# EVALUATION OF CONTAMINATED SEDIMENT REMEDIATION THROUGH POST-REMEDIAL MONITORING

This paper reviews site characterization, remediation and post-remediation monitoring of lake sediments contaminated with pesticide and metals. The remedy included an in-situ cap composed of dredged fill. Post-remediation monitoring indicated increases in the contaminant level in fish within the lake. This cast doubts on the effectiveness of the remedial action. It shows the importance of a well organized post-remedy monitoring plan that includes:

- Cap core samples must be tested at varying depths. New contamination may deposit on the upper portion of the cap.
- Fish testing should include lipid data, be species-specific and occur at the same time of year. It is feasible that the increase in pesticide concentrations in the fish could be related to an increase in lipid content and not another source of contamination or a failure in the remedy. Lipid content varies across species, as well as seasonally and in relation to diet. Not considering lipid content can induce bias and less precision into the fish data.



800.527.9948 Fax 847.577.5566

# EVALUATION OF CONTAMINATED SEDIMENT REMEDIATION THROUGH POST-REMEDIAL MONITORING

*Mark A. Travers* (mtravers@environcorp.com) and Bruce S. Kennington, ENVIRON International Corporation, Chicago, Illinois, USA

**ABSTRACT:** This paper will review site characterization, remedial actions, and post-remediation environmental monitoring for lake sediments impacted by a variety of pesticides and metals. The lake encompasses approximately 40 acres adjacent to a disposal site that has been closed for approximately 30 years. The results of pre-remediation data collection and site characterization efforts of private and governmental parties to access contaminant distribution will be reviewed. Decisions of stakeholders relative to remediation of the contaminated sediments (capping and containment of the contaminated sediments) are presented. Post-remediation monitoring that has been conducted since completion of the remediation has indicated increases in concentrations of contaminant levels in fish. Indicating potential issues with the contaminated sediment remedy. We will show that without critical analysis an otherwise successful remedial effort could appear flawed.

## INTRODUCTION

The following presents site characterization, remedial actions, and post-remediation environmental monitoring for a site in the United States with lake sediments impacted by a variety of pesticides and metals. The lake at this site encompasses approximately 35-acres adjacent to a closed disposal area (landfill) of approximately 70-acres. The landfill was closed approximately 30 years ago after a period of operation that encompassed approximately 30 years.

A series of investigations were conducted at the site (landfill and surrounding water bodies) beginning in 1970s and continuing into the remedial design phase of investigation in the 1990s. Along with the landfill and lake, characterization activities included an adjacent river and two other water bodies (smaller lakes). During the period of investigation, the site was placed on the National Priority List (NPL).

## LOCALITY

The lake is located within the medium sized city of the south-central United States. Bordering the lake is a residential area, a river, railroad, and closed landfill. The lake was the result of a commercial sand and gravel dredging facility that operated, in part, concurrently with waste disposal in the landfill. The lake is approximately 40 acres in size with a water depth more than 30 feet.

The lake receives water from groundwater discharge, local runoff, and occasional flooding from the nearby river. Under normal conditions, the water level of the lake is at a higher elevation than the adjacent river and flows into the river. At times, significant flood events in the river will cause the river to flow into the lake.

## GEOLOGY

The lake sediment is comprised primarily of sand and gravel intermixed with finer grained silts and clays. Two aquifers used for industrial and residential drinking water are located beneath the site but do not appear to be impacted by the site. The geology underlying the site includes the following

- Alluvium
- Loess
- Fluvial deposits
- Clay with minor lenses and interbedded fine sands and lignite
- Fine Sand
- Clay formation with sands and clays

## SITE CHARACTERIZATION

Site characterization activities conducted over the years indicated the presence of pesticides and metals in the sediments and fish within the lake. Specifically, the historical characterization efforts detected the presence of pesticides in the upper portions of the sediment of the lake. Pesticides that were detected at the mid-depth of sediment samples were similar but at detected at generally lower concentrations. The primary contaminants of concern in the lake include:

- Chlordane
- Chlordene
- Heptachlor-Epoxide (Heptachlor-E)
- Endrin

As presented in a summary of site risks prepared by regulators, the concentrations of pesticides in sediment presented a significant source of pesticides to the fish. Furthermore, long term and frequent consumption of fish from the lake were considered to present an unacceptable level of human risk. However, due to the changes that can occur to the sediment in a surface water body, it was decided to defer additional sampling to the design phase of the remedy. This sampling was to be conducted concurrently with the design so as not to delay the remediation process. The sampling was intended to verify the condition of the lake sediments and to better define the areas of contamination. This further sampling and characterization was not intended to affect the selected remedy unless surface sediment contamination concentrations had decreased to within acceptable risk limits. Acceptable risk levels were defined by USEPA as direct contact with surface water (swimming) or ingestion of contaminated fish (see following table).

## ALLOWABLE CONTAMINANT LEVELS IN FISH TISSUE

| Contaminant | Allowable Contaminant Level[1] (mg/kg) |
|---|---|
| Chlorodane | $8.3 \times 10^{-3}$ |
| Chlorodene | $8.3 \times 10^{-3}$ |
| Heptachlor | $2.4 \times 10^{-3}$ |
| Heptachlor Epoxide | $2.4 \times 10^{-3}$ |
| Aldrin | $6.54 \times 10^{-4}$ |
| Dieldrin | $6.7 \times 10^{-4}$ |
| Total BHC | $2.0 \times 10^{-2}$ |
| 4,4' DDT | $3.2 \times 10^{-2}$ |
| Endrin | 3.2 |
| Arsenic | $6.2 \times 10^{-3}$ |
| Barium | 538 |
| Nickel | 215 |
| Lead | 1.5 |
| Copper | 398 |
| Zinc | 2154 |
| Vanadium | 75 |

*([1] Based on a ($1x10^{-6}$) risk level for a 70 kg adult consuming 6.5 grams of fish per day)*

Additional sampling of sediments and fish in the lake were collected during the remedy design phase to document current conditions in consideration of changes that were expected to occur to the sediment in the surface water body over time. The sampling was also conducted concurrent with the design so as to not delay the remediation process. The intent of collection of the additional data was also to better define the contaminated areas and to determine acceptable sediment concentrations based on a $1x10^{-6}$ risk for fish consumption.

A total of 142 sediment samples were collected from 48 separate locations in the lake. The samples were collected on a 200-ft grid interval using a 5-foot long, 3-inch diameter, stainless steel tube. The individual sediment samples extracted from the 5-foot long core were 10 inches long. At the time, this was the most extensive characterization of the lake sediments that had been conducted.

Review of the data indicated that elevated levels of contaminants were generally limited in the upper 2 feet of the sediments. In addition, pesticide contamination more than 2 feet below the sediment surface was minimal where detected. Furthermore, most of the contaminated sediments were located in the eastern and western thirds of the lake. The two ends of the lake that contained the highest concentration of pesticides were also the deepest parts of the lake (i.e., depths of over more than 30 feet). The shallower, middle portions of the lake were typically less than 10 feet deep.

## REMEDY

The selected remedy involved containment of the contaminated sediments in the ponds using hydraulic fill (subaqeous capping) which was to specifically include the following activities:

1. a detained bottom profile survey using sonar techniques to determine pre-fill conditions;

2. construction of access roads to the lake;

3. installation of a pipeline and discharge headers from an inactive dredge pond located north of the adjacent river to the lake;

4. installation of geotextile onto slopes and bottom surfaces of the lake which may be susceptible to scour during the hydraulic fill operation;

5. placement of dredged fill by hydraulic methods in the lake;

6. placement of dredged and stockpiled backfill onto the upper slopes that cannot be covered effectively by hydraulic methods;

7. performance of a post-construction bottom profile survey in the lake to confirm the thickness of placed fill; and

8. harvesting and restocking of fish from the lake.

The remedial program outlined above was modified slightly during the design phase. It was decided that fish harvesting would be the first step in the remedy. This activity was completed in 1995 using Roetenone. Hydraulic fill was placed in each end of the lake to a depth of 3 feet over the existing sediments. Side slopes of the lake bottom were filled to have maximum slopes of 5 horizontal to 1 vertical. As presented above, based on the results of sediment sampling conducted during the remedial design, sediments in the middle portion of the lake contained lower concentrations of pesticides. Therefore, the decision was made to utilize the sediments from the middle third of the lake (below a depth of 3 feet) to fill portions of the east and west of the lake. This significantly reduced the hauling of capping material from off-site locations and the ultimate cost of capping.

## POST REMEDIAL MONITORING

A post remedial monitoring program developed as part of the design phase of the project. The post remedial monitoring was to be initiated 2 years following completion of the remedial construction activities. The post remediation program defined in the Long-Term Monitoring and Maintenance Plan, provided for comparison of fish collected from the lake to fish collected from the adjacent river. The river was selected to

represent background conditions. The monitoring program also included for baseline chronic toxicity testing of sediments from the lake. Fish surveys were conducted in 1999 and again in 2001. In summary the methodology developed for the comparison of fish tissue data over time is outlined below.

- If no exceedance of the standards established by USEPA has been determined after initial round of monitoring, the second round of monitoring will be conducted two years later.

- If an exceedance of the standards is identified, a confirmatory sampling round or the lake will be initiated in order to determine if the exceedance can be confirmed.

- If, after two consecutive monitoring events no exceedance of the standard has been identified, the monitoring frequency may be reduced.

- If an exceedance of standard confirmed has been deemed to occur, contingency measures will be evaluated.

Fish were collected from the lake in 1992 prior to remediation. The 1992 sampling event included collection of ten fish from each of three trophic levels of the lake. Five fish were also collected from each trophic level of the river. Sediment samples were also collected from six locations in the lake for bioassay testing.

The 1999 sampling event (initial post-remediation event) included collection of four fish from each trophic level in the lake and two fish from each trophic level in the river. A comparison of the fish size from the lake and river showed that, with except of bottom feeders in the lake, fish in the background location (river) were generally of the same size as fish in the lake. The 1999 pesticide results in fish tissue were the lowest average concentrations at each trophic level with exception of the chlordane concentrations of bottom feeders in the lake and endrin in bottom feeders and forage fish in the river.

The sampling event conducted in 2001 included a total of twelve samples, four from each of the three trophic level in the lake and two samples from the bottom feeder trophic level of the river. Consistent with prior monitoring events, the concentration of contaminants in lake fish was greater than that of fish in the river. Results of the monitoring (average concentrations) conducted in 1999 and 2001 are provided below.

**Summary of Average Pesticide Concentrations in Lake Fish**
**1999 and 2001**

| Trophic Level | Pesticide | Average Concentration (mg/kg) | |
|---|---|---|---|
| | | 1999 | 2001 |
| Bottom Feeders | Chlordane | 2.2 | 7.52 |
| | Chlordene | 0.207 | 0.054 |
| | Endrin | 0.045 | 0.148 |
| | Heptachlor-E | 0.042 | 0.143 |
| Top Predators | Chlordane | 2.2 | 16.13 |
| | Chlordene | 0.058 | 0.347 |
| | Endrin | 0.03 | 0.217 |
| | Heptachlor-E | 0.031 | 0.244 |
| Foragers | Chlordane | 0.26 | 0.208 |
| | Chlordene | 0.009 | 0.0043 |
| | Endrin | 0.008 | 0.0076 |
| | Heptachlor-E | 0.008 | 0.005 |

From a review of the above data we see that the average concentration of the chlordane, endrin, and heptachlor-e in bottom feeders increased approximately 3 times between 1999 and 2001. The concentration of all four pesticides increased by approximately 5 to 7 times in top predators from 1999 to 2001. The concentrations of the four pesticides in foragers were observed to be generally consistent between 1999 and 2001.

**Summary of Average Pesticide Concentrations in River Fish**
**1992, 1999 and 2001**

| Trophic Level | Pesticide | Average Concentration (mg/kg) | | |
|---|---|---|---|---|
| | | 1992 | 1999 | 2001 |
| Bottom Feeders | Chlordane | 0.022 | 0.068 | 0.083 |
| | Chlordene | 0.005 | 0.0013 | 0.0013 |
| | Endrin | 0.0016 | 0.0027 | 0.0013 |
| | Heptachlor-E | 0.0017 | 0.0013 | 0.0013 |
| Top Predators | Chlordane | 1.56 | 0.54 | 0.40 |
| | Chlordene | 0.005 | 0.0013 | 0.0016 |
| | Endrin | 0.011 | 0.045 | 0.021 |
| | Heptachlor-E | 0.054 | 0.01 | 0.0093 |
| Foragers | Chlordane | 0.0093 | 0.0642 | 0.022 |
| | Chlordene | 0.005 | 0.0013 | 0.0013 |
| | Endrin | 0.0029 | 0.0013 | 0.0013 |
| | Heptachlor-E | 0.0032 | 0.0013 | 0.0013 |

Over all three monitoring events, the average concentration of pesticides in fish from the river was observed to generally remain consistent throughout the monitoring period.

## DISCUSSION

The concentration of pesticides (chlordane, chlordane, endrin, and heptachlor-e) increased between 1999 to 2001. In response, a variety of contingency measures are being implemented to mitigate the potential exposure to humans. These include

- installation of access controls (e.g., fencing) around the lake;
- removal of access points to the lake (e.g., boat ramp); and
- harvesting of fish in the lake.

Concurrently with the above activities, potential causes of the increase in pesticide concentrations in fish are under review. However, the data set developed subsequent to remediation limits a complete evaluation of the issue. For example, lipid data were not collected as part of the post remediation fish sampling program so the pesticides concentrations in the fish cannot be lipid adjusted. Second, the post remediation sediment sampling was limited to the concentration of pesticides in the fish and the toxicity of the sediment. It is feasible that the increase in pesticide concentrations in fish could related to an increase in lipid content not another source of sediment contamination or a failure in the remedy. Lipid content in fish typically varies across species, as well as seasonally, and in relation to diet and food quality and quantity. Not considering lipid content can introduce bias and less precision into analysis of the fish data. Therefore, measures currently being considered include collection of additional fish samples but incorporating lipid content determination. In addition, to collection of lipid data, the time of year which fish collection is conducted must be consistent across all sampling events. The species collected should also be consistent. Monitoring also needs to consider other potential sources of chlordane from adjacent properties. Chlordane is persistent and was a common and widespread agricultural and household use as a pesticide in the United States until 1988. Residual chlordane remains in the environment, especially in soil. The prescience of chlordane on adjacent properties has the potential to enter the lake.

## CONCLUSIONS

In conclusion, the method of remediation for contaminated sediments in the lake was an appropriate response to the elevated concentrations of pesticides detected. Shortcomings in the design of the monitoring program have resulted in issues that may have may have resulted in concerns in appropriateness of the remedy.

Post-remediation monitoring programs need to be properly defined to avoid issues and questions years after the remedy is complete. In sufficient post-remediation monitoring may result in unnecessary issues and questions for an otherwise appropriate remediation program.