AMUR TERRIGENE AND CHEMICAL DISCHARGE FORMATION

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The main water runoff from the continent surface into the Pacific Ocean is directed from Eastern Asia. The biggest river systems are the Amur, Yangtze and Mekong which together with water discharge great amounts of terrigene, dissolved and organic matters. In the 20th century they turned out to be the main source of different anthropogenic substances carried out into the World Ocean. The Amur River system is the biggest in the northwest part of the Pacific.

Table 1.Mail Hydrological Characteristics of the Amur River (Pogadaev, 1990; Chudaeva, 2002)

Characteristics	***Values***
Multiyear average water runoff, km^3	369.1
Annual maximal runoff, km^3	459.2
Annual minimal runoff, km^3	135.0
Maximal discharge, m^2/sec	40 000.0
Minimal discharge, m^2/sec	153.0
Annual average suspended matter discharge, mln tons	24.0
Annual average water turbulence, mg/dm^2	90.0
Maximal water turbulence, mg/dm^2	517.0
Annual average dissolved matter discharge, mln tons	20.2
Annual average organic matter discharge, mln tons	5.3

The Amur basin is situated within several areas being different in their geological structure. Its northern and western parts lie in ancient Paleozoic structures of the Mongol-Okhotsk folded system stretching from the Amur source to the Amgun River. Mountain ranges are composed of terrigene-siliceous-carbonaceous sediments. Depressions are filled with younger sediments, Jurassic marine sand and slate sediments at the bottom and Cretaceous and Paleogene continental sandstone and coarse gravel sediments on top. The Mongol-Okhotsk geosynclines are characterized with numerous large faults and relatively low magmatism. Relief is formed with low and middle-height mountain ranges and intermontane plains overlapping at trough, such as Upper Amur, Upper Bureya, Upper Zeya, etc.

Large tectonic structures of the North-Manchzhursky, Bureinsky and Khankaisky massifs form the south and southeast part of the basin. They are remnants of the Chinese platform split in Pre-Cambrian. A horst, the Bolshoi Khingan Ridge anticline, takes the major part of the North-Manchzhursky massif. Paleozoic and Mesozoic sediments with granite and granodiorite inclusions compose the ridge. Effusive rocks, represented by quartz-porphyry and rhyolites, are vastly spread. Crystalline rocks of the Bureinsky massif in the west are covered with Cretaceous and Paleogene-Neogene unconsolidated sediments of Zeya-Bureya intermountain trough. On the rest of the territory they come to the surface in the form of Proterozoic metamorphic formations such as gneisses, quartzites, slates, phyllites and marbles. In the Khankaisky massif Late Proterozoic and Early Paleozoic rocks like sandstone, slate and limestone are common.

The most eastern part of the Amur River basin situates within the Sikhote-Alin folded area, which itself is a component of the East-Asian mobile belt. Heavily dislocated sediments are mostly composed of Jurassic and Cretaceous sandstone and slates with numerous intrusions of various composition: from granites to pyroxenites. Porphyries, basalts and andesites effusive formations are also well-presented. Middle-Amur, Udyl-Kizinskaya and Evoron-Chukchagirskaya vast intermountain depressions in this zone are composed with unconsolidated Paleogene-Quarterly formations up to 1400m thick.

Peculiar geological and geomorphological conditions determine the complex structure of the Amur valley. The river cuts through and passes mountain massifs and wide plains.

Most of its terrigene discharge is formed in the Middle-Amur. This 1000km-section includes the junctions of the biggest river tributaries: the Zeya, Bureya, Sungari and Ussiri Rivers, which compose 65% of water runoff and 90% of terrigene discharge. The major part of the Upper and Middle Amur area has low- and middle-mountain relief with 400-500m deep ruggedness. Steep slopes, widely distributed hard magmatic and metamorphic rocks produce particles of substantial size. Thus suspended matter discharge is comparatively small and rivers have low turbidity even in flood time.

The big Amur tributaries that flow though the plain areas produce most of the sediment flow in the Middle-Amur section. Clay and silt are mostly common. Active processes of riverbed changes in this river section cause water turbidity increase up to 400-500 mg/l and major detrital deposits.

In the Lower-Amur section together with banks washing out eolian processes generate much of detrital deposit formations. Amur eolian processes have two peaks: one in spring and one in autumn, a spring one being rather long from April to June. In April a lot of eolian material accumulates in ice and is carried towards the river mouth. In spring and the beginning of summer the river water level is rather low and drifts appear out of the water surface. Thus the strong wind blows away plenty of fine sand and dust.

At the end of interglaciation period and during the last Glaciation (30-12 thousand years ago) alluvium intensively filled the Lower and partially Middle-Amur valleys. Alluvium accumulation rate at that time was the highest in the Amur history. Vast areas of the middle-Amur lowland were covered with big shallow lakes. Alluvium accumulation regressively penetrated into the mountain territories. Later the overall river cutting and valley deepening took place.

Nearly 7 thousand years ago detrital deposits started to accumulate in the 1200 km passage from the mouth of river upstream. And this process is still going on. Its intensity is estimated 1.2 mm/year (Makhinov, 1990, 1999). At the result many lakes have been formed at tributary junctures. They play a regulatory role in water runoff and sediment discharge in summer.

In recent decades more sharp becomes the contract between maximums and minimums of such hydrological characteristics as water runoff, levels, turbidity, alluvium accumulation, and riverbed process intensity, thus causing irregularities of water, dissolved and solid matter discharge into the sea.

Suspended matter discharge also follows general geographic regularities. In the Russian section of the river its module changes from 8 to 32 tons/km^2 per year, with maximum amounts (20-32 tons/km^2 per year) on the Zeya-Bureya plain and in the Khanka Lake basin. The minimum suspended matter discharge module (less than 100 tons/km^2 per year) is characteristic for the river basins in the mountains Sikhote-Alin, Badzhal, Bolshoi Khingan and others.

Discharge changes throughout the year follow the evident decrease of the annual discharge anomaly amplitude in recent 20 years. Although in the last 80-year period positive anomalies dominated and increased with every period of high water level.

Amur runoff volume is assessed as generally increased by 10-12% in a hundred-year period due to precipitation increase in the Amur River basin, mostly in its lower reach. From 1891 to 2003 total precipitation in the cold period of the year (November – March) increased 2.0 times, and in its warm period (April – October) – 1.22 times (Butova et al., 2004). In the same period Amur basin moisture as a whole increased by 31%. Still, the Amur runoff volume did not increase much as the process was not only influenced by evaporation intensity due to air temperature rise in the region but mostly by water consumption, especially for agricultural purposes in the Sungary basin.

Multiyear suspended matter discharge regime shows general correlation with water discharge. Increased discharge was registered in 1960-ies, decreased discharge in 1970-ies and increased discharge again in 1980-ies. It is impossible to identify the trends of this process precisely because observation period was rather short and did not include several suspended matter discharge cycles. Comparisons with Sungary (Tsyamusi) suspended matter discharge in 1980-ies and 1960-ies, when runoff volumes were similar, reveal 8-10% increase of water turbulence and suspended matter discharge during the two decades.

On the whole Lower Amur suspended matter discharge shows the positive balance. In high-water periods turbid water flows from the river into the lakes and lots of terrigene material sediments there. Even ore sediments accumulate in the floodplain during floods. In the Amur Lower this figure comes to 20 mln tons. Only in the passage from Khabarovsk to Komsomolsk-on-Amur 5.0 mln tons of suspended matter are accumulated annually as average. Such dynamics of suspended matter discharge cause the formation of drifts and Amur valley bottom uplift at rate 1.0 mm per year. Sediments are accumulated in the river bed, floodplain and floodplain lakes, which are formed around the mouths of the Amur tributaries. As the biggest suspended particles sediment first, so down the river suspended matter is of more fine composition (Table 2).

Table 2. Changes in suspended particle size in the Amur Valley

Location	*Particle size, mm*					
	1-0.5	0.5-0.2	0.2-0.1	0.1-0.005	0.005-0.001	<0.001
Khabarovsk	24.2	38.4	11.7	6.9	18.8	-
Komsomolsk-on-Amur	4.6	21.8	8.9	5.3	20.6	38.8
Bogorodskoye	0.2	5.3	9.6	18.6	44.6	21.7

Transfer of fine-particle sediments through the river into its estuary has negative effect on the Amur delta formation. Runoff and tidal currents in the estuary and the Tatar Channel are strong (stronger than in the Lower Amur) and changing their directions. Shallowness of the estuary and the adjacent sea areas together with high wind waves during storms contribute to bottom sediments suspension and their transfer from the shores far into the sea.

Ice plays quite an important role in bottom sediment transfer in the estuary and the Tatar Channel as well. Mechanisms of including terrigene material into ice are intensive in shallow areas, sand banks and surroundings of Oremif and Vospry islands, which are the only above-water elements of the Amur delta. Terrigene content in ice may be 10 kg/m^2 (Makhinov, Ivanov, 2001). Bottom sediments transfer with ice provides a stable balance between terrigene input and output in the Amur estuary.

Directed accumulation in the Lower Amur valley significantly reduces terrigene material discharge into the sea. 20 mln tons of suspended matter sediment here each year. Such sediment accumulation determines specifics of several factors that effect ecological situation in the Lower Amur, its estuary and adjacent areas of the Seas of Okhotsk and Japan.

Sediment accumulation causes peculiarities and active dynamics of riverbed processes. The Amur riverbed is of multi-sub-stream type, which is characterized with complicated combination of sub-streams. They are of different size, relatively not deep (5-7 m) and with currents less strong than in mountain parts of the river. As the result summer water temperature rises up to 26^0C in some years. Thus the Amur is a source of large warm water masses that come into the southwest Okhotsk Sea.

Increase Amur runoff cause active riverbed deformations, such as the appearance of broad zones of young and low flood-plain massifs along big streams in the lowland areas of the valley. The rate of banks washing out is 10-20 meters per year. Thus large moving spits 2x10 km in size are quickly formed, causing further division of streams, accumulation of sediments in big amounts and thus reducing their transportation possibilities. In some parts of the river redistribution of runoff between the sub-streams leads to bank washing out even in winter. This is characteristic of sub-streams with curve linearization.

Erosion basis uplift in the Amur valley due to sediment accumulation causes the expansion of lakes and their transgression along the sub-stream valleys. Many lakes are more than 50 km^2 in size. Flat slopes in the Lower Amur undergo rapid swamping, which changes chemical discharge pattern and increases suspended and organic materials discharge into the river.

Amur runoff irregularity mostly intensified in summer is responsible for organic matter content fluctuations. In extremely low waters, registered in 2000 and 2001, dried bottoms of lakes and sub-streams were covered with vegetation. When the water level rose in autumn the Amur carried out into the sea huge amounts of biomass similar to a volley-discharge.

Excessive permafrost in the northern Amur basin is an important factor of river chemical discharge formation. Its thickness reaches 500 m and temperature is up to -5^0 C. Permafrost significantly reduces underground water flow and thus its dissolved matter discharge. Other important discharge regulative factors are bogs, swamped areas and underground flow from plains.

Anthropogenic impact on the Amur basin ecosystems coincides with natural river dynamics, determined by global climate changes. On the Russian territory of the basin 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 urgent the study of the formation of Amur runoff, dissolved and organic matter discharge as well as their impact on marine ecosystems.

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