GROUNDWATER DISCHARGE INTO THE WORLD OCEAN

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Contents

Summary

It is discussed the present-day state of the art of groundwater influence on water and salt balance of seas and oceans. This work represents the methods of a regional quantitative assessment of groundwater discharge to seas that permits on the base of analysis and processing the available hydrological and hydrogeological information to determine a groundwater inflow from land directly to seas by passing the river network. The international experience in studying the surface and groundwater interaction and assessing the role of groundwater in formation of water and salt regime of seas and large lakes in the coastal zones is briefly characterized. Approximate results of groundwater discharge assessment to the World Ocean with description of groundwater discharge from 1 km^2 of the catchment area and to the 1 km of sea and ocean coastal line are given. This paper informs about groundwater and salt discharge from each continent to the separate oceans and the World Ocean in the whole that characterize the total groundwater contribution in the global hydrological cycle and continental water balance.

1. Present-day concept of groundwater discharge into seas and oceans

Groundwater discharge into seas and the World Ocean occurs by three different, in essence, ways:

- as juvenile water, formed due to the Earth mantle degazation;
- with the river run-off as a subsurface component of it, and
- as groundwater discharge, formed in the land and discharged directly into the sea, by passing the river system

Juvenile water discharge into the ocean is a “subsurface” component of the water balance of seas and oceans, but, probably, the term “groundwater discharge” is irrelevant here. This aspect is complex enough and closely connected with a general problem of forming hydrosphere and of water origin. At present quantitative assessment of juvenile water inflow into seas is quite difficult. It is assumed that annual volume of juvenile water, inflowing out of volcanoes, hot springs and faults, does not exceed 1 km^3; this value is extremely small for the present balance of the World Ocean. At the same time annually a certain volume of water is excluded from the total circulation, and primarily, water of the crystal lattice of mineral sediments. The volume of juvenile water inflowing from magma approximately corresponds, in the most investigators' opinion, to the water volume excluded from circulation due to sedimentation.

Drained by rivers groundwater discharge is the second way, and the technique of its calculating is well developed at present. These discharge inflows into the ocean with the river water, it being a part of the total river runoff in the water balance, and hence is considered in it.

The third way is groundwater discharge directly from the continents into the seas and the World Ocean. This is precisely the component that is usually "lacking" under quantitative investigating of the water balance. Thus by groundwater discharge into seas will be meant the one formed in the land and discharged into seas, passing the river system by. In this case, if a total volume of water of the underground origin in seas and the World Ocean is meant, then it should be considered, that about a third part of the river runoff flowing into the seas is also formed by groundwater draining in the intensive water-exchange zone.

Considering the underground component, a mean perennial water balance of the globe can be characterized by the following equations: for a peripheral part of the land, being discharged into the ocean

$$E_{\text{ï}} = P_{\text{ï}} - R_{\text{ï}} - U_o \qquad (1)$$

for inland areas (not being discharged)

$$E_{\text{ç}} = P_{\text{ç}} \qquad (2)$$

for the World Ocean

$$E_o = P_o + R_{\text{ï}} + U_o \qquad (3)$$

for the globe

$$E = E_{\text{ï}} + E_{\text{ç}} + E_o = P_{\text{ï}} + P_{\text{ç}} + P_o = P \qquad (4)$$

where E - evaporation, P - atmospheric precipitation, R - river runoff, including surface and underground components, U - groundwater discharge from the land into the ocean, passing the river system by. Index: "ï" - peripheral part of the land; "ç" - inland (interior) areas; "o" - ocean.

Similar water balance equations were suggested by a famous Soviet hydrogeologist M.S.Lvovitch, and then were used by many authors. However, introducing of U_o - groundwater discharge, being formed in the peripheral part of the land, not drained by the river system, and passing it by, and discharging directly into the sea or ocean - is principally new in the above equations.

It should be noted that one more term, characterizing sea water outflow from the coast, should be introduced into equations (1) and (3). However, this process in natural conditions is particularly local, thus sea water intrusion into the coast cannot be considered as an element of the World water balance at this stage of investigations.

What is the reason for such an insufficient study of groundwater discharge into seas and oceans? One of the reasons is that it is the only element of water balance that cannot be measured, and there are often no data for reliable quantitative assessment of this element. There was no technique for it up to the present. The other reason is that many scientists thought that if groundwater discharge into seas is not large in comparison to other elements of water balance, then it can be determined as a remainder in the equation of mean perennial water balance. Calculated so groundwater discharge completely depends on the accuracy of assessing the mean values of precipitation, evaporation and river runoff including all the errors of determining them, that totally often exceeds the volume of groundwater discharge directly into the seas. It resulted in wrong conclusions, but the values of groundwater discharge into the sea depended completely on the assumed mean value of precipitation, evaporation and river runoff. Previously made investigations of the Caspian Sea water balance, when according to different authors groundwater discharge values differed almost in 150 times, can serve the most demonstrative example.

Such an approach seems wrong in principle just because groundwater discharge into the sea is not usually a big value, it is essential to determine it by immediate hydrogeological methods. It will make it possible to more reliably form an opinion on the accuracy of calculating other main water balance elements, besides quantitative assessing of groundwater discharge, i.e. to determine a real numerical value of error in calculating water balance and not an error due to groundwater discharge.

Investigations of groundwater discharge into seas do not basically differ from studying that into big lakes, hence all the aforesaid is concerned with water balance of lakes in full measure.

It should be noted that the most considerable investigations of groundwater discharge into separate seas were made by French, Yugoslavian, Italian and Russian specialists. Thus, according to Bodel and Margat (1980), submarine groundwater discharge from the territory of France is about 1 km^3yr^{-1}.

Calculations of groundwater balance, made by modeling the Aquitanian basin indicate that groundwater discharge into the ocean is 10-15 percent of common discharge balance of the Eocene-Paleogene aquifer. The results of assessing the groundwater discharge into the Caspian and Aral seas, the Baltic Sea (former Soviet Baltic territory), and also some big lakes of the former USSR (Baikal, Balkhash. Issyk-Kul) are given in a special professional literature.

Water of the ground hydrosphere due to its occurrence and spreading is subdivided into the groundwater of the land, overlapped by unsaturated zone and is in a close contact with atmosphere, and subaqual groundwater, occurring under the bottom of seas and big lakes and being in a hydraulic connection with them. Submarine water is most widely spread, conditions of its formation, spreading and flow being mainly caused by its interrelation with marine water.

Submarine water by origin is subdivided into infiltration one, formed in the land due to infiltration of atmospheric precipitation and surface water and sedimentary one, formed directly within the sea due to accumulation of sediments and their subsequent transformation.

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