

Research Technical Completion Report  
Project A-056-IDA

# THE SOURCE OF AMERICAN FALLS RESERVOIR POLLUTANTS



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#### ABSTRACT

The Upper Snake River Basin contained elevated amounts of cadmium and mercury. Three sources are possible: sewage effluents from large towns in the area, run-off from irrigated lands (both cadmium and mercury are found in phosphate fertilizers), or drift from air currents carrying emissions from phosphate and cement plants.

Industrial and municipal facilities located adjacent to the lower Portneuf River near Pocatello appear to be contributing cadmium and mercury to the aquatic environment.

Chlorinated hydrocarbons detected in dangerous levels in reservoir fishes are usually associated with agricultural pesticides that have entered the water; however, low solubility in water results in undetectable levels in both the Portneuf and Snake Rivers.

## INTRODUCTION

In 1971, the Idaho Department of Health and Welfare issued a warning against the consumption of fish from American Falls Reservoir due to mercury contamination. In response an extensive study was completed on pollutant residues (metals and chlorinated hydrocarbons) in reservoir sediments, water, and fishes (Johnson, Kent, and Campbell, 1977).

Elevated levels of mercury, cadmium and chlorinated hydrocarbons were found in both the fish and the water, in excess of limits at which protection of aquatic species is recommended by the Environmental Protection Agency. Utah sucker contained the greatest concentrations of pollutants, probably the result of their exposure to concentrated contaminants in the sediment resulting from their reservoir bottom feeding habits. These sucker are consumed by game fish, birds and humans, causing concern about the "biomagnification" potential higher up the food chain.

Investigation of pollutants in American Falls Reservoir has continued. Potential sources of contaminants from the Upper Snake River drainage basin have been investigated. Water and sediment samples were collected above and below potential non-point sources of contamination, as well as from hot springs and effluent outfalls. Reservoirs serve as "sinks" which trap and accumulate material transported downstream, as well as providing a large surface area for interaction with atmospheric pollutant sources. Contributions from the air-water interface were not investigated.

Several factors may play critical roles in future American Falls Reservoir pollution questions: The 1976 pollutant contribution resulting from the Teton Dam failure; the reduction of reservoir fish populations by its draining in 1977; and the reduced utilization of chlorinated hydrocarbons in agriculture. Control of pollutants will continue to be contingent on the identification of sources.

Often it is difficult to identify the sources of pollutants to the aquatic environment. There may be a large number of sources in a given area releasing materials into the water, making it difficult if not impossible to identify the source. Run-off from agricultural land and urban streets transport various pollutants to the rivers and streams. The release of the pollutant may be intermittent; industrial discharges are of this nature. Identification of the source can only be accomplished by constant monitoring of the waterway.

Soils laden with pesticides are carried in agricultural run-off and deposited in the sediments of the aquatic system. Agricultural run-off is the major source of nutrient and silt pollution to Lake Erie (Pettyjohn, 1972). Pesticides adsorbed to soil particles enter the lake where they accumulate in the sediments. The persistence and bioaccumulation of pesticides in aquatic flora and fauna is well known. In areas with industrial activity, pollutants are often carried from the flue and deposited miles from the source (Little and Martin, 1972; Roberts et al., 1974; Van Loon and Beamish, 1977).

Run-off and precipitation provide a transport mechanism for these pollutants to the aquatic environment (Lazrus, 1970; Hallsworth and Adams, 1973; Beavington, 1977). Although many pollutants do not occur naturally, others may be of regional importance (i. e., cinnabar ore--a source of inorganic mercury). Tailings from mining operations, as well as unavoidable disasters and spills may also be a source of pollutants to the aquatic environment.

Refuse entering the water from these sources may contain a variety of organic and/or inorganic substances which may or may not be detrimental to the environment. These pollutants are not limited to the point of entry, rather they are distributed for miles along the streambed. The contaminated soils and particulate matter are carried along by the current until they settle to the bottom in slack water areas such as reservoirs. Accumulation of contaminated silt and particulate matter expose reservoir organisms to high levels of pollutants.

The present study was designed to identify regional sources of pollutants. The collection of water and sediment samples from various areas of the Upper Snake River Basin above AFR has contributed to an understanding of the degree of pollution in various regions of the basin and evaluation of their potential contribution to the pollution of AFR. The Department of Health and Welfare has in past years collected samples from the Upper Snake Basin. These analyses have dealt primarily with quantification of nitrates, phosphates, and other naturally-occurring chemicals. Some data were

developed for heavy metals; however, no chlorinated hydrocarbon analyses had been recorded. Most analyses were of water samples, with only a few sediment samples analyzed. Water samples are good indicators of the more soluble pollutants, but are not good indicators of the environmental threat of pollutants dealt with in this study.

#### MATERIALS AND METHODS

Water and sediment samples were collected from 47 stations in the Upper Snake River Basin, from October 1976 to May 1978. One sediment and one water sample were collected at each site. Collection sites were chosen on the main Snake River tributaries above American Falls Reservoir, as well as site of potential local importance (i.e., canals and effluents).

Water and sediment samples were collected by wading into slack-water areas of streams and rivers. Sediments deposited in these areas may provide a more permanent record of pollutants present in the aquatic habitat (Oliver, 1973). Water samples were obtained by submerging a one litre, polyethylene container. The sample was immediately acidified to pH 2 by addition of nitric acid (EPA, 1971, Ekedahl, 1975). Coyne and Collins (1972) found immediate acidification reduced the rate of loss of mercury in water samples. Sediment samples were collected by hand dredging and placed in pre-cleaned glass containers. An Ekman dredge was used to collect sediment samples from reservoirs. Upstream and downstream samples, on the same waterway, were collected on the same day. All samples were stored at 10 C until analyses were performed. Samples were analyzed within one week after collection, except for samples 7 to 11. These samples were stored for one month. Water samples were not filtered prior to analyses.

Sample sites are referenced by using the River Mile Index, Snake River

(Herman Ray, personal communication) and U.S.G.S. topographic maps. The index and maps are incomplete, therefore, some sample sites may not be referenced.

The samples were analyzed for mercury, cadmium, PCB's and other organochlorines (i.e., aldrin, dieldrin, DDT, DDE, endrin, lindane).

Heavy metal analyses were performed using a Varian 1200 atomic absorption spectrophotometer with a Model 63 carbon rod atomizer and the Model 64 As/Se/Hg Analysis Kit. A linear strip chart recorder was used to record the results.

The vapor generation technique was used for the determination of mercury in water and sediment samples (Parker, 1972). Cadmium in water was determined by direct application to the carbon rod. One gram sediment samples were digested with 10 ml of nitric acid and diluted to 20 ml with distilled water for determination of cadmium.

Pesticide analysis was accomplished using the Hesselberg and Johnson (1972) technique. Sulfur interferences in sediment extracts were removed by the addition of copper. Analyses utilized a Hewlett-Packard Series 7400 gas chromatograph with electron capture detector (tritium). The operating conditions were as follows:

Column:	5-ft glass, 2 mm i.d., packed with 1.5% SP-2250/1.95% SP 2401 on 100/120 Supelcon AW-DMCS
Temperature:	Column 200 C Detector 210 C Injector 220 C
Carrier Gas:	Nitrogen at a flow of 25 ml/min
Volume Injected:	Approximately 5 $\mu$ l



## RESULTS

There were no pesticides detected in any samples collected during this study. Minimum detectable levels using the technique described are presented in Table 1.

Mercury in water was detected at only three stations (#8-4, #9-2, #10-4  $\mu\text{g/l}$ ). These stations are on the lower Portneuf River (Fig 1). Water samples collected above and below these stations on the same day had no detectable levels of mercury. Sediment samples collected simultaneously at stations on the lower Portneuf River (#7 to #11) had detectable levels at stations 10 and 11 (Fig 1 and Table 2). Stations 10 and 11 are located downstream from industrial and municipal discharge.

Cadmium was not detected in any water samples, however, sediment samples contained a wide range of values. The maximum value of 1.63 mg/kg was found at station 10, the sample site where the maximum mercury concentration in the sediment was found. Cadmium concentrations in the Portneuf River sediments increased as the river approaches the reservoir and reaches a maximum at station #10 just below industrial discharge. Downstream from the outflow the concentration of cadmium in the sediment decreases. Other Snake River Basin cadmium values detected were lower than those in the Pocatello area (Table 2, Fig 1).

## DISCUSSION

Identification of the types and sources of pollutants entering the aquatic environment can best be achieved by carefully choosing sampling stations and frequency of sampling. Pollutant levels need to be evaluated in terms of whether the contaminants being monitored are derived from natural and/or man-made activities (Oliver, 1973). Natural background

Figure 1. Sampling stations for American Falls Reservoir Pollutants Project\*

- #1 Portneuf River west of Lava, Idaho - Portneuf River Mile 55.5
- #2 Chesterfield Reservoir, Chesterfield, Idaho
- #3 Blackfoot River just below dam - Blackfoot River Mile 69.0
- #4 Blackfoot Reservoir at dam - Blackfoot River Mile 69.0
- #5 Blackfoot River near Dry Valley Creek, 7 miles S.E. of Henry, Idaho
- #6 Little Blackfoot River at Henry, Idaho
- #7 Portneuf River south of Pocatello, Idaho - Portneuf River Miles 21.0
- #8 Portneuf River in Pocatello - Portneuf River Mile 16.5
- #9 Portneuf River, east of Pocatello, upstream from industrial effluent -  
Portneuf River Mile 13.5
- #10 Portneuf River east of Pocatello, downstream from industrial effluent -  
Portneuf River Mile 13.4
- #11 Portneuf River at Syphon Road - Portneuf River Mile 11.0
- #12 Tilden Bridge, Snake River - Snake River Mile 750.3
- #13 Blackfoot River, Riverton Road - Blackfoot River Mile 7.5
- #14 Snake River, Swan Valley, Idaho - Snake River Mile 888.0
- #15 Springfield Reservoir drainage into American Falls Reservoir, Danielson Creek
- #16 McTucker Creek, @ 1/4 mile east of confluence with Snake River
- #17 Snake River, Tilden Bridge - Snake River Mile 750.3
- #18 Snake River, Heise, Idaho - Snake River Mile 850.7
- #19 Willow Creek, Ririe, Idaho - Willow Creek Mile 6.9
- #20 Snake River, Idaho Falls, Idaho - Snake River Mile 795.9
- #21 Snake River, Blackfoot, Idaho - Snake River Mile 764.0
- #22 Snake River, Shelley, Idaho - Snake River Mile 787.8
- #23 Snake River, Roberts, Idaho - Snake River Mile 835.0

- #24 South Fork of Teton River, Rexburg, Idaho - Teton River Mile 5.9
- #25 North Fork of Teton River, Rexburg, Idaho - Teton River Mile 6.3
- #26 Henry's Fork of Snake River, St. Anthony, Idaho - Henry's Fork River Mile 31.9
- #27 Falls River north of Chester, Idaho - Falls River Mile 2.1
- #28 Henry's Fork of Snake River, Last Chance, Idaho - Henry's Fork River Mile 87.6
- #29 Teton River, Tetonia, Idaho - Teton River Mile 48.8
- #30 Portneuf River, Price Road, McCammon, Idaho - Portneuf River Mile 44.0
- #31 Portneuf River, West of McCammon, Idaho - Portneuf River Mile 41.5
- #32 Marsh Creek, McCammon, Idaho
- #33 Portneuf River west Inkom, Idaho - Portneuf River Mile 34.0
- #34 Portneuf River at Portneuf Gap, Idaho - Portneuf River Mile 25.5
- #35 Spring Creek, Sheepskin Road, Fort Hall Bottoms, Idaho
- #36 Clear Creek, @100 yards upstream from entrance of Gibson Drain, Fort Hall  
Bottoms, Idaho
- #37 Gibson Drain, @10 yards from confluence with Clear Creek, Fort Hall Bottoms,  
Idaho
- #38 Clear Creek, @100 yards downstream from entrance of Gibson Drain, Fort  
Hall Bottoms, Idaho
- #39 Ross Fork Creek, Cemetary Road, Fort Hall Bottoms, Idaho
- #40 Tyhee Wasteway, Syphon Road, Chubbuck, Idaho
- #41 Tyhee Wasteway, 1.6 miles N.W. of Pocatello, Idaho
- #42 Tyhee Wasteway, 2.6 miles N.W. of Pocatello, Idaho
- #43 Tyhee Wasteway, 3.6 miles N.W. of Pocatello, Idaho
- #44 Tyhee Wasteway, 4.6 miles N.W. of Pocatello, Idaho
- #45 Tyhee Wasteway, 5.6 miles N.W. of Pocatello, Idaho
- #46 Batiste Springs, enters near Portneuf River Mile 13
- #47 Municipal effluent, enters near Portneuf River Mile 13

\*River Miles are reference points for location of sample sites

FIG. 1. SAMPLING STATIONS IN UPPER SNAKE RIVER BASIN.

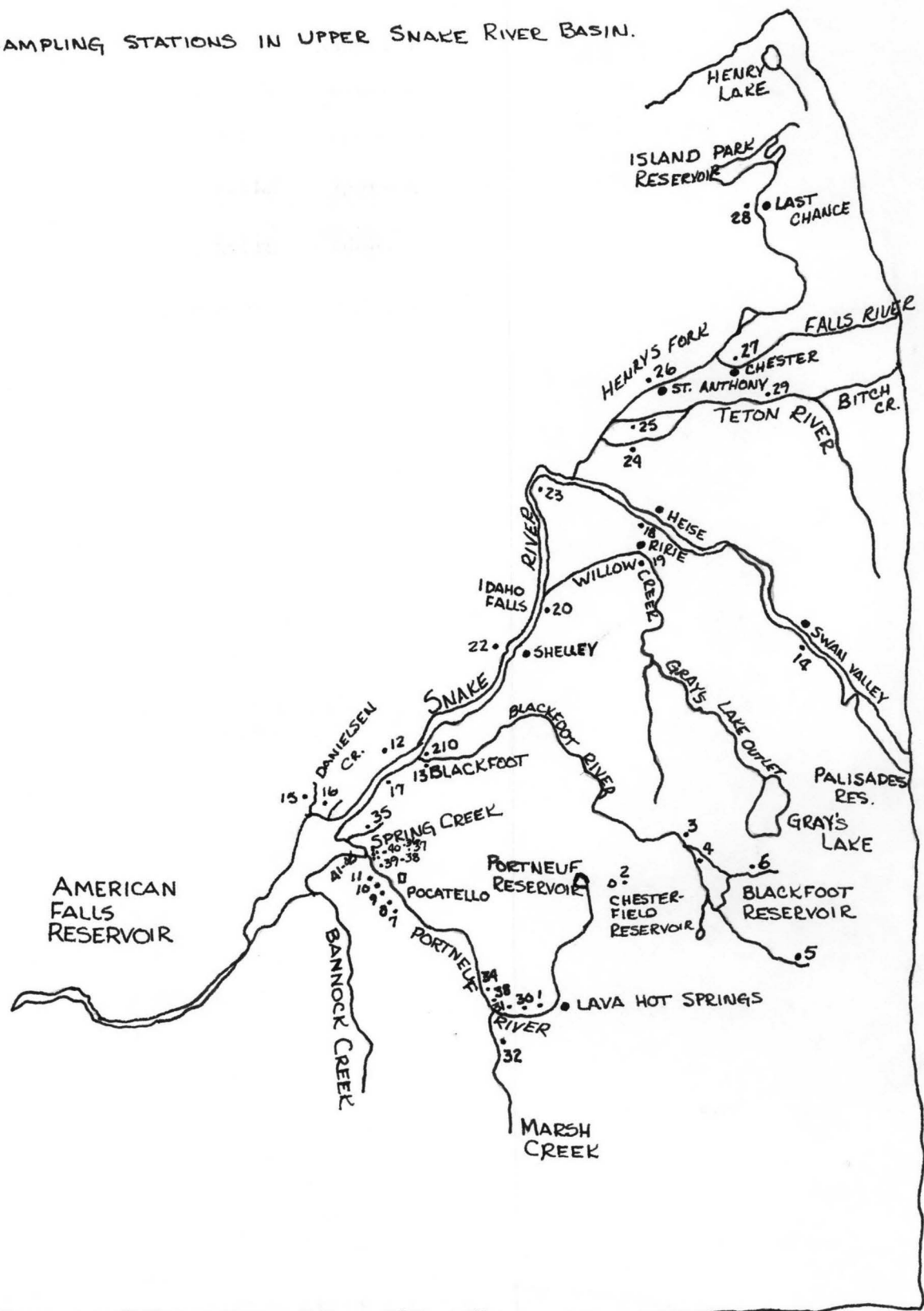


Table 1. Chlorinated hydrocarbon detection limits ( $\mu\text{g}/\text{kg}$ )

DDT	DDE	DDD	Lindane	Endrin	Dieldrin	Heptachlor	PCB's
25	5	5	2	50	2	2	2

Table 2. Mercury and cadmium in sediments from the Upper Snake River drainage (see Figure 1 for station locations).

Station Number	Hg <sup>1/</sup>	Cd	Station Number	Hg	Cd	Station Number	Hg	Cd
1	<u>2/</u>	<u>2/</u>	17		.12	33		
2			18		.05	34		.08
3			19		.11	35		.09
4			20			36		.04
5			21		.27	37		.07
6			22		.18	38		.05
7		.18	23			39		.21
8		.31	24		.18	40	.04	.58
9		.72	25		.20	41		1.05
10	.40	1.63	26		.22	42		.83
11	.20	.96	27		.04	43		1.05
12		.09	28		.23	44		.80
13		.14	29		.20	45		.40
14		.08	30			46		
15		.10	31			47		
16		.15	32		.09			

<sup>1/</sup> Concentration in mg/kg

2/ Absence of a value indicates  $< 2 \mu\text{g}/\text{kg}$  [Hg],  $< 3 \mu\text{g}/\text{kg}$  [Cd]

levels for various metals (i.e., mercury) are characterised by great variability (Aaronson, 1971).

Most rocks and soils contain mercury at concentrations of less than 100  $\mu\text{g}/\text{kg}$  (Hammond, 1971). Mercury is however found in trace amounts throughout both the lithosphere and hydrosphere (Goldwater, 1971). A U.S.G.S. 1970 survey of surface waters in the United States indicated concentrations were generally less than 0.1  $\mu\text{g}/\text{l}$  mercury (Hammond, 1971). Richins and Risser (1975) stated that the mean natural mercury content for uncontaminated water is presumed to be 0.03  $\mu\text{g}/\text{l}$  and for uncontaminated stream and river sediments 0.073  $\text{mg}/\text{kg}$ .

Mercury was found in the water and sediment of the lower Portneuf River and sediment from the Tyhee Wasteway canal. Lower Portneuf River samples (stations 8, 9, 10, 11) were located in an area of relatively concentrated population (45,000) and industrial development. Aaronson (1971) in order to illustrate the effects of industry and population centers on mercury contamination in the Saskatchewan River collected water samples above and below Edmonton. Above Edmonton water samples contained less than 0.05  $\mu\text{g}/\text{l}$ , below 0.12  $\mu\text{g}/\text{l}$ . Stations 8 and 9 located on the Portneuf River in downtown Pocatello had 4 and 2  $\mu\text{g}/\text{l}$ . A large number of potential (downtown) sources make their identification difficult, if not impossible. Station 10 with 4  $\mu\text{g}/\text{l}$  is located below the outflow of a phosphate processing facility, 3 to 4 miles west of Pocatello. Phosphate processing has mercury as one of its by-products. Sediments collected immediately below the outflow of the processing facility (station 10) contained 0.40  $\text{mg}/\text{kg}$  mercury, downstream sediments (station 11) contained 0.20  $\text{mg}/\text{kg}$  mercury. Mercury concentrations have been noted to diminish downstream from a source, although bottom sediments and

suspended particulate matter usually contain more mercury than the water itself. A number of springs enter the Portneuf River between stations 10 and 11 and may dilute water levels of mercury and flush away contaminants from station 11. The Pocatello sewage treatment facility effluent also enters the river between stations 10 and 11. Municipal sewage may contribute heavy metals to the aquatic environment (MacKenthum, 1973). Chlorine bleaches which may enter sewage plants contain 0.2  $\mu\text{g}/\text{l}$  Hg (Oliver, 1973). The mercury present at station 11 could have originated from this source as well as from the effluent of the phosphate plant and downtown sources. Analysis of the sewage effluent and springs between stations 10 and 11 revealed no detectable quantities of mercury. The Tyhee Wasteway (station 40) sediments contained 0.04 mg/kg mercury (Table 2). The Wasteway flows to Ross Fork Creek near the city of Blackfoot with irrigation water from the Blackfoot River and empties into AFR (Fig 1). The origin of mercury in the canal sediments is unknown. It is possible that some of the irrigated lands had in past years been treated with mercurial insecticides and irrigation runoff carried contaminated soil to the canal. Mercury pollution from this source has been shown to be significant in other parts of the world (Goldwater, 1971; Wood, 1972). Mercurial insecticides have been prohibited for use in Idaho for several years. The 0.04 mg/kg mercury found in the Wasteway is below the 0.07 mg/kg indicated as the background level for uncontaminated stream and river sediments (Richin and Rissen, 1975). Sediments collected from Ross Fork Creek do not contain detectable levels of mercury, suggesting that the mercury in the Wasteway is not of natural origin.

The loss of mercury from water samples has been studied by several investigators (Coyne and Collins, 1972, Rosain and Wai, 1973; Feldman, 1974;

Bothner and Robertson, 1975). Results of these investigations indicate that the concentration of mercury in water samples may either increase or decrease. Container type, pH of water sample, and duration of storage can alter the final mercury concentration in water samples. Ekedahl (1975) states that "samples may be filtered and acidified to pH 3.5 with acetic acid, this acidification reduces biological activities in the sample and minimizes precipitation and adsorption on the walls of the sample container. This preservation technique often is replaced by adding concentrated nitric acid to a pH of approximately 2." Rosain and Wai (1973) found that mercury loss was retarded when water samples were acidified with nitric acid to pH 2. Further reduction of pH 0.5 substantially reduced mercury loss. Bothner and Robertson (1975) acidified sea water samples with HCl and HNO<sub>3</sub> to pH 0.5. Mercury values increased in some samples and decreased in others. The increase may be the result of leaching from container surfaces. Several studies (Feldman, 1974; Rosain and Wai, 1973; Coyne and Collins, 1972; Bothner and Robertson, 1975) have shown that the type of container used can alter the amount of mercury lost during storage. The first three studies used a variety of containers, i.e., polyethylene, polyvinyl chloride and glass containers. The results indicate that mercury was lost regardless of container type. Rosain and Wai (1973) concluded that no container was superior. Bothner and Robertson (1975) found the concentration of mercury increased in sea water stored in polyethylene bottles and remained unchanged or slightly decreased in water stored in glass bottles. The water samples were acidified to pH of 0.5.

In general, increased storage time increases the loss of mercury from the water sample (Coynes and Collins, 1972). Bothner and Robertson (1975) found the opposite trend in water samples placed in polyethylene bottles.



Based on the information presented above, there still seems to be some question as to the proper method for storage of water samples for mercury analysis. It is possible that water samples collected from stations 8, 9, and 10 may be contaminated by leaching of surface containers as suggested by Bothner and Robertson. However, the pH of the water samples was 2 and not 0.5 as in Bothner and Robertson study. At pH 2 Rosain and Wai (1973) have concluded that mercury is lost via adsorption. If mercury is lost at pH 2 then the concentration of mercury found in water samples collected from 8, 9, and 10 would be conservative values. Loss of mercury due to absorption may have resulted in disappearance (non-detectable level) of mercury in other water samples collected. In view of this possibility, other potential sources of mercury to American Falls Reservoir may have gone unnoticed.

Persistent pesticides have been found in waters all over the world, including areas where their use is unknown (Stickel, 1973; Rosen, 1966). This illustrates an important concept, one which is not limited to pesticides alone; pollutants are carried throughout the world via water evaporation, precipitation, and wind currents (Pierson et al., 1973). Rains in Sweden have been shown to contain an average of 0.2  $\mu\text{g}/\text{l}$  mercury (Hammond, 1971). The primary source of metals in precipitation is human activity and this source contributes significantly to the overall levels of these pollutants in the aquatic environment (Lazrus et al., 1970; Bruland et al., 1974).

Pesticides have been detected in AFR (Johnson et al., 1977). Absence of pesticides in samples collected from the tributaries of the reservoir is not surprising; those reported are relatively insoluble in water and have in recent years been prohibited for agricultural use in the United States. The previous source of pesticides was probably from agriculturally contaminated soils. Laboratory and field data indicate that

pesticides are readily absorbed to particulate matter and transported to the aquatic environment (Weidhass et al., 1960; Edwards, 1973). Irrigation and spring snow melt runoff could have carried these pesticides to the tributaries and AFR where they have accumulated. Flood waters scour the stream and river beds yearly, transporting the contaminated sediments to the reservoir. Failure to detect pesticides in samples collected during this study should not be construed to mean there are none present in the rivers and streams which flow into AFR. The evidence does indicate that the pesticides in detectable amounts are not widespread in the watershed.

There is no naturally occurring cadmium in the aquatic environment. Cadmium is tightly bound with other metals and is not readily removed by leaching (Hem, 1972). Background levels of cadmium (1 µg/l) in water may occur as a by-product of refining or other industrial processes (i.e., production of phosphates) (McCaul, 1971).

Cadmium is widespread throughout the Upper Snake River Basin. The highest levels were found in Portneuf River sediments, below the effluent outfall of a phosphate processing facility (station 10, Table 2). Cadmium, like mercury, is a by-product of phosphate processing. Commercial phosphate fertilizers contain as much as 1.8 mg/kg cadmium; superphosphate fertilizers contain up to 8.9 mg/kg (McCaul, 1971). Cement processing has also been implicated in the release of cadmium into the environment (Bertine and Goldberg, 1971). A cement factory is located upstream from station 34. Samples upstream from this facility did not contain detectable levels of cadmium, while sediments at station 34 contained cadmium levels of 0.08 mg/kg.

Detection of cadmium is not confined to industrialized and developed areas of the Upper Snake River Basin. Many of the sampling stations are located in areas of sparse population with no "development." These undeveloped areas,

regions with no major cities or industrial facilities, had river sediment concentrations as high as 0.23 mg/kg. Concentrations as high as 10 µg/l and much higher have been reported in waters from undeveloped drainages (McCaul1, 1971; Durum et al, 1972). Transport of cadmium to these areas may be the result of fertilizer run-off from agricultural lands. Intensive irrigation of lands and the need for large quantities of fertilizer for the sandy soils of Southeast Idaho makes the transport of cadmium to rivers via run-off a likely explanation. Cadmium may also be transported by wind from various industrial facilities. Deposition of metals in Australia were the result of atmospheric fallout from a smelter complex (Beavington, 1977). Similar results have been reported in the U.S. (Hallswort and Adams, 1973; Roberts et al. 1974). Air pollution studies in the Pocatello area have revealed that fluorides emitted from phosphate plant stacks are carried considerable distances and plants downwind from the effluent exhibit decreasing concentration with distance. A similar pattern can be noted for cadmium (Table 2). Precipitation and dry fallout will deposit the cadmium over a wide area. The differential distribution of cadmium throughout the Upper Snake River Basin may be the result of a combination of both agricultural run-off and industrial air emissions.

#### CONCLUSIONS

This study illustrates the degree of pollution in various regions of the Upper Snake River Basin above AFR. The origin of mercury can be linked to industrial, agricultural and domestic activities located along the various streams and rivers. Mercury in water samples from stations 8 and 9 indicate that potential sources of contamination exist in the downtown area of Pocatello. Cadmium and mercury are known to be by-products of phosphate processing. Discharge of effluent from the phosphate processing

facility may contaminate receiving waters which supply AFR. Other sources may be present which contribute to the pollution of AFR. Future monitoring will show whether trends illustrated here continue to be important in the distribution of pollutants in AFR water and sediments.

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