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Enhancing Resilience for Sustainable Development in Lake Baikal and Baikal Basin: Fresh Water Paradise

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Abstract: Ensuring the water availability with better quality and quantity for all through sustainable management of it by the year 2030 is one of the top priorities of the United Nations Sustainable Development Goals (SDGs). With having proper knowledge about drivers causing water quality deterioration at right time will help policy makers to take right measures to retrieve the quality back to normal or at least stop further degradation. With the above theme, this work tries to give insight about the factors affecting water quality/quantity and strategy or action plan needed to overcome the challenges by enhancing community resilience for lake Baikal and Baikal basin. Main factors affecting water quality include anthropogenic activities well supported with lack of proper law enforcement, quality monitoring and climate variability.

Keywords: Lake Baikal; Water resources; Stresses; Sustainable management.

Introduction

Lake Baikal which is located in the south-east region of Siberia in Russia is globally significant as unique water resource. As it won't be overstated if it is said as is one of the world's most exceptional lakes. This is the world's oldest lake with more than 25 million years old as well as world's deepest lake with 1642 m. Most important is Lake Baikal stores more than 20% of the Earth's fresh and unfrozen water, With this it is also known as the world's most voluminous lake with area of 23,600 km (Robinson, 2001). In order of volume, it contains more amount of water than combined volume of all the five of USA Great Lakes (World Bank, 1996) (Figure 1).

The statistics of Lake Baikal which comprises length around 636 km and width ranges from 27 to 80 km. The famous characteristic of the lake is crystal clear clarity of the water, which even reaches to 45-55 metres in some areas. The lake Baikal water flowing into the lake from over around 300 years now. Situated on lake's western shore, the river Angara is only outlet of lake Baikal. The largest city of the region is Irkutsk, located on the river Angara. The Russian Government declared Lake Baikal to be one of the Seven Wonders of Russia in year 2008 (Baasanjav and Tsend-Ayush, 2001). The Lake was added to the UNESCO list of World Heritage Sites (UNESCO, 1996) in year 1996, because of cultural, archaeological and historical values and considered as natural phenomena which represent

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Figure 1: Location of Lake Baikal in Siberia.

the exceptional examples of ongoing biological and ecological processes and the freshwater ecosystems developments and as this can be considered as the significant habitat for the conservation of biodiversity (William and Conroy, 1991). Furthermore, the Baikal region includes cultural and archaeological monuments, many of them considered traditionally sacred.

The very important characteristic of this freshwater lake, which makes study of this area more necessary, is the impressive level of diversity because of presence

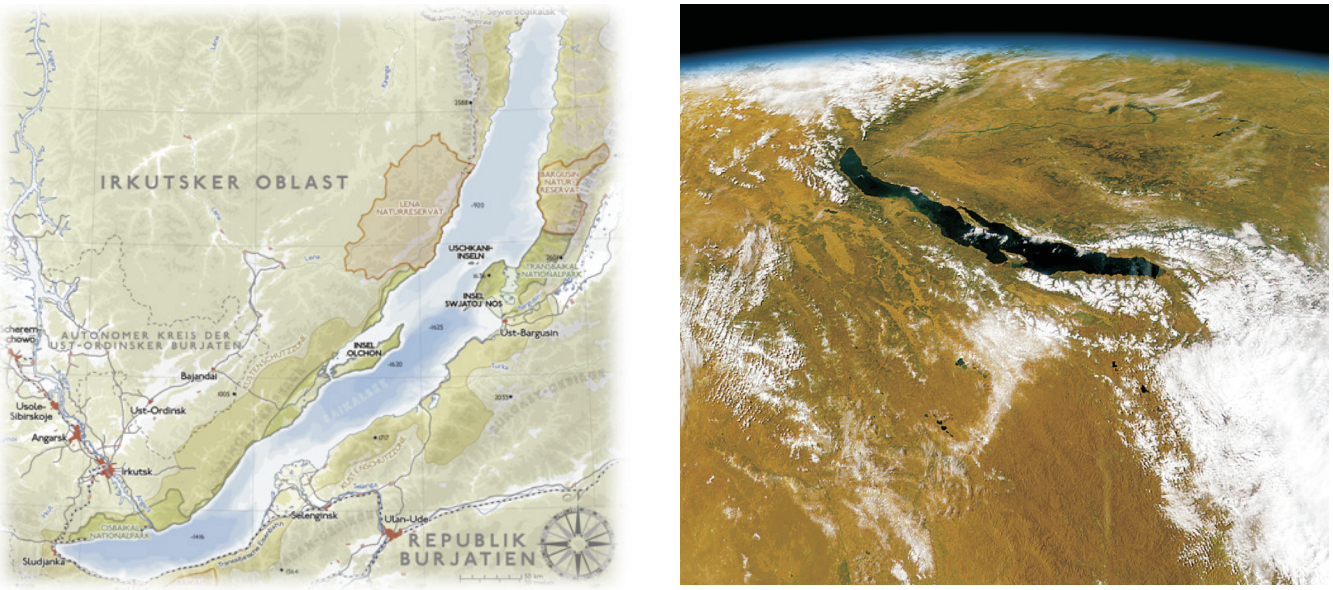

Figure 2: (Left) Lake Baikal location, (Right) orbital view of Lake Baikal.

of oxygen down to its deepest depths. The facts are 85% of known species (2565 in number) described as animal species (Timoshkin, 1995) and 40% of the 1000 endemic plant species (Bondarenko et al., 2006) are present here. The world's only fresh-water seal, the "Nerpa" or "Baikal seal" (Phoca sibirica), is the largest animal in the lake.

Description of Baikal Basin

Baikal Basin is a cross country ecosystem with more than 500,000 km area shared between Mongolia and Russia, with over 400 streams and rivers. Although lake Baikal is situated entirely in Russia (Figure 1), river Selenga is one of the major trans boundary water system in Asia and lake Baikal's biggest tributary. On average it brings more than annually 30 km^3 of water to the Lake, which is around 60% of total inflow into the lake. Annual run off of around 46% of river Selegna is generated in Mongolia. The catchment area for river Selenga is 447,060 km^2, from which around 33% (148,060 km^2) is within Russia and rest 67% lies within Mongolia. The Mongolian importance to the lake's long-term ecological health can be understood by the fact that the river Selenga comprises over 80% of the Baikal Basin. The delta with Selenga river of lake Baikal is one of the largest fresh water delta in the world added to RAMSAR list of international wetlands in 1994. A very large number of migrating, breeding and moulting water birds gather (come to) at the wetlands in the Selenga delta. Approximately number of total number of birds passing through the delta is 5,000,000 per year, which speaks about bio diversity this region holds (Matveyev et al., 2006).

Challenges—Environment and Sustainable Development Context

There are many challenges around the Baikal basin and Lake Baikal region, as number of human activities causing the changes in the flow of water and the interactions with hydrological cycle increase at many levels, like excess withdrawal of water from lakes, rivers and ground water in unsustainable methods causing various environmental damages. Deforestation around Siberia (Tundra) are also causing landscape changes which ultimately affect the quality and quantity of ground water and surface water of rivers (tributaries) of Lake Baikal.

The nature and amount of wastes coming in this lake is massive that just overpower the nature's ability to break them down into less harmful substances or make it degradable. An pervasive problem facing all the fresh water lakes is eutrophication, and problem for rivers is degradation of water quality.

Pollution has various environmental impacts within the Baikal basin and Lake Baikal being generated from various point and non-point pollution sources. The basin's ecosystem is facing threat from poisonous chemicals from industrial waste, toxic substances being dumped in water without any facility of treatment, increased levels of nutrients, heavy metals and suspended solids in Selenga Delta and coastal areas nearby. The biggest danger for water quality from land-based activities includes both point (e.g. industrial waste, chimney) and non-point (e.g. fertilizers, contamination of water) sources of pollution, which are also increasing threat to the Lake Baikal and its ecosystem. The point source releases such as municipal and industrial waste water from the major contributions (e.g. Ulan-Ude, Selenginsk, Irkutsk and Ulaan Baatar), placer gold mining, steel works & wood works and pulp & paper mills discharge good amounts of pollutants into ground and surface waters of lake and river.

Impact of Mining

The location of the Baikal region is situated where mining is the heart of the region's economic development and at the core concerns related to its adverse impacts to basin's ecosystem health. These impacts range from the contamination (e.g. cyanide, mercury, cadmium, lead, zinc, fluorine and chloride. All pose a serious threat to the Baikal basin ecosystem as well as to human health.) from toxic material and chemical used by the mining industry either legally/illegally, change into hydrological proceses, and deterioration in the quality of water.

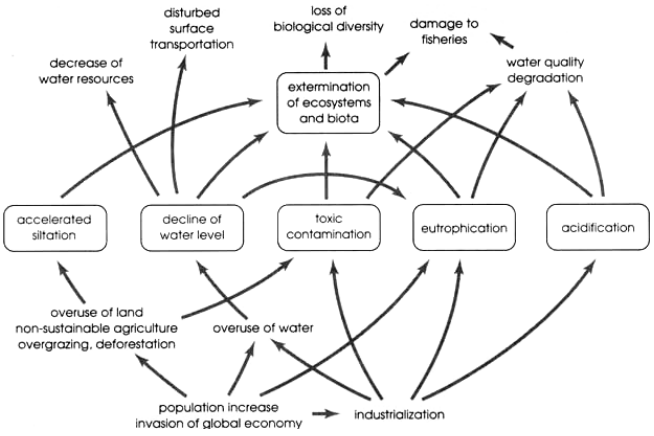

Figure 3: Graphical representation of enviornmental problem of Lake Baikal and Baikal basin (Baikal Watch, 1999).

Table 1: Analysis of stress on Baikal/Selenga basin ecosystem health/Sources of stress and underlying causes (Baikal Watch, 1999)

Sector	*Stress*	*Source*	*Underlying cause/Barriers*
1. Lake Baikal water quality	• Water temperature rise • Coastal erosion and submersion of delta marshes • Rise in suspended solids along coastlines	• Climate variability • Rising lake levels • Poor sanitation, erosion	• Global CO_2 emission • Irkutsk hydropower station flow regime on Angara river • Lack of public funding for sanitation improvement, lack of enforcement of sanitation measures, pulp and paper mill wastewater releases
2. Baikal/Selenga Tributary river water quality	• Deteriorating water quality and elevated suspended solids and pollution levels • Mercury releases and stream bed degradation • 780 streams, 590 lakes and tens of mineral springs dried up 2003-2005	• Pollution from industrial and municipal sources • Artesian gold mining • Climate variability and unsustainable uses	• Insufficient private and public investment in sanitation causing deteriorating condition of water works plus weak enforcement of pollution laws and conflicting water resource authorities • Low economic opportunities pushing citizens to try small scale unregistered alluvial gold mining • Global CO_2 emission and poorly regulated water abstraction practices
3. Selenga basin groundwater	• Localized increases in chemical and nutrient pollution	• Insufficient centralized sanitation systems and poorly designed private systems • Poor understanding of groundwater pollution sources	• Lack of public and private funding plus lack of public awareness and uneven and weak enforcement of pollution discharge laws • Lack of groundwater monitoring
4. Fisheries	• Loss of Grayling, Lemok and Taimen populations in lower Selenga region • Reduction in Omul and Sturgeon populations • Rise in invasive species (Rotan, amur Carp, amur Catfish)	• Reduction in food sources (stoneflies, mayflies etc.) from river bed disturbance and high suspended solids especially from alluvial gold mining • Degradation of spawning grounds from alluvial gold mining, industrial water pollution, cattle grazing in stream beds • Drastically reduced numbers of adult fish due to overfishing and illegal catch • Weakened indigenous fisheries • Past release of alien species for improved fish catching opportunities	• Weak enforcement of pollution, conservation and fisheries laws • Weak oversight of mining and timbering operations even within protected areas • Lack of awareness of economic advantages to healthy and well-managed migratory fisheries in terms of commercial catch and tourism opportunities • Lack of enforcement and inefficient stocking progress • Lack of understanding of risk from release of non-native fish
5. Other aquatic flora and fauna	• Reduction in zoobenthos in Baikal coastal areas and delta • Reduction in Nerpa (freshwater seal) population	• Oxygen depletion • High toxicity levels plus habitat disturbance and illegal poaching	• Rapid spread of Canadian Elodea (aquatic vegetation) • Pollution plus weak enforcement of species protection laws
6. Basin forests	• Forest fires • Illegal timber removal • Stunting and death of especially coniferous trees like pine, fir, spruces	• Warming temperature and draught • Increased urbanization • Increased acidification of rain water	• Breakdown in Mongolian forestry service • Lack of enforcement against illegal logging • Increased air pollution especially during winter season
7. Human health	• Elevated levels of viral Hepatitis A (VHA) in Baikal basin • Anthrax poisoning in two areas of Buryatia	• Tainted decentralized source of drinking water • Exposure to anthrax from decaying livestock carasses	• Localized groundwater contamination from poor sanitation • Insufficient public water supply system (only 10% of population served) • Poor disposal system for dead livestock
8. Social/Economic Quality of Life	• Population loss • High poverty ratios	• Outmigration and natural loss • Lack of economic opportunities	• Low level of development of social and economic infrastructure

Impact of Hydrological Regime and Erosion, and Increase of Population

The erosion of waste-rock piles and tailing repositories are one of the important concerns in the Baikal basin region. In Mongolia, most piles of waste rocks from industrial mining are unstable and have danger of erosion. A small amount of rainfall in the region can washout gravel into soil in the valley streams and reach the lakes. Land can become polluted and streams, rivers, deltas and more over and near shore zone. The increase in urban population within the basin region has resulted in massive increase in the pollution level of Selenga river tributaries such as the Tuul, Kharaa, Eroo, Orkhon and Chikoy. In 2006 approx 400 gold-mining enterprises were registered in the Selenga basin, and reports say many more unregistered while no enterprise invested money in the pollution control measure even to earn more profit.

Impact of Deforestation and Forest Fire

Deforestation is biggest concern in the region as in last one decade an approx 40% of the total forested area of the Basin got reduced. Foreseen impact in various degrees can be seen due to over cutting and anthropogenic (man-made) fires. Particularly affected have been the forest islands in the forest-steppe. In central Siberia, warmer and possibly drier summers are predicted to exacerbate the frequency and intensity of forest fires.

Impact of Nutrient Loading

The climate change will likely increase nutrient inputs (nitrogen and phosphorus) to Lake Baikal from both the basin and atmosphere. This, together with higher temperatures, will enhance primary productivity (PPR). Scientists are predicting that increased spring runoff resulting from increasing winter precipitation, coupled with the thawing of the permafrost, will most likely increase the loading of nutrients, sediments, and dissolved organic carbon (DOC) and particulate organic carbon (POC) to arctic lakes (Wrona et al., 2006). Atmospheric inputs of nutrients from forest fire ash are likely to increase in years to come. Summer forest fires have already increased in frequency and severity near Lake Baikal: seven of the years between 1998 and 2006 were considered extreme fire years in Siberia (Soja et al., 2007).

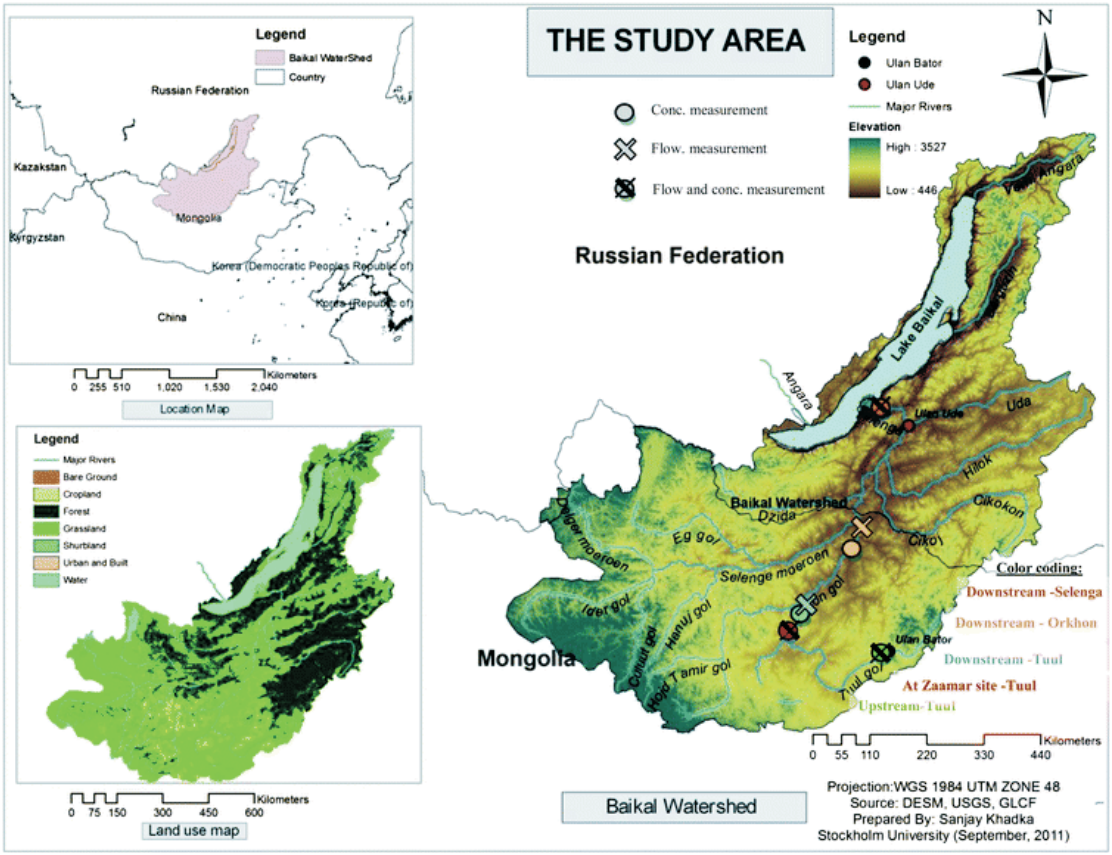

Figure 4: Baikal basin: Gold mining sites (Borodin and Syroechkovski, 1983).

Impact of Groundwater Pollution in the Basin
The primary source of drinking groundwater plays a very important role in the region from point of view of socio-economic role in both countries of the region. Groundwater is directly associated with surface waters.

Impact of Habitat Destruction
Destruction and/or modification of critical riparian, forest, and steppe habitats are increasing threats to Baikal's biodiversity and ecosystem health. Resource exploitation and associated infrastructure within the Baikal basin is spurring the degradation and destruction of wetland areas.

Impact of Climate Change
This is evident by various facts that the rapid climate change in the Baikal Basin, from Lake Hövsgöl in Mongolia to Lake Baikal, is now abundant. As we all know annual temperature of air has increased by 1.2° over last century, almost double the global average, temperature of winter increased by more than 2°C than observed in summer i.e. 0.8°C (Shimaraev et al., 2002). During the last 50 years, average temperatures in Mongolia have increased by 2°C and the growing season has increased by a month. According to recent analyses of ice cover and water temperature over the Lake Baikal, it is responding strongly to climate change (Moore et. al., 2009). Surface waters of Lake Baikal warmed rapidly and significantly to a depth of 25 m during the last 60 years (Hampton et al., 2008) and there is an observed warming trend in Baikal lake temperatures during the same six decades (+1.21°C since 1946). In addition, the ice-free season lengthened 18 days from 1869 to 2000, and ice thickness decreased 12 cm between 1949 and 2000 in the southern basin (Shimaraev et al., 2002).

The Strategy and Action Plan to Overcome the Challenges by Enhancing Community Resilience

In the face of such barriers, addressing strategy should look for the impacts on socio economic context, trans-border cooperation and the environmental aspects. The focus of the action plan needs to include both hard and soft measures, at both centralized and localized levels.

Overcoming Socio-economic Barrier
The level of social development in the Baikal basin is relatively lower than the average of Russia by indices (per capita income, unemployment and poverty).

- Improving the low level awareness about environmental degradation on human health.
- Working toward public recognition of the causes of environmental degradation in the Baikal basin and Lake Baikal.
- Understanding the ongoing impacts of climate change on the Baikal basin and the resilience of its ecosystems.
- For environmental protection in the region, coordinated efforts across border, collaborative effort by both countries.
- Producing effective economic and policy tools for environment safety measures.
- Focusing on practical monitoring to enable scientists and decision makers to see and understand trends in the important parameters of ecosystem.

Overcoming Information Barrier

- To improve this proposed action plan to overcome law-policy barrier suggesting 7-fold plan for protecting the sound use of water resources, preventing pollution and water depletion. .
- Joint research, assessment and planning in flood management by both nations.
- Joint task force for monitoring of water quality and prevention of pollution.
- Joint commission for preserving conditions for natural migration of fish and other aquatic fauna.
- To develop the common guidelines for river basin water management.
- To developing joint hydrological monitoring and pollution control procedures.
- Developing tools for information exchange on managing water measures.

Overcoming Environmental Barriers
Focus on studies on the Selenga Delta habitat and issues related with water quality, including toxic pollutant and nutrient loading, water fluxes, sedimentation effect, and the wellbeing.

- Developing and analyzing the impact on delta flora and fauna of changing water conditions, including recommendations on optimal flows, as well as in-stream constructed wetlands.
- Integrated solution for the surface and ground water resources management of the basin and pollution issues.
- Hot spot analysis of pollution of Baikal basin, including a prioritized list of projects to be considered for future investment, the development of prefeasibility studies and revised regulations to

reduce industrial pollution loading in the Baikal/ Selenga basin.
- Joint actions to enhance ecosystem protection.
- Joint Russian-Mongolian Task Force on Trans-boundary Water Use and Protection.
- Establishing the infrastructure (transport, energy, waste management, waste recycling, waste water treatment) regarded as an obligatory standard by investor, then they could be the basis for a sustainable tourism development.
- Eco-tourism should be promoted where tour agency should take into consideration the criteria for sustainable tourism.

Conclusion

Lake Baikal and Baikal basin is one of the very important regions in the world because the lake has 20% of world's fresh water and great biodiversity hub. It is difficult to explain the global significance and quality of Lake Baikal itself and by extension the greater Baikal basin in which the Lake exists. Baikal is the world's oldest (>25 million years), deepest lake (1642 m). With 20% of the Earth's unfrozen fresh water, it is the world's most voluminous lake containing more water than all five of North America's Great Lakes combined. The diversity of flora and fauna found in Lake Baikal is higher than any other freshwater lake in the world which is getting impacted by the human activities and above stated reasons in the region. The suggested strategy will help in containing the loss and give a sustainable approach for government and local communities to cooperate and save this great significant lake and basin.

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