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TRACKING POLYCHLORINATED BIPHENYLS IN THE MILLERS RIVER BASIN, MASSACHUSETTS

During the summer and fall of 1999, the U.S. Geological Survey measured polychlorinated biphenyl (PCB) concentrations in passive samplers deployed in the Millers River Basin in Massachusetts. The observed PCB concentrations and congener-pattern changes indicated a historical release of PCBs likely occurred on the Otter River at the upstream margin of Baldwinville, Massachusetts. PCB concentrations decreased significantly downstream of the confluence of the Otter River with the Millers River because of dilution of Otter River water with mostly uncontaminated water from the Millers River and volatilization of PCBs in steep reaches of the Millers River. The PCB load in the Millers River was relatively small compared with PCB loads in other PCB-contaminated rivers in the Northeast. The likely source of PCBs in the Millers River Basin is the remobilization of PCBs associated with stream sediments. PCBs deposited on the sediment likely originated from an upstream source. Estimated concentrations of PCBs in water throughout the main stems of the Millers and Otter Rivers exceeded the U.S. Environmental Protection Agency's water-quality criterion, which is based on the cancer risk associated with eating fish taken from the water. PCB concentrations detected in indicator fish (white suckers; Catostomus commersoni) sampled in 2000 were four times less than concentrations detected in the same species sampled in 1985-88.

Where Do PCBs Originate?

PCBs are a group of 209 individual compounds (called congeners) of varying toxicity. They were first synthesized in 1881. It was soon discovered that their properties of fire resistance, non-conductivity, and low volatility were useful in industrial applications. By 1929, the Monsanto Chemical Works Company was manufacturing PCBs on a large scale for use as coolants in industrial transformers and capacitors. Eventually, many home, office, and industrial items contained PCBs, including caulk, waxes, asphalts, paints, fluorescent lighting fixtures, hydraulic fluids, inks, dyes, and carbonless copy paper. In the United States, researchers often refer to PCB mixtures by their Monsanto trade name, Aroclor. Aroclors are mixtures of PCB congeners that were produced commercially and designated by numbers, such as 1016 and 1242.

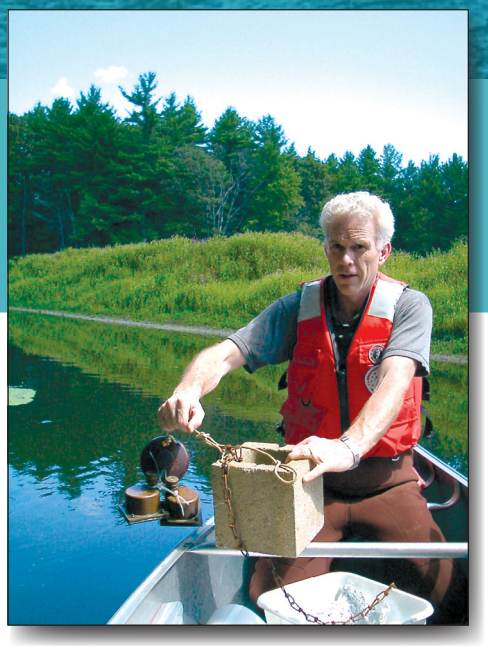
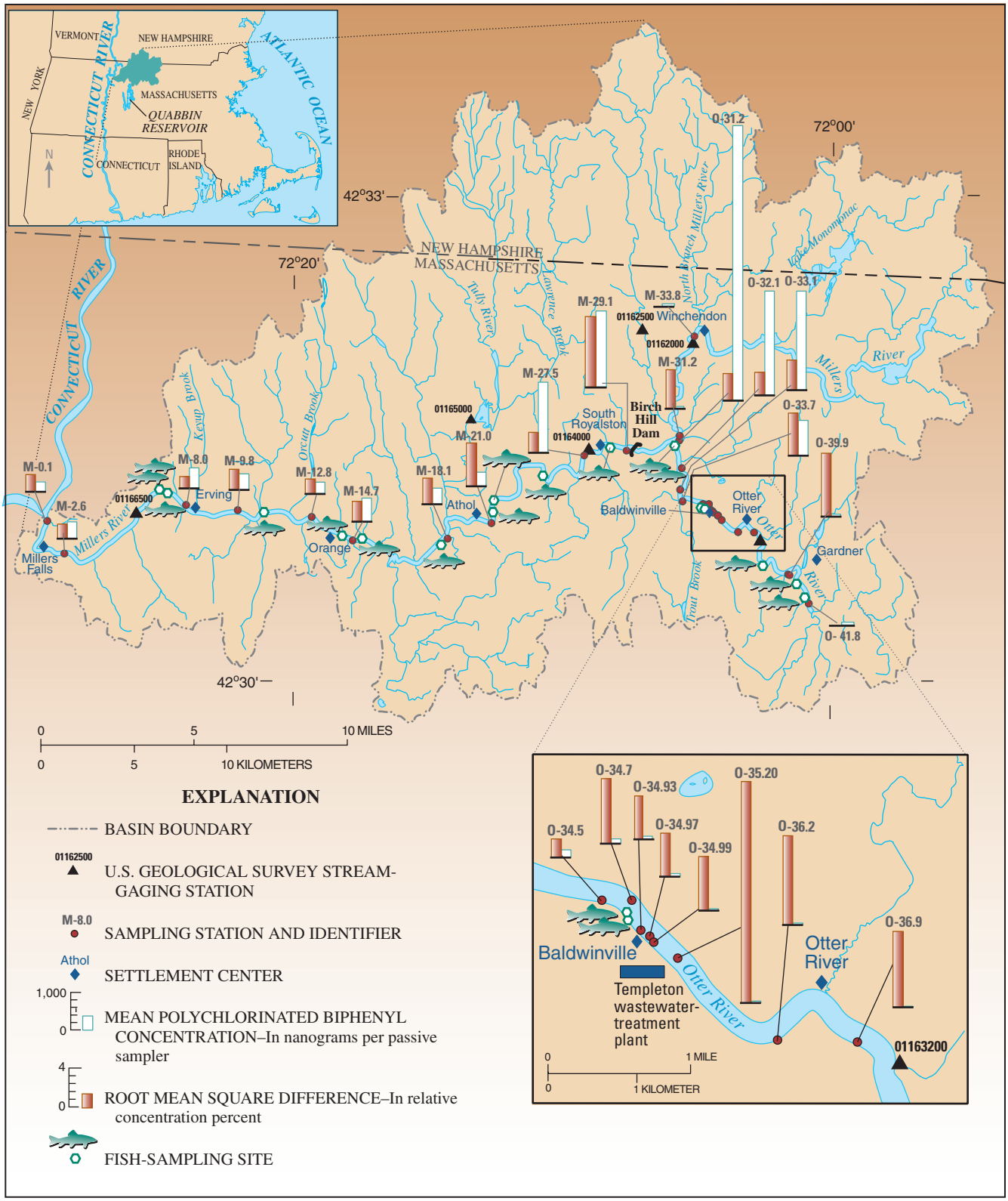


Figure 1. A U.S. Geological Survey research scientist deploys a passive water-column sampler in the Otter River, Massachusetts.

Introduction

In March 1999, the U.S. Geological Survey (USGS), in cooperation with the Massachusetts Executive Office of Environmental Affairs Millers River Watershed Team and the Massachusetts Department of Environmental Protection, began an investigation of PCBs in the Millers River and one of its tributaries, the Otter River. The purposes of the study were

- to determine the source(s) of elevated PCB concentrations observed in 85 fish-tissue samples from 12 fish species in both rivers during earlier investigations by the Massachusetts Division of Water Pollution Control and the U.S. Army Corps of Engineers (ENSR Corporation, 2000), and
- to establish the extent of fish exposure to PCBs along the main stem of the Millers and Otter Rivers in Massachusetts.



U.S. Geological Survey digital data, Universal Transverse Mercator projection, Zone 19, 1:24,000

Figure 2. Passive-sampler deployment and fish-sampling sites, mean polychlorinated biphenyl (PCB) concentrations, and change in congener patterns along the Millers and Otter Rivers, Massachusetts. PCB concentrations increased and congener patterns changed in the downstream direction beginning at river mile O-35.2. In this study, a river mile refers to the distance from the confluence of the Millers River with the Connecticut River to the sampling station, as measured along the river channel. The sampling station is named with the first letter of the river on which the station is located and the river mile. For example, the sampling station on the Otter River that is 36.2 miles from the confluence of the Millers River with the Connecticut River is named O-36.2.

This Fact Sheet discusses the results of this investigation. It also presents annual loads of PCBs passing the USGS stream-gaging station in South Royalston on the Millers River (USGS stream-gaging station 01164000) and discusses concentrations of PCBs found in fish samples. More detailed information about the study results and data-collection methods can be found in Colman (2001).

Study Design

Although PCBs generally accumulate in sediments, it is the dissolved form that enters bacteria and plants at the lowest level of the food web (Colman, 2001). In this study, passive water-column samplers were deployed in the Millers and Otter Rivers to estimate dissolved PCB concentrations in river water (fig. 1). Results from these samplers, which absorbed PCBs over a 2-week period, were obtained at 26 stations in the Millers and Otter Rivers (figs. 1 and 2), to identify the reaches most likely to be source areas leading to exposure of fish to dissolved PCBs (Colman, 2001).

The PCBs absorbed by these samplers were quantified in terms of congeners—individual PCB compounds. The congener patterns of Aroclors, mixtures of PCB congeners that were produced commercially, are the source of the congener patterns currently present in stream samples. By analyzing PCBs in terms of their congener patterns, researchers can "fingerprint" PCB sources and track the movement of PCBs in the environment. Congener patterns are unlikely to be exactly the same in samples from different sources; therefore, significant changes in these patterns, or fingerprints, within a river reach can indicate additional sources of PCBs (U.S. Environmental Protection Agency, 2002a).

Changes in PCB concentrations and PCB-congener patterns between sampling stations can be quantified and were determined by using a statistic referred to as the root-mean-square difference (RMSD). The RMSD measures the difference in normalized congener patterns between pairs of samples at a particular sampling site or between sampling sites, such as the next sampling site immediately upstream (Colman, 2001).

In addition to the passive-sampler survey, average daily loads of PCB congeners were calculated from composite river-water samples collected at a USGS stream-gaging station in South Royalston, MA (USGS stream-gaging station 01164000). In 2000, white suckers (*Catostomus commersoni*) were collected at four sites and their tissue analyzed for total PCB concentration as Aroclors. These data were compared to fish-tissue data from white suckers collected in 1985-88 (fig. 3).

PCBs in the Environment

PCB compounds are extremely persistent and break down slowly in the environment. They are less soluble in water than many other contaminants and tend to accumulate in sediments. PCBs are found in remote areas of the world, such as the Arctic, thousands of miles from any sources. This fact indicates that PCBs can be transported over great distances by water and air. They are found in almost every living organism on Earth, including humans.

In 1977, the U.S. Environmental Protection Agency (USEPA) banned the use of PCBs in the United States because of evidence demonstrating that PCBs are hazardous to human health. Between 1929 and 1977 it is estimated that about 450 million pounds of the more than 1.25 billion pounds of PCBs manufactured in the United States had found their way into the environment (ATSDR, 2003). Today, PCBs are an environmental contaminant of concern at a number of sites in Massachusetts and throughout the United States.

PCB Distribution in the Otter and Millers Rivers

Clear trends were present in the PCB distribution resulting from the passive-sampler analyses (Colman, 2001). In the Otter River, PCB concentration increased substantially in the downstream direction, beginning at river mile O-35.2, with the greatest concentration measured in the entire basin occurring between river miles O-32.1 and O-31.2 (fig. 2). The maximum change in the PCB-congener pattern, as indicated by statistical analysis of sample results, was determined to be farther upstream, between river miles O-36.2 and O-35.2. Also, a large relative increase in PCB concentrations in the Otter River coincided with the pattern change between river miles O-36.2 and O-35.2.

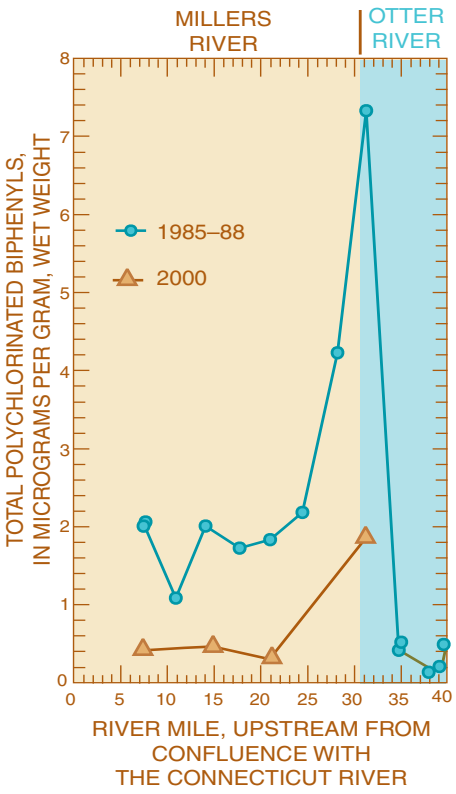


Figure 3. Polychlorinated biphenyl concentrations in fish tissue sampled from the Millers and Otter Rivers, Massachusetts. Concentrations in fish were four times less in samples collected in 2000 than in samples from previous studies.

Below the confluence of the Otter River with the Millers River, PCB concentrations decrease by a factor of four (Colman, 2001). Dilution from the relatively uncontaminated upstream Millers River most likely causes this decrease. In steeper gradient, more turbulent sections of the river (river miles M-27.5 to M-21.0 and M-8.0 to M-0.1; fig. 4), volatilization, the escape of PCBs from water into the air, may also account for the decrease in concentrations.

Possible Sources of PCBs

Commercial manufacturing of PCBs in the United States ended in 1977; therefore, measured concentrations of PCBs in the study area are not likely to be a result of active discharge. Instead, current concentrations probably come from PCBs associated with stream sediments or sediment deposited along the Millers and Otter Rivers. As PCBs discharge into a river, they attach to fine-grained sediment suspended in the water column. These particles move downstream with the flowing water and ultimately settle in reaches of the river where the gradient decreases or in slack pools. Eventually, the PCBs that accumulate in the sediment may leach from the sediment back into the water column. This process is likely responsible for the current PCB concentrations in water samples from the Millers and Otter Rivers.

Figure 4. A section of turbulent water on the Millers River, Massachusetts, at river mile M-26.5. As the river tumbles through these steep sections, dissolved PCBs can escape from the water into the air.

Immediately downstream of river mile O-33.1, the gradient of the Otter River decreases. Over the years, fine-grained sediments have settled in this reach of the river, which is characterized by riparian wetlands. Apparently, the PCBs in these sediments are now leaching back into the water, as indicated in results obtained from applying the RMSD method to PCB concentrations and changes in PCB-congener patterns at consecutive sampling stations (Colman, 2001).

If the present-day source of PCBs to the water-column source is contaminated streambed sediments, then the original source would be upstream of those sediments. The progressive increase of PCB concentrations downstream from river mile O-35.2, with the maximum pattern change between river miles O-36.2 and O-35.2, supports a hypothesized present-day PCB source that is within a downstream reach between river miles O-36.2 and O-31.2 (fig. 2). Examination of congener concentrations and congener patterns downstream of the Birch Hill Dam indicates no additional PCB sources to the Millers River, other than streambed sediments.

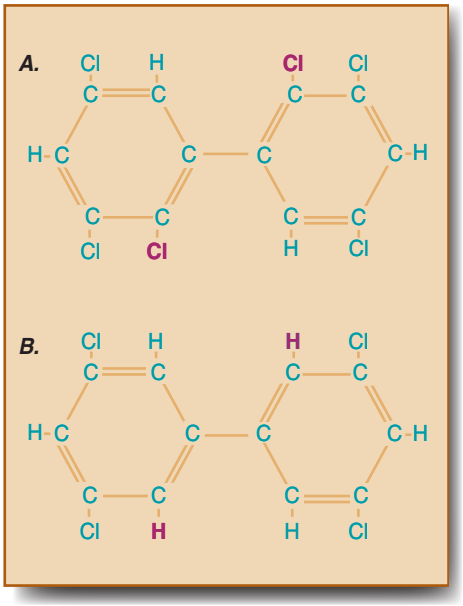
In the Otter River, a large concentration increase and the greatest congener-pattern change occur between river miles O-36.2 and O-35.2. River mile O-35.2 is upstream from pipe outfalls in the community of Baldwinville, including the wastewater-treatment plant in Baldwinville that collects and treats waste from residences and industries in the community. Although pipe outlets and the treatment plant are downstream of the station at river mile O-35.2, sludge from the plant was placed in a landfill adjacent to the river upstream of the plant and upstream from the sampling station at mile O-35.2.

Human Health Hazards of PCBs

PCBs can cause cancer and many other serious non-cancer health effects in humans by affecting the immune, reproductive, nervous, and endocrine systems (U.S. Environmental Protection Agency, 2002b). Because PCBs persist for long periods in the environment, they can build up in the body fat of animals, including fish, that eat contaminated food over many years.

People are exposed to PCBs mainly through eating fish or other seafood caught from PCB-contaminated water. High concentrations of PCBs have been found in several types of fish, shellfish, marine mammals, and waterfowl. The tissues of older animals living in contaminated areas usually have the highest concentrations. When these animals are eaten, the PCBs become even more concentrated as they move up the food chain.

People can also be exposed to PCBs in places where these chemicals were used, spilled, or discarded. They can be absorbed through skin during handling of the chemicals, contaminated soil, or other contaminated items.



Different congeners result from substitution of chlorine atoms for hydrogen atoms on different carbon atoms on the biphenyl ring structure. Examples of a (*A*) higher-weight polychlorinated biphenyl molecule and a (*B*) lower-weight polychlorinated biphenyl molecule are shown in this diagram. In this study, the percentage of lower-weight congeners increased significantly from river mile O.36.2 to O-35.2 relative to higher-weight congeners.

The PCBs detected along this river reach may also have discharged to the Otter River before the wastewater-treatment plant began operating in 1979, may have existed in plant effluent after it commenced operation, or may have seeped into the river from sludge in the landfill (Colman, 2001).

Load of PCBs in the Millers River

The PCB load is the mass of dissolved PCBs and PCBs associated with suspended particulate matter passing by a specific point over a given time interval. The PCB load determined from samples collected by the USGS on the Millers River at South Royalston, MA (USGS stream-gaging station 01164000), was about 9 pounds per year. This result, distributed between the dissolved phase and suspended particulate matter, indicates that measurable amounts of PCBs continue to be transported downstream in the Millers River. Although the load was small when compared to loads in other PCB-contaminated rivers in the Northeast, such as the Housatonic River (Gay and Frimpter, 1984), concentrations in river water from South Royalston to the confluence of the Millers River with the Connecticut River were high enough to cause concern about PCB accumulation in fish tissue.

Fish Exposure to PCBs in the Millers River

The USGS was able to estimate, as presented in Colman (2001), the amount of dissolved PCBs that might be available to fish by measuring the concentrations of PCBs collected by passive samplers. Estimated water-column concentrations varied from less than 1 ng/L (nanogram per liter), in upstream reaches of the Millers and Otter Rivers, to about 300 ng/L on the Otter River just upstream from the confluence with the Millers River. At the first station downstream of the confluence, at river mile M-29.1, the estimated concentration of dissolved PCBs decreased to about 60 ng/L. Downstream of river mile M-29.1, in the first turbulent section below the confluence, the estimated dissolved PCB concentrations were as low as about 10 ng/L and remained between roughly 10 and 20 ng/L to the confluence of the Millers River with the Connecticut River (Colman, 2001).

In 1992, the USEPA established a water-quality criterion for concentrations of PCBs in water of 0.044 ng/L on the basis of the cancer risk associated with eating fish taken from PCB-contaminated water. The USEPA subsequently reassessed the cancer risk and amended the criterion to 0.17 ng/L in December 1999 (Federal Register, 1999). Except for the upstream stations on the Millers and Otter Rivers, estimated concentrations in all reaches (more than 30 river miles) downstream from the maximum pattern change (from river mile O-36.2 to O-35.2) exceeded the USEPA's water-quality criterion.

PCB Concentrations in Fish

Although the estimated fish-exposure levels exceeded the USEPA water-quality criterion through much of the study area during this investigation, PCB concentrations in fish, as determined by a survey of white suckers, have declined since earlier investigations were conducted. Concentrations of PCBs in fish-tissue samples collected in 2000 were four times less than concentrations found in samples collected from 1985–88 (Robert Maietta, Massachusetts Department of Environmental Protection, written commun., 2001).

The decrease in PCB concentrations in fish since the earlier studies indicates that fish exposure to PCBs in the Millers River Basin is decreasing. This decrease is most likely the result of little or no additional PCBs recently entering the system and the gradual burial, degradation, and leaching of existing PCBs attached to the sediment.

Why White Suckers?

For this study, white suckers were selected because of their ubiquity throughout the Millers and Otter Rivers and because of the availability of white-sucker data from earlier studies. It is important to note that PCB concentrations in fish tissue vary by fish species and age of fish. For example, white suckers actually feed at a low trophic level on the food chain; therefore, PCB concentrations in their tissue do not represent the highest concentrations found in fish.

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For More Information

State advisories are available on concentrations of PCBs that may be harmful to people in fish and waterfowl. For more information, contact the Massachusetts Department of Public Health, Bureau of Environmental Health Assessment at (617) 624-5757 or visit their Web site at http://www.state.ma.us/dph/beha/ and type polychlorinated biphenyls or PCBs into the DPH search frame.

For more information about this or other USGS investigations in Massachusetts, contact the Northborough District office at 1-800-696-4042 or visit our Web site at http://ma.water.usgs.gov/.

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The Millers River at the USGS South Royalston stream-gaging station where the PCB load data were collected.