NATURAL AND ANTHROPOGENIC FACTORS OF THE AMUR RIVER RUNOFF FORMATION

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The Amur River is one of the greatest rivers in East and North-East Asia. Compared to rivers, flowing into the Pacific Ocean, the Amur River basin has the largest area (1 855 000 sq. km). Its drainage system is spread over territories of four countries, namely the southern part of the Russian Far East (1 003 000 sq. km), North-East China (820 000 sq. km), East Mongolia (32 000 sq. km) and a small territory of the North Korea along the coast of Lake Chonjy and a part of its water area (about 5 sq. km).

The plan of the Amur River basin resembles a triangle with its peak directed to the center of Asia and its bottom line stretched along the shores of the Sea of Japan and the Okhotsk Sea for 1500 km. Amur basin northern boundary mostly coincides with mountain ridge axes and its southern boundary predominantly crosses lowland territories. The basin is asymmetric if viewed orographically. Mountains with abundant terrigene ciliceous and carbonaceous rocks prevail in its northern part. Its southern part is mostly composed of lowland territories with Cenozoic unconsolidated sedimentary deposits and hills with various rocks of sedimentary and magmatic origin.

In the Neogenic and Quaternary period of the river net development substantial river changes occurred owing to not high mountain divines between watersheds of the Amur tributaries, volcanic activities and intensive tectonic movements. For quite a long period of time Zeya and Upper Amur systems belonged to the Lyaohe river basin and flew into the Yellow Sea. Only at the end of the Pliocene the Amur river acquired its modern flow direction, although some changes occurred even later. During Glaciation and Late Quaternary period the Upper Vitim basin (the Lena River system) was part of the Amur basin with the runoff into the Shilka River. At some stages of relief development the Amur basin expanded due to river net of the Tugur River, which now flows into the Tugur Bay of the Okhotsk Sea.

Such general geographic characteristics as latitudinal and latitudinal zoning, meridional segmenting account for distinct natural differences in the river basin. Forest and steppe zones dominate. The northern part is covered with coniferous forests (larch and pine grow in the west and spruce and fir in the east), whereas mostly broad-leafed-coniferous forests cover the Sikhote-Alin and Khingan mountain ranges and spread over mountains further to the southern boundary of the Amur basin. Plains in the southern part are tallgrass steppes.

In the north of the river basin high mountains over 1400 m have only mountain tundra without any trees. Approximately 30 % of basin area is a territory of permafrost rocks. Bogs with up to 2.0 meters peat layers are widely spread throughout this territory and to the south of it.

Average annual Amur runoff is 369.1 cu km of water (Mordovin, 2001), 263.6 cu km of which are formed in the Russian part of the river basin (6.4% of Russian total). Chinese and

Mongolian portion is 105,5 cu km, which is 46.2% of additional water resource that comes from neighboring countries.

Viewed from long-term river regime standpoint Amur runoff distribution is not stable. The maximum record 459.2 cu km (1985) nearly twice exceeds the minimum 250.8 cu km (1979). Annual maximum discharge fluctuations are even more contrasting and range from 15 to 40 thousand cu m/sec (Fig. 1). Absolute maximum exceeds absolute minimum more that 65 times.

Amur River water supply is rather stable. The main water source remains precipitation, supplying 70-80% of water. Under ground waters contribute 17-25% and snow melting in spring floods adds 2-7%. In years, when the water level is high, the portion of precipitation increases and vice a versa, in years of low water under ground waters become the major water source.

There are four distinct phases in the Amur water regime: spring floods, summer low water, summer and autumn floods and winter low water.

Spring floods are formed due to snow melting coupled with rain and wet snow storms. This phase lasts up to 2 month in the Lower Amur region. In winter precipitation is less mineralized than in summer. Average snow mineralization is 12-40 mg/cu dm, 115 mg/cu dm being its maximum (Pogadaev, 1990). HCO , SO, CL , Mg , Na, K, Ca prevail in snow composition. Dust storms mostly happen in late winter and spring. They color snow in yellow and yellow-red. A yellow snow on February 14, 1966 covered more than 2 000 sq. km in the Lower Amur and its mineralization reached 70 mg/cu dm. Even more intensive dust storms were registered in April 2001 and 2002. They frequency evidently increased in the last decade. The dust mainly comes from semidesert areas in North-East China and East Mongolia.

A short period of summer low waster is usually registered at the end of June and beginning of July. It lasts less 30 days in most years and is characterized by insignificant precipitation or none at all. During this time water is mostly supplied from under ground waster sources, lakes and swamped areas.

The phase of rain floods in the Amur hydrological regime usually lasts from July to September or October. This period is often characterized by 1 to 5 distinct high water peaks, down the river gradually turning into one long period of high water. High water levels, flood plain and lakes overflow prevent ground waters drainage into the river. Thus, total mineralization of river water is only 10-60 mg/cu dm as precipitation mineralization in summer is 7-9 mg/cu dm average (Pogadaev, 1990).

Winter low water period is the longest, lasting from November to March. Water level drops down and reaches its minimum in March. Absence of liquid precipitation and deep soil freezing account for main water supplies from riverbed alluvial sediments and water-bearing mellow soil horizons. Average Amur water mineralization in winter is 80-150 mg/cu dm, with maximum peaks up to 3000 mg/cu dm in low-water years.

One of the Amur water regime peculiarity is the distinct repetition of 8 to 15-year periods of low water and high water. For the last fifty years high water periods occurred in 1951-64, 1980-91, whereas 1964-79, 1992-2003 were the periods of low water. Moreover the contract between the peaks of water parameters is increasing. Extremes of all parameters, such as runoff volume, water level and water discharge, suspended matter discharge, have been registered in previous years. No doubt, this is the result of growing industrial activities in the river basin. Besides the Amur runoff formation is influenced by global climate changes, that caused recent 10-15% increase of precipitation in the Amur River basin (Novorotsky, 2002). Such increase of Amur water regime instability might worsen ecological situations and cause qualitative and quantitative changes in water ecosystem.

Extremely low Amur water in 2000, 2001 and 2003 caused intensive etmogenic processes, drying and overgrowth of lakes and sub-streams, degradation (drying and productivity decrease) of flood plain ecosystems. Low water caused water temperature rise, which resulted in active algae growth, overgrowth of dry bottoms of lakes and sub-streams. Covered later with water, vegetation died and heavily enriched water with organic matter, which with floods in autumn was transmitted into the Amur River. Thus, quantitative changes of the Amur runoff had a significant impact on Amur its water quality.

The most serious impact and intensive hydrological regime changes are caused by hydro-power stations, mostly the three big ones, namely Zeiskaya and Bureiskaya in Russia and Funmanskaya in China. Total area of their regulation does not exceed 10% of the river basin. Nevertheless they drastically change the river runoff and cause significant transformation in the Middle and Low Amur water regime.

For the recent 30 years after the construction of Zeiskaya hydro-power station industrial activities impact has been getting worse. Amplitude of annual water level fluctuations in the passage from Blagoveshchensk to Nikolaevsk-on-the-Amur reduced from 2.0 m to 0.6 m, but water level in winter there raised from 1.0 m to 0.1 m. Runoff distribution changes throughout the year caused transformations of the river bed and water chemical composition, particularly in winter, higher water temperatures in summer, and other processes, which negatively effect river water ecosystems.

Zeya natural water discharge in winter used to be 60-100 cu m/sec. After the hydro-power station was put into full operation water discharge reached 600-700 cu m/sec, thus rising winter water level throughout the Amur. Average amplitude of water level fluctuations in the passage from Blagoveshchensk to Khabarovsk decreased for 2.3-1.0 m.

Amur runoff changes due to economic activities in the river basin brought about negative processes in stream and flood plain ecosystems in the Amur river valley. After 10 years already in most big tributary junctions large accumulative relief forms appeared as floods in the tributaries continued but water discharge in the mainstream lower the dam became much less.

More active now are processes of islands join the main river banks. As ground water level drops, productivity of flood plain meadows decreases and bushes start to grow there. Long-term large-scale changes of water regime are predicted, including Low Amur flooding expansion, intensifying the ecological load on Amur water ecosystems in summer, changes in pollution distribution in water and bottom sediments in the Tatar Strait and the Sakhalin Bay.

Byreiskaya hydro-power station full operations will deepen the impact on Amur water regime and hence on other components of natural environment, especially in the flood plain and adjacent lowland territories.

The Amur ranks among rivers with a high natural pollution level. It discharges into the world ocean approximately 24 million tons of suspended matter. Average water turbidity is 90 mg/cu dm. Suspended matter discharge with equal amount of water increased by 14% in recent 15-20 years as the result of man activity in its basin, plough land expansion in the North-East China in the 1950-ies in particular. In 1998 because of Sungary River floods water turbidity grew and reached its maximum (over 400 mg/cu dm) even in overall low water conditions.

Terrigene material presence in the Amur River is explained by several factors, the most significant of them being highly intensive river-bed deformations and low steadiness on river banks. Bank erosion rate is 50 meters per year, the standard average being only 6-12 meters. Most intensive is the erosion in lowland river passage, where the stream is constantly redistributed between the sub-channels. Most active bank destruction processes occur in areas of complex economic activities (Khabarovsk, Komsomolsk-on-the-Amur, Poyarkovo), and junctions of big tributaries with dams (the Bureya and Sungary rivers).

Solids discharge increases due to soil cultivation, timber harvesting, fires, embankment and dam constructions (300 km long on the Chinese side of the Middle Amur), which undermine river-bed steadiness and stimulate erosion processes. Flood plain ecosystems suffer different transformations, mainstream undergoes subdivision into channels, big shoals are formed, water current and runoff volume fluctuations deepen. All these processes endanger sustainable conditions of Priamurje water ecosystems.

Water chemical composition has been greatly changed as well, coupled with seasonal and long-term fluctuations. Annually the river discharges into the sea 18.3 million tons of dissolved substances and 5.5 million tons of organic matter (Chudaeva, 2002). Economic activity impact is also extensive. For example, the Russian side is responsible for 1 billion cubic meters of sewage, which annually pollute the Amur, 400 million tons being contaminated and 15% not treated at all.

Water chemical composition changes throughout the river and in time. It characteristics are not yet studies to the full. Main pollutants include ammonia and nitrite nitrogen, phosphates, iron, oil products, phenols, heavy metals (mercury, lead, copper, zinc, etc.). Chlorine-containing organic substances are most poisonous. The Sungary River brings from China lots of dissolved material. Its share in overall Lower Amur pollution is ranges from 60 to 90% of estimated parameters.

Owing to increase of industrial, agricultural and sewage contamination of Lower Amur tributaries in the last decade, the concentration of dissolved substances, especially organic matter significantly rose, thus causing changes of water quality, the worst being in winter. For many years already (1996-2004) the water in winter down the stream gets an unpleasant smell and "chemical" taste.

The Institute of Water and Ecology Problems, Far Eastern Branch of the Russian Academy of Sciences (IVEP FEB RAS) in 2003 carried out a survey on the impact of big cities (Blagoveshchensk, Khabarovsk, Amursk, Komsomolsk-on-the-Amur) on water quality in the Amur River. Their share in total river pollution was found to be not very significant. Nevertheless, cumulative effect of such pollution in respect to bottom sediments and low selfpurifying potential of the river, whereas the transboundary impact is strong, should be kept in mind.

Surveys of the present-day dynamics of the Amur river bed revealed certain trends in river channel processes and flood plain formation (Makhinov, 2003). New phenomenon was identified and called “directed accumulation of sediments”. It determines the development of natural complexes in 1400 m long segment of the Middle and Lowed Amur valley.

Directed accumulation has a specific influence on the formation of the river-bed, flood plain, lakes and adjacent lowlands, which in its turn decisively influences the structure and evolution of soil and vegetation, bogs formation and natural complexes development not only in the flood plain, but in the vast neighboring territories. Future surveys of river regime transformations due to significant natural factors are challenging and, no doubt, will reveal previously unknown regularities of natural complexes functioning in specific conditions of geodynamic processes.

Biological components of natural complexes undergo drastic changes under anthropogenic impact as compared to natural factors. Forest fires constitute the heaviest burden and 80% of them are caused by men. 90% of total forest area in the Amur basin was transformed because of fires. IVEP FEB RAS research indicated strong impact of fires on all landscape components, such as soil, flora and fauna, water quality. Water temperature regime and chemical composition transformations in rives that flow through fire endangered territories increase concentrations of solids and dissolved matter in the Amur runoff in summer.

The Amur River ranks first in the North-East Asia by the amount of suspended sediments and substances of anthropogenic origin, discharged into the sea. It is the main source of pollution of the Okhotsk Sea and the northern part of the Sea of Japan with oil products, heavy metals and various organic components.

Unique geographic position of the Amur estuary, blocked from the sea by the Sakhalin Island, as well as specific water and ice regimes there, determine complicated dynamics of currents and sedimentation in the estuary and formation of delta and flood plain in the Lower Amur. Interrelation of continental and marine factors in river runoff and sediment distribution result in delta fragments formation (Oremif and Vospry islands) and unique coexistence on a small territory of different ecosystems – from tundra to coastal high-grass meadows.

The Amur estuary is an important geochemical barrier, where sedimentation is intensive. But strong current and ice regime specifics prevent sedimentation in Amur estuary and liman. Nearly all terrigene material is carried from the estuary into the Sakhalin Bay and the adjacent part of the Okhotsk Sea, where is it caught by sea currents, transported far south and further gradually distributed in the southern part of the Okhotsk Sea. The Amur estuary presents a unique contact zone, where geomorphologic, hydrologic and biologic processes intervene. To our regret, no complex studies of this area have been undertaken so far.

Anthropogenic impact on the Amur basin ecosystems coincides with natural river dynamics, determined by global climate changes. On the Russian territory landscapes undergo insignificant transformations and even some virgin natural landscapes are preserved. Although the region is characterized by specific geographical location and many unique natural processes, transformations of its natural environment are still little studied, thus making various assessments and predictions less reliable.

Recently obtained results of different natural components studies serve a solid foundation for complex research of water ecosystem functioning regularities in the Amur river basin, their transformations caused by natural and anthropogenic factors, as well as for assessment of Amur runoff impact on Okhotsk Sea marine ecosystems.