Reprinted from the *Journal of Environmental Quality*
Vol. 3, no. 4, Oct.-Dec. 1974, Copyright © 1974, ASA, CSSA, SSSA
677 South Segoe Road, Madison, Wis. 53711 USA

Sediment in Irrigation and Drainage Waters and Sediment Inputs and Outputs for Two Large Tracts in Southern Idaho

M. J. Brown, D. L. Carter, and J. A. Bondurant

Sediment in Irrigation and Drainage Waters and Sediment Inputs and Outputs for Two Large Tracts in Southern Idaho[1]

M. J. Brown, D. L. Carter, and J. A. Bondurant[2]

ABSTRACT

Sediment inputs from Snake River irrigation water and sediment losses back to the river were measured for two large irrigated tracts in southern Idaho. There was a net sediment accumulation of 0.69 metric tons/ha onto the 65,000 ha Northside tract but a net sediment loss of 0.46 metric tons/ha from the 82,000 Twin Falls tract. Differences in sediment losses from the two tracts result from the difference in sedimentation in the drain-ways of the two projects. Sediment deposited in drains on the Northside tract amounted to 4.5 metric tons/ha compared to 0.95 metric tons/ha for the Twin Falls tract. Drains on the Northside tract were constructed to grade whereas most drains on the Twin Falls tract are natural channels with steeper gradients. The net amounts of sediment eroded from farms within each tract were 4.0 metric tons/ha for the Northside tract and 1.42 metric tons/ha for the Twin Falls tract. This erosion loss from farms could be reduced within each tract by more careful use of water and construction of on-farm sediment retention ponds. This would also reduce the amount of sediment returned to the river and lower costs of mechanically removing sediment from drains and canals. Construction of sediment retention ponds along main drains and reducing the amount of surface runoff returning to the river would also reduce the amount of sediment returning.

Additional Index Words: irrigation return flow quality, irrigation runoff.

Approximately 3.6 billion metric tons of sediment are washed into tributary streams in the USA each year, and about one-fourth of it reaches seas (8, 10). Sediment is a resource out of place and thus a waste and pollutant. It is the most important water pollutant from the standpoint of quantity. Sediment causes many problems, including adverse effects on water for domestic and industrial uses and undue wear on pumps and sprinkler nozzles. Sediment clogs screens; covers fish spawning beds, fills reservoirs, lakes, and ponds; clogs stream channels; creates turbidity; impairs water distribution; destroys aquatic habitat; and transports attached chemical substances (3, 5, 8, 9, 10).

Sediment arises from erosion, and half of it probably comes from agricultural land (10). Much of the erosion takes place during and following storms and with runoff from snowmelt. Soil erosion also arises from irrigation. In contrast to the situation under rainfall where the velocity and volume of water increase down the slope, under rill irrigation the velocity and volume decrease down the slope. Therefore, under rill irrigation extensive erosion often occurs at the top of the field with subsequent deposition toward the end (6). Therefore, extensive within-field erosion can occur without much net sediment loss from a field. Slope, stream size, and the crop are important controlling factors governing both within-field erosion and sediment loss from a field. Irrigation is assumed by many to cause extensive erosion that contributes large quantities of sediment to rivers and streams, but more information is needed to evaluate the validity of these suggestions (7).

This paper reports sediment concentrations in irrigation and surface drainage waters and sediment inputs and outputs for two large irrigation tracts in southern Idaho under existing water management practices. In addition, detailed information is presented for some subunits within these tracts.

DESCRIPTION OF STUDY AREAS

The two study areas (Fig. 1) were large irrigated tracts developed by the Twin Falls Canal Company and the Northside Canal Company. From early April to mid-November each year, water is diverted from the Snake River at Milner Dam for both tracts. Canal flows in the early spring and late fall are smaller than during the peak irrigation season of June, July, and August because of the consumptive use pattern of crops.

The Twin Falls tract comprises 82,030 ha south of the Snake River. This tract slopes generally north-northwest and the steepness varies from near level to as much as 15% over short distances in some fields. Surface and subsurface drainage returns to the Snake River that flows through a canyon approximately 165 m deep. The tract has four major natural surface drains; Rock Creek, Cedar Draw, Mud Creek, and Deep Creek (Fig. 1); and 14 smaller surface drains. Artificial subsurface drainage is present on parts of this tract. A detailed discussion of the drainage and water, salt, and nutrient balances have been presented previously (1, 2).

Soils over most of the Twin Falls tract are moderately deep, uniformly textured, silt loams derived from calcareous, wind deposited material, varying from a few cm to 15 m deep. These soils are well-drained, but extensive areas contain a lime and silica cemented hardpan (Caliche) that begins between 30 and 45 cm below the surface and varies in thickness from 20 to 40 cm. These highly productive soils are underlain by fractured basalt to depths of several hundred meters. Water infiltration rates average about 0.5 cm/hour for a 24-hour irrigation, and most crops are irrigated in furrows.

The Northside tract is north across the Snake River Canyon from the Twin Falls tract. Water is delivered to 65,350 ha, but there are numerous areas of nonirrigated rough land with exposed basalt outcroppings throughout the tract. Also, several areas in the tract are sprinkler irrigated from a ground water supply, the Snake Plain Aquifer, but no surface runoff occurs from these areas. Drainage from this tract is mostly to the southwest or west into the Snake River Canyon. Surface runoff is carried by 6 surface drains, K, N-32, J-8, S, W-26, and W (Fig. 1), and no artificial subsurface drainage is required.

Some of the soils on the Northside tract are the same as described for the Twin Falls tract, but at least half of the area is comprised of shallower, coarser textured soils.

[1]Contribution from the ARS, USDA, Western Region; Idaho Agr. Exp. Sta. cooperating. Received 9 Oct. 1973.

[2]Soil Scientists and Agricultural Engineer, respectively. Snake River Conservation Research Center, Kimberly, Idaho 83341.

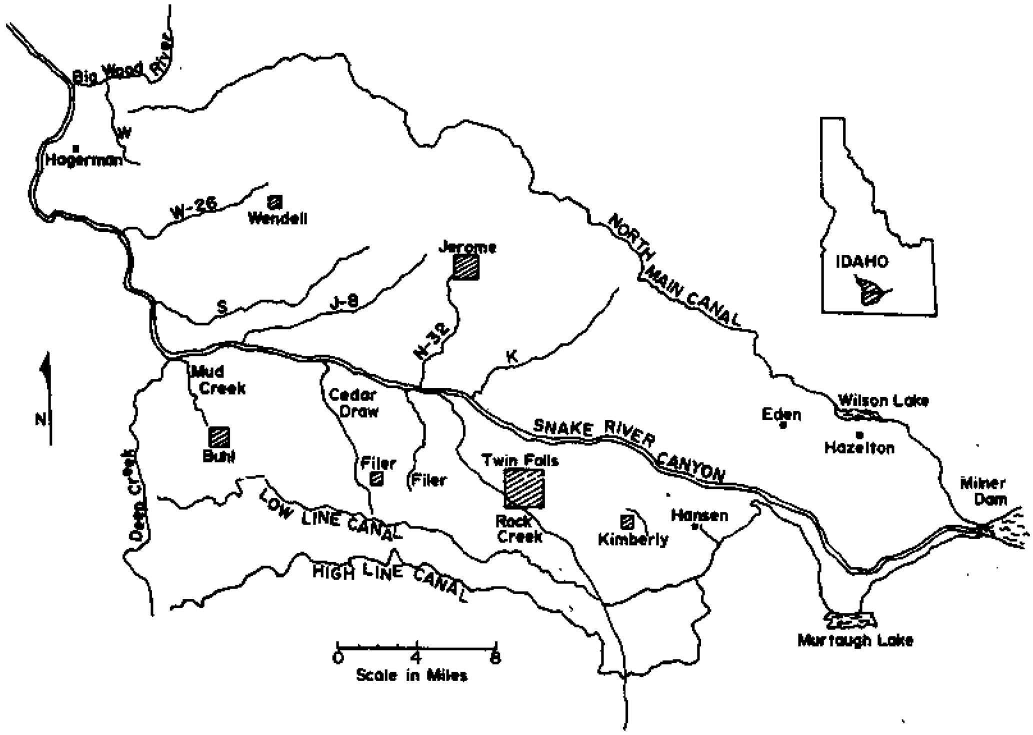

Fig. 1—The Northside and Twin Falls irrigation tracts showing main canals and surface drains.

There are large areas of fine sandy loams and some areas of sands known locally as "blow sands". These sandy soils are susceptible to wind erosion, and sometimes large quantities are deposited in the surface drains, particularly during the late winter and early spring. Soils on the Northside tract have moderately high to high infiltration rates, and irrigation is mostly in small furrows.

The irrigation and drainage systems for both tracts are designed for redistribution of surface runoff water. On the Twin Falls tract, most of the surface runoff water from lands above the low line canal enters that canal and is redistributed along with river water for irrigating lands below. Surface runoff water collected in drains on both tracts is redistributed into canal laterals. The only surface runoff water not subject to redistribution is that in drains too deep or at elevations too low for redistribution by gravity flow. Thus, much of the water is rediverted several times before it reaches the river as surface return flow from these tracts.

The first irrigation water was delivered to some farms on the Twin Falls tract in 1905, and the entire tract was irrigated by 1907. The Northside tract was developed more gradually. The first water deliveries were made in 1909, most of the land was irrigated by 1918, but some areas were developed in the 1920's. Mean annual precipitation on both tracts is 210 mm.

The major crops grown include dry beans (*Phaseolus* spp.), sugarbeets (*Beta vulgaris* L.), alfalfa (*Medicago sativa* L.) spring and fall grain, corn (*Zea Mays* L.) and pasture with smaller acreages of dry peas (*Pisum sativum* L.), and potatoes (*Solanum tuberosum* L.). Row crops comprise about 40% of the area and are normally seeded in April and May. Usually the last crop harvested is sugarbeets in late October or early November.

METHODS AND PROCEDURES

Sampling sites were established during the 1969 and 1970 irrigation seasons near points where drainage water from the six major drains of the Northside tract and four major drains from the Twin Falls tract enter the Snake River Canyon. In addition, sampling sites were established for three subbasins of the Twin Falls tract. One subbasin was a 1,215-ha area northeast of Filer, drained by the Filer drain (Fig. 1). Another was a 325-ha drainage southeast of Kimberly, drained by the Kimberly drain which flows into a lateral canal. The third was a 200-ha subbasin west of Hansen, drained by the Hansen drain which also flows into a canal. Only the sections of the Kimberly and Hansen drains above the sampling points are shown (Fig. 1). Sampling sites on the main canals for the tracts were below the outlets from Wilson and Murtaugh Lakes (Fig. 1) which are relatively small holding reservoirs. The quantities of water diverted were obtained from the two canal companies and the US Geological Survey.

Each sampling site was at a wier, drop structure, or culvert satisfactory for measuring waterflow and collected water and sediment samples. All samples were collected using a slot sampler (4) or by catching the entire flow to assure representative samples. Water stage recorders were placed at all sites except on the Filer drain which was gauged at each sampling.

Flow rates in 13 additional small drains on the Twin Falls tract were obtained by current meter measurements at an appropriate channel cross section. Sediment concentrations were determined four times during the irrigation season in these drains.

Preliminary data were collected in 1969, and more complete data in 1970. This information was used for improving techniques used during the 1971 season. The 1971 data were then used for computing sediment inputs and outputs.

Samples were usually collected at 2-week intervals from late April through September on the Northside tract and from late May through September on the Twin Falls tract during the 1971 irriga-

Table 1—Water diverted, sediment concentration and sediment diverted from the Snake River for two large irrigation tracts in Southern Idaho for the 1971 irrigation season

	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
				Northside Canal Company						
Diverted water, 10^4 m^3	8,162	23,542	25,265	30,170	30,093	21,491	8,823	3,084	--	150,631
Mean sediment conc., ppm	63	63	29	37	33	26	26	26	--	
Sediment diverted, metric ton	5,102	14,726	7,433	11,095	9.960	5,548	2,595	794	--	57,253
				Twin Falls Canal Company						
Diverted water, 10^4 m^3	9,843	23,917	23,917	28,185	28,456	17,762	4,218	1,628	382	138,310
Mean sediment conc., ppm	74	40	52	85	55	29	29	29	29	
Sediment diverted, metric tons	7,239	9,674	12,313	23,838	15,696	5,225	1,241	479	112	75,817

Table 2—Sediment concentrations in drainage waters from two large irrigated tracts during the 1971 season, ppm

Drain	Sampling date												
	4/20	5/3	5/17	5/28	6/7	6/15	6/29	7/13	7/26	8/10	8/24	9/8	9/28
					Northside Canal Company								
K	240	190	270	140	200	160	110	120	90	90	40	40	40
N-32	380	100	150	120	170	90	70	30	180	20	20	60	50
J-8	1,580	1,430	2,610	510	660	660	300	80	170	110	70	100	110
S	320	350	110	140	100	200	440	110	130	90	60	130	140
W-26	160	80	100	60	100	130	100	60	160	100	40	50	50
W	160	50	60	30	30	40	20	20	30	20	20	10	40
					Twin Falls Canal Company								
				5/25	6/2	6/15	6/29	7/13	7/26	8/10	8/24	9/8	9/28
Rock Creek	--	--	--	540	300	140	190	310	320	390	200	120	150
Cedar Draw	--	--	--	200	210	100	120	220	550	520	330	150	200
Filer Drain	--	--	--	710	400	210	710	2,250	2,120	1,410	820	270	290
Mud Creek	--	--	--	260	180	140	130	120	200	190	250	260	130
Deep Creek	--	--	--	200	110	70	80	60	70	110	100	100	90
			4/20	5/14	5/26	6/23	7/6	7/20	8/3	8/17	9/2	9/16	10/5
Hansen Drain	--	--	--	1,550	380	510	3,180	14,500	4,970	290	3,160	280	--
Kimberly Drain	--	--	4,180	1,080	360	610	2,860	1,420	4,960	180	150	70	40

tion season. Data collected during the 1969 and 1970 seasons indicated that sampling at 2-week intervals gave a reasonable measure of sediment inputs and outputs. More frequent sampling did not improve the accuracy of the measure sufficiently to warrant the increased effort and expense required. Ten liters of water were transferred to plastic buckets, and the sediment allowed to settle for a week. The supernatant was siphoned off, and the sediment dried and weighed. A settling time of 1 week is approximately three times longer than necessary, according to Stokes Law, for 1.0 μm diameter particles to settle 22 cm, the water depth in the containers.

The quantity of sediment passing each sampling site was computed by multiplying the total volume of water passing that point for the week before and the week after sampling (or other appropriate periods), by the sediment concentration at sampling. Sediment inputs and outputs were computed for the two tracts. The quantities of sediment removed mechanically from canals and drains were estimated from company records.

RESULTS AND DISCUSSION

The sediment concentrations were low in the irrigation water diverted for the tracts but were higher early in the season than during the late part of the season (Table 1). The concentration remained higher further into the season for the Twin Falls tract than for the Northside tract. This probably results from differences in system design and differences in the flow velocities as water passed through the small holding lakes. More sediment settles from water diverted into the Northside tract canal between the diversion point and the sampling point below Wilson Lake than is the case for the Twin Falls tract between the diversion and the sampling point below Murtaugh Lake, as evidenced by sediment concentrations in the canal water for the two tracts. After September 1, the sediment concentrations in canal waters for both tracts were low and constant. Even at these low sediment concentrations, rather large quantities of sediment are brought into the irrigation tracts by the irrigation water because the quantities of water diverted are large.

The sediment concentration in the drainage streams followed different patterns (Table 2). The concentrations were highest early in the season and decreased during the season in some drains, for example, N-32, J-8, and W. Concentrations were high in several drains from mid-July through early August when irrigation of row crops was most frequent. Cedar Draw and Filer Drain contained peak sediment concentrations during July.

Sediment concentrations in drainage waters exceeded those in irrigation waters severalfold most of the time except in the W drain which serves much like a sediment detention basin. The sediment concentration in the Filer drain was about 25 times that in the irrigation water during July as the extreme in this study for a drain entering the river. Results from the W drain indicate that by using sediment detention basins, drainage water can be returned to the river with about the same sediment concentration as in the irrigation water.

Table 3—Sediment inputs and outputs for two large irrigated tracts for the 1971 irrigation season

Irrigation tracts	Seasonal water flow	Sediment input	Sediment output
	10^4 m^3	—— metric tons ——	
Northside Canal Company, 65,350 ha			
Diverted from Snake River	156,631	57,250	
Drains, total returned to Snake River	9,037	--	12,080
K	1,410	--	1,300
N-32	2,478	--	2,160
J-8	622	--	3,550
S	1,780	--	3,440
W-26	1,787	--	1,280
W	960	--	350
Net sediment input or output	--	45,170	--
Sediment mechanically removed from drains and canals annually	--	--	295,000
Twin Falls Canal Company, 82,030 ha			
Diverted from Snake River	138,310	75,820	--
Drains, total returned to Snake River	37,424*	--	113,610
Rock Creek	13,930	--	43,090
Cedar Draw	4,144	--	8,750
Filer Drain	1,084	--	11,280
Mud Creek	7,239	--	13,820
Deep Creek	4,732	--	5,630
Thirteen small drains	6,295	--	31,040
Net sediment input or output	--	--	37,790
Sediment mechanically removed from drains and canals annually	--	--	78,000

* Includes subsurface drainage water. Only 14% of the diverted water returned as surface runoff (see references 1 and 2).

The sediment inputs and outputs (Table 3) indicated a net sediment accumulation of 45,170 metric tons or 0.69 metric tons/ha for the Northside tract and a net sediment loss of 37,790 metric tons or 0.46 metric tons/ha from the Twin Falls tract. The reasons for the net gain on the Northside tract are that the company allows only 6% of the diverted water to return to the river as surface runoff, and the drains are nearly flat. Large quantities (Table 3) of sediment are deposited in the drains requiring mechanical removal. The Northside Canal Company keeps records of the quantity of sediment mechanically removed from canals and drains each year. Some canals and drains are cleaned every year, but others are cleaned only after sediment accumulation seriously restricts flow. This may be every second or third year or longer. An estimate of the quantity of sediment deposited in canals and drains each year was obtained by averaging the quantities removed mechanically over the past 5 years. This quantity was 295,000 metric tons (Table 3), and it was assumed to be the amount deposited during the 1971 season for purposes of discussion in this paper. This is equivalent to 4.5 metric tons/ha. Essentially all of this sediment is removed from canals and drains downstream from where surface runoff returns to the system, and sediment in the canal water diverted from the river cannot be separated from sediment in surface runoff. We assumed that the 295,000 metric tons of sediment deposited in canals and drains plus the 12,080 metric tons entering the river in return flow was the total of all sediment entering the system in both diverted and surface runoff water or 307,080 metric tons. Subtracting the 45,170 metric tons entering in the irrigation water leaves 261,900 metric tons or 4.0 metric tons/ha as the quantity eroded from farms during the irrigation season. Actually, the amount eroded would exceed that amount, because much of the sediment entering in the irrigation water applied to alfalfa, small grain and pasture would be deposited on the land. Therefore, the 261,900 metric tons is a net quantity representing the minimal quantity of erosion. Also, there is extensive within-field erosion by which soil is eroded from the top of the field and deposited toward the end. In a few instances, crops at the lower end of the field were covered by sediment and farmers commonly must remove sediment from drain ditches at the ends of their fields. Within-field erosion on the tracts was not measured in this study, but it represents a serious erosion problem.

The Twin Falls Canal Company mechanically removes about 78,000 metric tons or about 0.95 metric tons/ha of sediment from canals and drains downstream from where surface runoff reenters the system (Table 3). Following the same reasoning applied to the Northside tract, the amount of sediment eroded from farms in the Twin Falls tract was about 116,600 metric tons or 1.42 metric tons/ha. Again this does not include within-field erosion. This company allows 14% of the diverted water to return to the Snake River as surface runoff (1, 2). The 37,424 × 10^4 m^3 of return flow shown in Table 3 includes subsurface drainage water and the total amounts to 27% of the diverted water. That is the amount of water measured where drains enter the river for determining the total quantity of sediment returning. In contrast to the Northside tract, water flows in drains from the Twin Falls tract all year because of the subsurface drainage (1, 2).

Considerably less soil is eroded from farms on the Twin Falls tract than on the Northside tract, but more sediment eroded from the Twin Falls tract reaches the river. The main reason for this difference is that drains on the Twin Falls tract are generally steeper allowing water to flow more rapidly than in drains on the Northside tract. Most of the drains on the Twin Falls tract are natural channels, and rapid water flow transports entering sediment to the river. Drains on the Northside tract have been constructed to grade, and the water flow rate is slow enough that much of the entering sediment settles in these drains. The second factor, as previously shown, is that more surface runoff occurs from the Twin Falls tract than from the Northside tract. Both of these factors function in favor of a lower sediment loss from the Northside tract.

Results from the two tracts indicate that both have advantages and disadvantages. When comparing the two systems from the standpoint of preventing sediment from returning to the river, the Northside tract, with its nearly level drains and small percentage of surface return flow, is superior. When comparing the erosion from farms, it is evident that farmers on the Twin Falls tract are doing a better job of keeping the soil on the farm where it should be. It is evident that sediment retention basins could be used to advantage on both tracts for reducing the amount of sediment returning to the river. It is also evident that steepness of drains is an important factor in the amount of sediment reaching the river. Both tracts could greatly benefit by improved practices that would keep the soil on the farm and prevent it from entering drains. This would reduce the amount of sediment entering the river and minimize the need for mechanically removing sediments from drains, canals and sediment retention basins.

Detailed studies of three subbasins within the Twin Falls tract show differing results. Nearly 10% of the sediment returned to the Snake River from the Twin Falls tract came from the 1,215-ha Filer subbasin which contributes only about 3% of the drainage water (Table 3). Erosion in the subbasin amounted to about 11.4 metric tons/ha. Velocities in the Filer drain are sufficient to prevent settling and the flow length to the Snake River is short. The sediment concentration in drainage water from the Filer subbasin was much higher during July and August than in the major drains (Table 2). The Hansen and Kimberly subbasins are about 7 km from the Snake River, and they drain into lateral canals so little of the sediment reaches the River. The sediment concentrations from these two subbasins were very high when row crops were being irrigated following cultivations during June, July, and August (Table 2).

Comparing results from subbasins with those for the entire Twin Falls tract emphasizes the care that must be exercised in drawing conclusions from erosion and sediment control studies. It is evident that much more erosion occurred on the three subbasins per unit area than was the case for the entire tract. Obviously then, other subbasins within the tract are serving as sediment deposition areas, and much of the deposition is in the drains and, in some instances, the canals. Studying the entire tract gives integrated results that are most important from the standpoint of irrigation return flow quality but does not reflect the within-tract and within-field erosion. These results also point out that properly constructed sediment retention basins located in the right places could remove much more sediment from drainage waters on this tract. Some additional benefits of settling basins might be N removal by phytoplankton and recreation such as fishing and water sports. The sediment could be used to fill low areas in farms and for landscaping.

LITERATURE CITED

1. Carter, D. L., J. A. Bondurant, and C. W. Robbins. 1971. Water-soluble NO_3-nitrogen, PO_4-phosphorus, and total salt balances on a large irrigation tract. Soil Sci. Soc. Amer. Proc. 35:331–335.
2. Carter, D. L., C. W. Robbins, and J. A. Bondurant. 1973. Total salt, specific ion, and fertilizer element concentrations and balances in the irrigation and drainage waters of the Twin Falls tract in Southern Idaho. USDA, ARS-W-4. 37 p.
3. Glymph, Louis M., and Herbert C. Storey. 1967. Sediment—its consequences and control. *In* N. C. Brady (ed.), Agriculture and the quality of our environment. Amer. Ass. Advance. Sci. Pub. 85. p. 205–220.
4. Heinemann, William H., and Melvin J. Brown. 1972. Fractional water-sediment sampler. Soil Sci. Soc. Amer. Proc. 36: 376–377.
5. Joint-Task Force of the US Department of Agriculture and the State Universities and Land Grant Colleges. 1968. A national program of research for environmental quality-pollution in relation to agriculture and forestry. USDA, Washington, D. C.
6. Mech, Stephen J., and Dwight D. Smith. 1967. Water erosion under irrigation. *In* Robert M. Hagan, and Howard R. Haise and Talcott W. Edminister (ed.), Irrigation of agricultural lands. Agronomy 11:950–963. Amer. Soc. Agron., Madison, Wis.
7. National Technical Advisory Committee on Water Quality Criteria. 1968. Research Needs, US Dep. of the Interior, Fed. Water Pollut. Contr. Admin. p. 70–71.
8. Robinson, A. R. 1971. Sediment. J. Soil Water Cons. 26: 61–62.
9. Utah State University Foundation. 1969. Characteristics and pollution problems of irrigation return flow. US Dep. of the Interior, Fed. Water Pollut. Contr. Adm., p. 56–57.
10. Wadleigh, C. H. 1968. Wastes in relation to agriculture and forestry. USDA Misc. Pub. No. 1065. 112 p.