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LAKE GUSINOE TO BAIKAL VIA SELENGA DELTA: PROTECTION-DESTRUCTION SPIRAL

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Abstract

Lake Gusinoe is the largest water body in the Buryat Republic (South Siberia, Russia) and still the only source of both drinking and industrial water supply. All the wastewater is thrown away into the same lake. Most of the tributaries, concentrated on the western lakeshore, disappear into the coarse deposits of alluvial fans soon after they emerge from the mountains. Anthropogenic impacts on the lake ecosystem increased during the 20th century. The biggest environmental polluters are the Gusinoozersk coal mine, the Kholboldzhinsky opencut coal mine, and the Gusinoozersk State Regional Power Plant (Gusinoozersk SRPP). The Gusinoozersk SRPP takes a large amount of freshwater from the Zagustai River, the longest influent of Lake Gusinoe, to produce hot water and steam for the turbines. The warm wastewater is discharged back into the lake. As a result of this, an unfrozen patch of water measuring about 2 km^2 is formed on the lake in winter, and the water temperature in the upper layer is 13–14°C higher than the lower ones. Some chemical components (e.g., sulfate, phenol, iron ions) of both the lake water and surface/groundwater of the Lake Gusinoe Basin are with constant excess of the maximum allowable concentration (MAC). The Gusinoozersk SRPP is also the main air polluter. Now Lake Gusinoe is constantly polluted and in the state of degradation. Lake Gusinoe might be possible one of the largest pollution sources in the Baikal region, because the connecting transboundary Selenga River is the main inflow of Lake Baikal.

Keywords: transboundary river, ancient lake, Na process, desalination, coal mine, wastewater control, thermal power plant, heat pollution

1 INTRODUCTION

In 2005, Pisarsky, Hardina and I reported on the state of Lake Gusinoe (Pisarsky et al., 2005) (Figure 1). The paper provides limnological information on the evolution of lake environments and biotic communities as a result of anthropogenic impacts as well as natural processes over a considerable period of years.

Figure 1. Two principal aquatic resources of Lake Baikal [top] – the Siberian kharius (grayling) *Thymallus arcticus* (Pallas, 1776) [left], the Baikal omul *Coregonus autumnalis migratorius* (Georgi, 1775) [right]; location of Lake Gusinoe* [foreground graphic]; major environmental polluter of Lake Gusinoe (the Selenga River Basin) – the Gusinoozersk State Regional Power Plant (thermal power plant) [background photo]

*Orange-colored areas indicate the distribution of traces of Mesozoic lakes, based on the sedimentary layers produced by them (revised from the maps in Martinson, 1989 and Pisarsky et al., 2005).

The investigations at Lake Gusinoe and the neighboring smaller lakes have been carried out since 1999, unfortunately, Professor Pisarsky passed away on January 24 of this year, and Ms. Hardina, one of his students at the time of publication, has retired from the laboratory, so now I inherit this work from them. Once, we made every effort to seek out any published information about the environmental polluters of Lake Gusinoe, but in vain. At present the situation is completely changed and it is relatively easy to obtain them (e.g., The Republic of Buryatia National Library, 2006; Afanasieva et al., 2007; Mun et al., 2008). In this paper, I try to reconsider the issues, taking account of the additional data after publication of the previous report.

As to the anthropogenic impacts on the lake ecosystem, especially in the southern region, Pisarsky and Hardina had strongly considered the Trans-Mongolian Railroad (TMGR) and military installations to be the major sources. I, however, omit such buildings from my discussion because their argument is unsupported scientifically by the facts.

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2 ANCIENT LAKES OF TRANSBAIKAL REGION

2.1 What is the origin of "goose-ful" lake?

Except for Lake Baikal, Lake Gusinoe (situated at 51°06′–51°17′ N, 106°16′–106°30′ E; Figure 1) is the largest water reservoir in the Buryat Republic (the Republic of Buryatia, capital Ulan-Ude City), which belongs to the Transbaikal region in the Asian part of Russia. The Selenga River ("Selenge" in Mongolia) is a transboundary water system, which rises in central Mongolia and flows into Lake Baikal, forming an arcuate delta (Figures 1, 2). The outflow water of Lake Gusinoe is also carried into Lake Baikal through the Selenga River etc.

In 1940s, Professor Vereschagin, the first director of the Baikal Limnological Station of the USSR Academy of Sciences, set up the hypothesis that the origin of Baikal fauna could be traced back to the extinct ones formed during the Mesozoic Era, but he couldn't prove it (Martinson, 1989). Later, Russian paleontologist Trussova (1971, 1975) found very good preserved specimens of a primitive crustacean from Mesozoic sediment in the Transbaikal region. On the other hand, my works confirmed that some “living fossils” from the Olkhon Island (Figure 1) and Mongolia are closely related to the extinct species (Naganawa & Orgiljanova, 2000; Naganawa & Brtek, 2006; Alonso & Naganawa, 2008). Why on earth is the sediment on its island older than the lake? (The age of Lake Baikal is about 25 million years!) The reason is that there were a chain of shallow lakes, extending from the Transbaikal region to Mongolia during the Mesozoic Era; and Olkhon Island, Lake Gusinoe and some river valleys are traces of the ancient lakes.

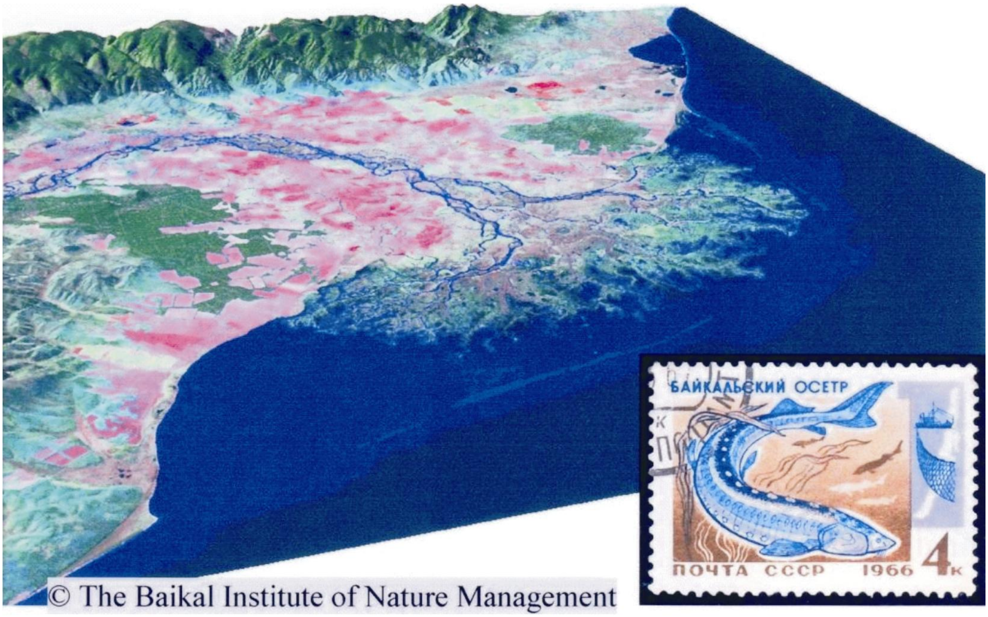

Figure 2. Selenga Delta* [3D graphic]; the Baikal sturgeon *Acipenser baeri baicalensis* Nikolskii, 1896 [right bottom]

*Pink-colored places are residential areas and lands using for agriculture.

2.2 Na process and desalination of Lake Gusinoe

A lake is defined as a soda lake when its water contains carbonate ions (CO_3^{2-}), hydrocarbonate ions (HCO_3^{-}), and sodium ions (Na^{+}) and is alkaline (pH > 8.35) or when sediments of sodium carbonate (Na_2CO_3) can be observed in the shore zone and also on the bottom if the lake has dried up. This means that the Na process (i.e., the soda process, meaning the formation of dry soda [Na_2CO_3]) is complete. In the case of sodium carbonate–hydrocarbonate waters with a pH ≥ 8.35, with or without minimum dry soda sediments, the Na process is incomplete; full saturation does not occur because of cation exchange ($Ca^{2+} \rightarrow Na^{+}$). The total salinity of the lake water is thus lower than in the case of full saturation.

Many investigations, continuing up to the present, indicate that the water of Lake Gusinoe is gradually desalinating and that the process has been going on for decades. At present, traces of the former salinity of the lake water have been preserved in the form of abnormal values of certain components; several saline lakes also exist around Lake Gusinoe that are undergoing the same process of desalination.

In the early stage of the evolution of Lake Gusinoe, both soda (Na_2CO_3) and salt (NaCl) precipitated under dry climate conditions. Later, as the amount of precipitation with Ca hydrocarbonate components increased, desalination of the lake water was accelerated by the lower salinity (Pisarsky et al., 2005).

3 RELATIONS BETWEEN PROBLEMS AND CAUSES

3.1 The Gusinoozersk industrial complex

Within the spoil heap of the Gusinoozersk coal mine (Figure 3), 72,000 m^3 of coal wastes are accumulated (data in 1990s). About 30% (100 ha) of the area of waste banks are reusing for farmland. In the case of Kholboldzhinsky opencut coal mine (Figure 3), which is the biggest enterprise in the Buryat Republic, 220 million m^3 of coal wastes are accumulated. Only 5% (45 ha) of the area of destroyed lands around the mine are reusing for farmland, but over 70% of the rest of them are still occupied by dumps.

The water management of Lake Gusinoe is serious. The purification plant by the lake does not work well. The total suspended substances throwing into the lake are 4.8 times more than maximum allowable concentration (MAC), sulfates – 4.7 times more, phenol – 2 times more, and iron – 1.2 times more (iron ions – 2.6 times more). Oil products and persistent organic pollutants thrown from the industrial settling tank are with constant excess of MAC. Incomplete purified water as much as 2 million m^3 is thrown into the lake every year.

As the biggest lake among the industrial center, Lake Gusinoe, which is the main source of life supply, is included in the industrial circulation and receives all the wastewater and storm wastes. According to the Republic of Buryatia State Ecological Committee, the total amount of harmful substances thrown into the atmosphere from stationary sources and motor transport is 37,000 tons per year (The Republic of Buryatia National Library, 2006).

3.2 Wastewater control in Lake Gusinoe Basin

Lakes are open systems that exchange energy and mass with the environment. These exchange processes are described by use of "forcing functions" (the forces on the lake as function of time). Forcing functions are either controllable or uncontrollable; the former are, for instance, in- and outflow of water, nutrients and toxic substances, and the latter, precipitation, wind, solar radiation, etc. The core of lake management is to find the relations between the forcing functions and state variables of the lake, and to use the knowledge of these relations to change the controllable forcing functions to achieve a desired state of the lake (Jørgensen & Vollenweider, 1989).

The present state of Lake Gusinoe is an example of bad lake management, because the lake is used for the production of drinking water and the water authorities make a lot of effort to produce high quality drinking water. Separately from this issue, the wastewater authorities worry about the influence of wastewater on the water quality of the same lake (i.e. lake → waterworks → domestic and industrial water supply → wastewater treatment → lake). No coordination is there between the two authorities. Lake Gusinoe is still the only source of domestic and industrial water supply, and also of the drinking water for the neighboring populated areas (mainly for Gusinoozersk City, population 24,000; data in 2008). At the same time, all the wastewater is thrown there.

Thus, the above-mentioned water management completely lacks a concept of water recycling. Some industries can recycle their water or partly use treated wastewater, and thereby decrease the costs of both waterworks and wastewater treatment, and even the impact on the ecosystem.

3.3 Thermal power plant and heat pollution

One of the main lake polluters is the Gusinoozersk State Regional Power Plant (Gusinoozersk SRPP, thermal power plant) (Figures 1, 3), which throws the warm wastewater from the water-cooling towers into the lake, as a result of this it is subjected to heat pollution. An unfrozen patch of water measuring about 2 km^2 is formed on the lake in winter, the water temperature in the upper layer becomes higher by 13–14°C than that of the lower ones, which is 1.5–2 times higher than the annual standard water temperature of the lake. Warm wastewater causes growing thickly of waterweeds and changing the whole hydrobiological relationship.

Everyday 15,000–16,000 m^3 of insufficiently clarified waters from the biological sewage disposal facilities of the power plant and the neighboring populated areas; 2,000 m^3 from the industrial settling tank; as well as 2 million m^3 of warm wastewater after cooling the turbines, are thrown into Lake Gusinoe. The Gusinoozersk SRPP is also the main air polluter (The Republic of Buryatia National Library, 2006).

3.4 Influence of warm wastewater on fishes

The major spawning grounds are distributed along the western lakeshore and also in the mouths of the influent rivers Zagustai and Tsagan-Gol (the latter shows the lowest water salinity) (Figure 3), because the oxygen regime and the water salinity are dominating factors for the survival of fish eggs and fries.

[Positive factors] – Since the early 1980s, a fish farm has been in operation (main species farmed being the carp *Cyprinus carpio* Linnaeus, 1758 and the Baikal sturgeon *Acipenser baeri baicalensis* Nikolskii, 1896; Figure 2), using the warm wastewater from the Gusinoozersk SRPP.

[Negative factors] – The northern part of Lake Gusinoe had suffered a major thermal load from the Gusinoozersk SRPP (Figure 3). During 20 years after construction of the thermal power plant, in Lake Gusinoe two fish species, the burbot *Lota lota* (Linnaeus, 1758) and the Siberian loach *Noemacheilus barbatulus toni* Dybowski, 1869, completely disappeared. The lenok *Brachymystax lenok* (Pallas, 1773) and the Siberian kharius (grayling) *Thymallus arcticus* (Pallas, 1776) (Figure 1) were on the verge of dying out from the ichthyofauna structure. The disturbance of the water balance in Lake Gusinoe (and also of the spawning migrations) meant that the Amur sazan *Cyprinus carpio* subsp. became a rarely seen species.

The major influence of the warm wastewater in the northern areas appeared at both the beginning of and throughout spawning and affected the species distribution throughout the lake. In the warmed zone, Amur sheatfish *Silurus asotus* subsp., ide *Leuciscus idus* (Linnaeus, 1758) and Siberian dace *L. leuciscus* subsp. were absent. In the zone of considerable influences by the warm wastewater from the Gusinoozersk SRPP, even at the spawning grounds (Figure 3), fries of perch *Perca fluviatilis* Linnaeus, 1758, roach *Rutilus rutilus lacustris* Pallas, 1814, and pike *Esox lucius* Linnaeus, 1758 were completely absent.

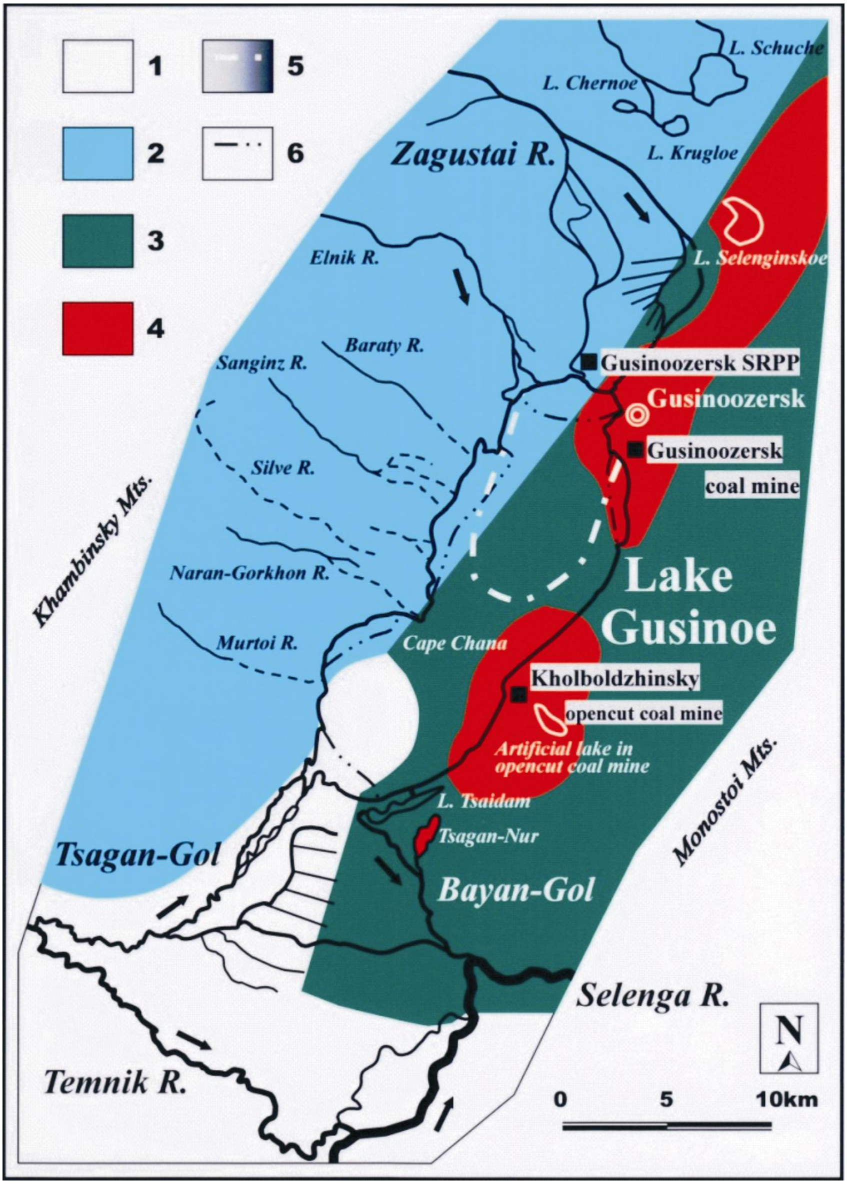

Figure 3. Distribution map of four hydrogeochemical zones of the Lake Gusinoe Basin*

*Squares indicate major pollutants in the Lake Gusinoe Basin. The basin is divided into four hydrogeochemical zones: ultrafreshwater [1], freshwater [2], mineralized water [3], and hyposaline and saltwater [4]. The areas surrounded by lines [5 and 6] are the zone influenced thermally by the Gusinoozersk State Regional Power Plant (Gusinoozersk SRPP) [5] and spawning grounds [6] (revised from the map in Pisarsky et al., 2005).

4 A NIGHTMARE SCENARIO

4.1 Never-ending story

The Buryat Republic is a part of Siberian Federal Districts of Russia, which is located along most of the eastern and partly northwestern shore of Lake Baikal. Currently, about 86% of the total population of the republic lives in the Selenga River Basin (Figure 1). Even the capital Ulan-Ude and the third major city Gusinoozersk also still suffer from severe depopulation because of their high rates of unemployment.

The republic has the limitation of water supply due to outdated water supply systems and their inefficient operation (Mun et al., 2008). The rivers of the Lake Gusinoe Basin are fed mainly by rainwater; 90% of annual precipitation (only 250–400 mm) occurs in summer–autumn season. Most tributaries show considerable water level fluctuation and they have occasionally disappeared (Figure 3), then there is a severe shortage of water during the rest of seasons. Lake Gusinoe has a weak nature of its running waters (with a coefficient of relative water exchange of 0.0025); 10–70% of wastewater is treated but the rest and insufficiently treated wastewater is returned to the same lake.

4.2 Is the delta an impregnable fortress?

A comparative analysis on some heavy metals' transference (Anenkhonov & Pronin, unpublished data) indicated that the amounts of accumulated heavy metals in the Selenga Delta against the amounts of leakage to Lake Baikal through the delta are as follows: Fe (iron) – 36,180/24,120; Mn (manganese) – 1,060.8/707.2; Pb (lead) – 524.4/349.6; Cu (copper) – 249.6/166.4; Zn (zinc) – 157.2/104.8; Cd (cadmium) – 4.9/3.3 (tons per year). The ratio of accumulation in the Selenga Delta is 60% on average.

Some researchers exaggerate the biological purifying of the delta, connecting mostly with microbiological processes, in addition, plants and animals are taking part in the different steps of purifying as absorbers. The situation is, however, still too serious for comfort; for instance, the data do not include any amounts of Hg (mercury), considered as one of the most toxic elements. And nobody knows where the toxic metals have gone, and how much influence do the accumulated toxic elements have on residential areas and farmlands near the delta (Figure 2). The accumulation of heavy metals in plants in the region of strong industrial pollution (e.g., the Gusinoozersk industrial complex, mainly the Gusinoozersk SRPP) is connected with the income not only from the atmosphere but also from polluted soil (Afanasieva et al., 2007).

5 CONCLUSIONS AND PERSPECTIVES

The principal sources of influence on the ecological system from Lake Gusinoe via Selenga Delta to Lake Baikal are the industrial complexes of Gusinoozersk, Ulan-Ude and other cities and towns of the Selenga River Basin (industrial wastewater and air pollution). Their probable pollutants are (1) heavy metals: Hg, Cd, Pb, Fe, Cu, Zn; (2) petroleum, phenol, PAH (polycyclic aromatic hydrocarbons), benzene; (3) dioxin-like chemicals: PCDD, PCDF, DL-PCB; (4) insecticides and pesticides: DDT, DDE, HCB (hexachlorobenzene), Chlordane, etc. The actual conditions of these pollutions are still to be proved.

It is obvious that the Lake Gusinoe Basin is subdivided into two zones of influence: the western and the eastern zones (Figure 3). Both the inflow of mineralized waters into the eastern zone and the high rates of evaporation are producing situations for salinization and rapid wetlands formation. The existence of such two contrastive zones is additional evidence of the importance of surface and subsurface drainage of the Temnik River for preservation of such a large reservoir as Lake Gusinoe.

Ms. Rachel Carson (1962) wrote, “The history of life on earth has been a history of interaction between living things and their surroundings. To a large extent, the physical form and the habits of the earth’s vegetation and its animal life have been moulded by the environment. Considering the whole span of earthly time, the opposite effect, in which life actually modifies its surroundings, has been relatively slight. … Given time – time not in years but in millennia – life adjusts, and a balance has been reached. For time is the essential ingredient; but in the modern world there is no time.”

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