Bay via a transport pipeline. The remaining portion is used for irrigating vegetation along the roadways and a local golf course.

Small samples of the effluent stream are taken at regular intervals to give us a composite sample of all the liquid effluent that leaves the LLNL. These results provide a record of the effluent by which LLNL is assured of compliance with local regulations.

The sewer-monitoring system was designed and constructed to detect toxic-material releases and to facilitate immediate response to such releases. This is necessary in preventing damage to the LWRP and regions receiving discharged effluent. If toxic materials are detected at levels that exceed predetermined LLNL alarm limits, signals are sent to a central alarm station that is manned 24 hours a day and a sample of the suspect toxic effluent is automatically collected. Since at least four hours pass before LLNL effluent reaches the treatment plant, sufficient time is available to alert emergency personnel, evaluate the situation, and, if necessary, arrange for diversion of the material to emergency holding basins at the treatment plant. The toxic waste can be treated in the basins or removed without destroying or reducing the efficiency of the treatment plant.

An automatic on-line, sewage-effluent-monitoring system has been developed that diverts a representative fraction of the total waste stream leaving the site. This portion is monitored for pH, radiation, and heavy metals as it passes through a detection assembly. The assembly consists of an industrial pH probe, two NaI radiation detectors, and an x-ray fluorescence metal detector. A microprocessor collects, reduces, and analyzes the data to determine if the levels are acceptable by established environmental limits.

MONITORING SYSTEM COMPONENTS

The on-line monitoring system consists of several components. The flow route to these components starts at a point in a manhole where all LLNL sewage-discharge lines converge. As the sewage flows through a Parshall flow-measuring flume, approximately 40 liters/minute of the sewage is pumped to an aboveground building where the detection instrumentation is located. Inside this building, the sample enters a tank housing the high- and low-energy radiation detectors, pH probe, and a sample line leading to the metal analyzer unit. After it is scanned, the sample is returned to the sewer via an outlet pipe.

RADIATION DETECTORS

Radioisotopes being used at LLNL that could be released in quantities exceeding regulatory guide levels are ^{90}Sr, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{244}Cm, and ^{3}H. All of these, with the exception of ^{90}Sr and ^{3}H, emit heavy element x-rays and low-energy gamma rays during decay. For ^{90}Sr, low-energy bremsstrahlung photons give an indication of specific activity. Cate and Hoeger (1) designed a radiation detection system with the primary detector, a 3 x 127 mm NaI crystal separated from the sample by a thin polycarbonate plastic sheet. This allows recognition of the low-energy x rays, gamma rays, and bremsstrahlung photons in the range of 10 to 100 keV. In addition, a 50 x 50 mm NaI crystal detector is mounted immediately adjacent to the sample tank to provide detection of high-energy (100-1000 keV) events. The low-energy beta particles emitted from tritium will not be detected by this system. A separate tritium detection unit is being developed.

This system gives us a minimum detectable activity in a 10-minute count time (95% confidence level) of 1.6 x 10^{-6} μCi/ml or 0.016 of the concentration guide for ^{239}Pu, and 3 x 10^{-6} μCi/ml or 0.3 of the concentration guide for Sr^{90} (17-minute count at 95% confidence level). The concentration guides are limits of continuous release for a 40-hour work week. These are found in DOE Order 5480.1 (2).

The electronics associated with the detectors includes single-channel analyzers and a Digital Equipment Corporation LSI-11 microprocessor which compares the data to preset alarm levels. The count rates are checked every minute. If the current rate is greater than the alarm levels, the count rate over the past 60 minutes is averaged. If this average exceeds the preset levels, an alarm is sent. This is a way of monitoring for low-level continuous releases.

pH MONITOR

There are many locations in LLNL where acid and basic solutions are used routinely. An accidental release of extreme pH levels could damage the LWRP. Therefore, the pH is monitored continuously by a commercial industrial pH probe housed in the tank holding the radiation detectors. Output from the probe is recorded on a seven-day circular chart and is sent to the DEC LSI-11 microprocessor to be evaluated. The average pH level is checked every minute. If the high or low level is exceeded, the pH from the previous 30 minutes is averaged. The low and high pH limits have been set taking into account pH and length of time of release.

METAL DETECTOR

The deleterious effects of excess concentrations of heavy metals on the necessary bacteria population in the sewage treatment plant prompted a search for a continuous metal-detection system that would prevent the recurrence of plant down-time caused by a metal release to the sewer. Available commercial units were not suitable for sewage analysis. Cate, Matthews and Rueppel then designed a monitoring unit capable of detecting hazardous concentrations of ions found to be most harmful to the bacteria in the treatment plant process, specifically copper, nickel, chrome and zinc (3). The system is fairly reasonable in cost, works on-line and in real time, does not require extensive pretreatment of the sample, and requires minimal maintenance.

The metal detection unit is an x-ray fluorescence analyzer (XRFA). Its design is based on the principle that elements emit characteristic x-ray lines when excited by a radiation source. These x-ray lines can be measured by energy-dispersion techniques to determine their energy, which permits species identification, while the intensity of the lines is proportional to concentration.

A portion of the sample stream that flows through the tank is routed through a grinder to reduce any solids to particles 100 microns or less in diameter. The flow is then introduced through a nozzle into a flume inclined at a 45^{0} angle. The flow spreads to a sheet 1 mm in depth before it reaches the source/detector region of the unit. A thin plastic window backed by air is positioned under the stream in this region to prevent detection of the chrome and nickel in the stainless steel flume. A ^{109}Cd source is used to excite the elements of interest if they are present in the stream, and a commercial xenon-CO_2 mixture x-ray proportional counter is the detector used. The output from the detector goes to amplifiers, then through an analog-to-digital converter interfaced to a DEC LSI-11 microprocessor.

A dual-register system for the data output allows both rapid response to a high metal concentration (500-3600 sec count) and more sensitive response to low concentrations released over a longer time frame (5000-36,000 sec accumulated count). The longer count length is used as the activity of the ^{109}Cd source decays. The data counting system also provides for advisories at concentrations that are elevated, but not at alarm levels.

Maximum permissible discharge concentrations for copper, chrome, nickel, and zinc have been established at LLNL based on studies of the effects of toxic metals on sewage treatment and the dilution factors resulting from the intermixing of LLNL's effluent with the domestic sewage from Livermore. These concentrations, as well as the short and long count time alarm limits for the elements of concern, are shown in Table 1.

GRAB SAMPLER

The identification and concentration of the toxic material is needed to evaluate an alarm situation. An automatic grab sampler extracts a sample from the waste stream as soon as the alarm is tripped. This mechanism can also be activated manually.

TABLE 1. LLNL Maximum Permissible Metal Discharge Limits and XRFA Alarm Limits

Single Metal	LLNL Limit (ppm)	XRFA alarm limit ppm)[a] Short Count	Long Count
Cr	100	107	50
Cu	10	17	10
Zn	50	50	50
Ni	10	23	10
Hg	--	16	10
As	--	10	10
Pb	--	12	4
Combined metal	100		

(a) Count times vary from 500 - 3600 second (short) and 5,000 - 36,000 second (long), depending on the source strength.

SYSTEM MONITOR

Since the operation of the whole monitoring system depends on the pumping of a continuous flow through the instrument tank, we installed a sensitive differential pressure switch on the tank. Changes in pressure drop across the system indicate changes in flow rate and will trigger an alarm. Other problems such as a count rate lower than background and power failures will also send an alarm signal to the central alarm station.

CONCLUSIONS

The on-line sewer monitoring system cannot in itself prevent the accidental discharge of toxic materials into sewers. However, by rapidly detecting releases and sounding alarms to alert emergency personnel to respond, actions can be taken to prevent damage to the environment. Because it is a real-time system, LLNL personnel can more easily locate the source of a toxic discharge and take corrective action to prevent its recurrence.

REFERENCES

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(3) Cate, Jr., J. L., M. A. Matthews and D. R. Rueppel "A Prototype On-line X-Ray Fluoresence Analyzer for Detection of Metals in Sewage", Proceedings of the 34th Industrial Waste Conf., Purdue Univ. 1979. Ann Arbor Science.