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Global Change and Climate History

Magnitude and Significance of Carbon Burial in Lakes, Reservoirs, and Northern Peatlands

U.S. Geological Survey Fact Sheet FS-058-99 **April 1999**

Fact: Lakes, reservoirs, and peatlands collectively cover less than 2 percent of the Earth's surface but bury organic carbon at an annual rate that is four times the carbon burial rate in all oceans, which cover 71 percent of the Earth's surface.

Carbon Burial in Lakes

Elk Lake, Minnesota, is typical of the many lakes in glaciated parts of the Midwestern United States that bury organic carbon at a rate of about 72 $g/m^2/yr$.

It is estimated that freshwater lakes in the world have a total area of about $1.5x10^{12}$ m^2 (Shiklomanov, 1993; table 1). Including saline inland seas in this total would add another $1x10^{12}$ m^2. The 28 largest (area of each > 5,000 km^2) freshwater lakes in the world have a total area of $1.18x10^{12}$ m^2 or about 79 percent of the total area of all freshwater lakes. If the 28 large lakes bury organic carbon (OC), on average, at the same rate as Lake Michigan (5 $g/m^2/yr$), then the annual rate of OC burial in these 28 lakes is about 6 Tg/yr (6 terragrams per year or $6x10^{12}$ g/yr; table 1). If the smaller lakes bury OC, on average, at the same rate as an average Minnesota lake (72 $g/m^2/yr$), then the annual rate of OC accumulation in these smaller lakes is about 23 Tg/yr ($23x10^{12}$ g/yr; table 1). If saline inland seas bury OC at the Lake Michigan rate, this would be an additional 5 Tg/yr, for a total of 34 Tg/yr for all freshwater lakes and saline inland seas (table 1). Mulholland and Elwood (1982) estimated the OC burial in all lakes and inland seas (excluding the Black Sea) to be 60 Tg/yr today (table 1) and an average of 20 Tg/yr for the last 10,000 years. Stallard (1998) modeled terrestrial sedimentation as a series of 864 scenarios. For lake area, he used $1.54x10^{12}$ m^2, the area of the 250 largest lakes in the world. This is close to the total of large and small lakes given in table 1. Again, including inland seas to this total would add an additional $1x10^{12}$ m^2. Results of scenarios for lakes and reservoirs were divided into two components, those with clastic sediments and those with organic sediments. The results of OC burial in the most likely of Stallard's scenarios for lakes range from 48 to 72 Tg/yr (table 1), the average of which is close to the 60 Tg/yr estimated by Mulholland and Elwood (1982). We will use an average of 54 Tg/yr (table 1). The closeness of these estimates, calculated by different methods, suggests that this value is not in error by more than a factor of two.

Table 1. Burial of organic carbon.
[OC, organic carbon. Large lakes include 28 lakes, each with an area greater than 5,000 km^2]

Location of sediment carbon sink	**Area of carbon sink ($x10^{12}$ m^2)**		**OC burial rate ($g/m^2/yr$)**	**Amount of OC buried ($x10^{12}$ g/yr)**	
Carbon burial in lakes, reservoirs, and peatlands					
LAKES					
Large	1.18		5	6	
Small	0.32		72	23	
Inland seas	1.00		5	5	
Total	2.50[a]	........2.50[a]		34[a]	
				60[b]	
				48-72[c]	
				54[d]	...........54[d]
RESERVOIRS	0.40[a]		400	160[a]	
	0.66[c]			300-400[c]	
	0.66[c]			200[b]	
	0.53[d]	........0.53[d]		265[d]	..........265[d]
PEATLANDS (present)	3.30[e]	........3.30[e]	29	96[e]	..............96[e]
TOTAL "LAND" (lakes, reservoirs, peatlands)		**6.33**			**415**
Carbon burial in the world's oceans					
OCEANS					
Margins	42[f]				

Basins	320[f]			
Total	362[f]	362[f]	60-130[f]	
			82[g]	
			115[h]	
			97[d]	97[d]
TOTAL "OCEAN"		**362**		**97**
"Land"/"Ocean" quotient		**0.02**		**4.3**

[a]Dean and Gorham (1998). [b]Mulholland and Elwood (1982). [c]Stallard (1998). [d]Mean of above estimates. [e]Gorham (1991). [f]Emerson and Hedges (1988). [g]Sundquist (1985). [h]Arthur and others (1985).

Carbon Burial in Reservoirs

Lake Powell, Utah, was formed by the damming of the Colorado River behind Glen Canyon dam at Page, Arizona. The drainage basin of the Colorado River is underlain mostly by soft, easily eroded sandstones and shales. The tremendous sediment load delivered to Lake Powell by the Colorado and its upstream tributaries, the Green and Gunnison Rivers, results in the rapid accumulation of sediment behind Glen Canyon dam. The high sediment-accumulation rates in reservoirs globally results in an estimated organic-carbon burial rate in reservoirs of about 400 $g/m^2/yr$.

The total area of reservoirs in the world ($0.4x10^{12}$ m^2, Shiklomanov, 1993; $0.66x10^{12}$ m^2, Stallard, 1998) is smaller than that of lakes, and the average percentage of OC in their sediments (about 2 percent; Mulholland and Elwood, 1982; Richie, 1989) is much less than in most lake sediments. However, because the average sedimentation rate in reservoirs (about 2 cm/yr; Mulholland and Elwood, 1982) is much higher than that in lakes, bulk-sediment accumulation rates are higher, and OC accumulation rates are higher. The main reason that the sedimentation rate is so high in reservoirs is that most are located in arid or semiarid lands underlain by soft, easily eroded sedimentary rock. At an average sedimentation rate of 2 cm/yr, an average bulk density of 1 g/cm^3, and an average OC content of 2 percent, the average OC accumulation rate in reservoirs is 400 $g/m^2/yr$, and the world's reservoirs are burying OC at a total annual rate of 160 Tg/yr (table 1). This is close to the 200 Tg/yr estimated by Mulholland and Elwood (1982) for the annual accumulation of carbon in reservoirs. Stallard (1998) did a detailed compilation of global reservoir areas and came up with a total area of $0.66 x 10^{12}$ m^2 (table 1). The results of OC burial in the most likely of Stallard's scenarios for reservoirs range from 300 to 400 Tg/yr. Thus, the global annual OC burial rate in reservoirs is between 160 and 400 Tg/yr. We will use an average of 265 Tg/yr (table 1).

Carbon Burial in Peatlands

Wetlands that accumulate more than 30 cm of organic peat are called peatlands (Gorham, 1991). In Europe, they are called mires. Peatlands are concentrated in northern Russia, the Baltic States, Fennoscandia, Canada, and the Northern United States (particularly in Alaska) where they make up 9.7 percent of the total land surface (Gorham, 1995). It is estimated that the total area of unmined northern peatlands is $3.3 x 10^{12}$ m^2 (Gorham, 1991). The estimated present average rate of OC accumulation in northern peatlands is 29 $g/m^2/yr$ (Gorham, 1991). Using this rate for all northern peatlands, their total OC burial amounts to 96 Tg/yr (table 1).

Carbon Burial in Oceans

Globally, continental margins only amount to 12 percent of the area of the world oceans, but they are estimated to account for 44 percent of the present burial of OC in the oceans (Emerson and Hedges, 1988). Very little OC accumulates in the deep ocean basins, mainly because any organic matter produced in surface waters decomposes before it gets to the bottom. Estimates of OC burial in all oceans of the world vary, but tend to be about 100 Tg/yr (table 1).


A forested peatland, Shingobee Fen, in northwestern Minnesota. Unlike bogs that receive moisture from precipitation and feed the ground-water table, fens are fed by ground water. This forested fen receives a large discharge of nutrient-rich ground water that provides an environment for rare aquatic plants.

Conclusions

The total annual OC accumulation in lakes (54 Tg), reservoirs (265 Tg), and northern peatlands (96 Tg) is 415 Tg (table 1). Despite the total area of these three carbon sinks being only about 2 percent of the world ocean's surface area, they bury more than four times more carbon than the oceans (table 1).

It should be noted that the drainage of peatlands for forestry and agriculture, and use of peat as fuel, is releasing carbon to the atmosphere. Gorham (1991) estimated that such processes release about 35 Tg/yr from northern peatlands, and more southerly regions may actually be releasing more carbon from drained peatlends than is fixed in undrained sites. On the other hand, cultural eutrophication may have increased lake sedimentation of OC four- to five-fold in small lakes, an increase of 23-32 Tg/yr.

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