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# 24. Characteristics of Water and Alluvial Transit through the Danube Delta

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Abstract: A part of the Danube's water that runs through the Black Sea to the Danube Delta's main rivers, enters a variety of ways (canals, gorges, and river spills) inside the Danube Delta and the Razelm-Sinoe Lagoon Complex, Black. The measurements showed that the Danube water access to the Delta takes place on the upstream half of the arms, and the evacuation takes place halfway downstream. Knowing the transit of water and alluviums through the hydrographic units within the Danube Delta is of particular importance to the Delta habitat. Danube water transits the Danube Delta's interior through the hydrographic units Sontea-Furtuna, Matita-Merhei, Gorgova-Uzlina, Puiu-Rosu and Dranov-Razelm. Based on a hydrological model elaborated by the author, the water flows and the volumes of water entering and leaving the Danube Delta hydrographic units were determined. The results of the calculations showed that the largest water transit through the Danube Delta is through the hydrographic units Sontea-Furtuna and Matita-Merhei, followed by Gorgova-Uzlina, Puiu-Rosu and Dranov-Razelm. The dates of the measurements of the Danube alluvial flows, carried out in the past and to this day, allowed to know the evolution of the concentration of the suspended alluviums at the entrance to the Danube Delta. Data processing results in a decrease in average annual concentrations of Danube sludge concentrations from average values of about 300 mg/m$^3$ in 1840 to about 80 mg/m$^3$ in 2014. The overall trend of the decrease in time of concentrations of Danube alluvial sediments was mainly due to the hydrotechnical arrangements made in time in the Danube river basin and was accentuated after the barrage of the Danube bed at Iron Gates 1 and 2 in the years 1971 and 1984. The fluctuations in the Danube Delta concentrations in the Danube Delta in the Danube Delta caused time to diminish the access of the river valleys within the Danube Delta and to diminish the Danube delta between the arms. Thus it results that the process of clogging of hydrographic units subject to alluvia is very slow, equal to about 1.26 mm/year in the hydrographic unit Sontea - Storm and 0.51 mm/year in the hydrographic unit Gorgova - Uzlina.

**Keywords:** water and alluvial transit clogging

## INTRODUCTION

In the last 6 millenniums, in the process of forming the Danube Delta, millions of morpho-hydrographic units were created, of which 5 were between Delta's arms (**figure 1**).

Knowing the transit of water and alluviums through the hydrographic units within the Danube Delta is of particular importance for the Delta habitat. The complex scientific researches carried out in the last two centuries in the Danube Delta responded to the deep knowledge of the biological and physical processes in the Delta (Petrescu 1957, Diaconu et all., 1963, Banu and Rudescu 1965).

## MATERIALS AND METHODS

One area of these researches refers to the hydrological research, which has deepened the knowledge of the Danube water flow and alluviums on the main branches and the hydrographic network of gorges and canals inside the Danube Delta. Evidence of the results obtained from these researches is the numerous national and foreign scientific papers that have been published concerning the hydrology of the Danube Delta since the second half of the 19th century.

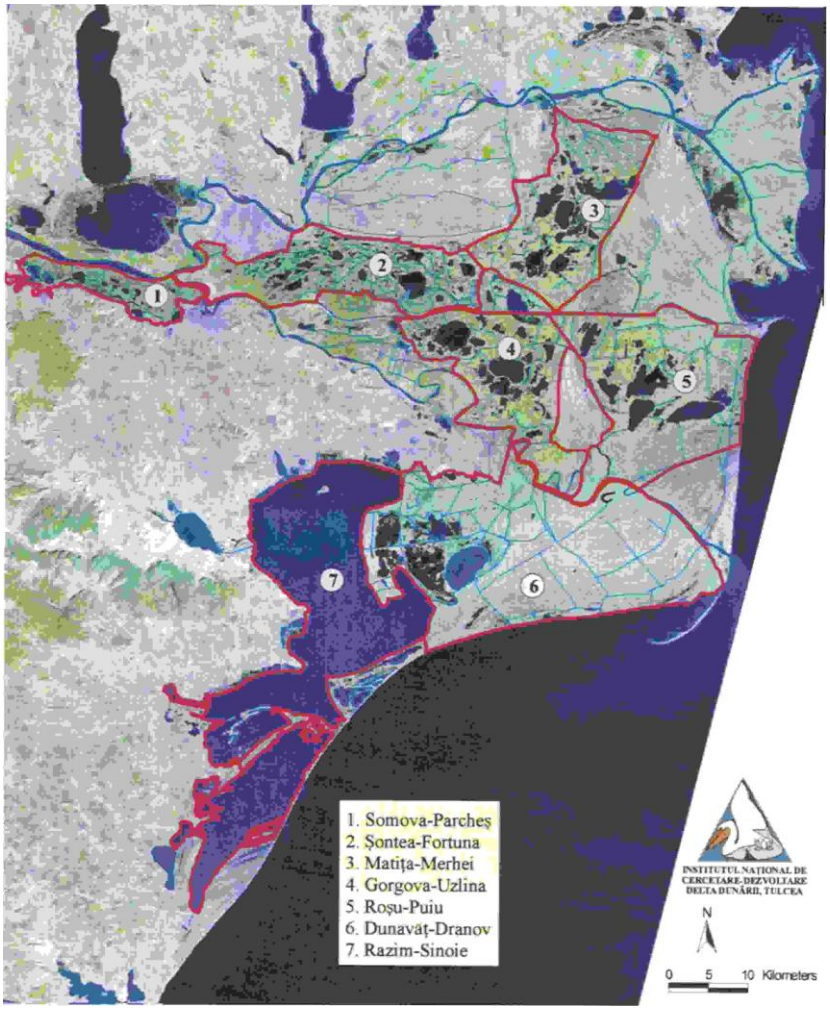


**Figure 1.** Map of the Danube Delta with presentation of morphohydrographic units (2, 3, 4, 5 and 6-7) (Constantinescu, Trache, 2000)

Among other things, the Danube's water and alluvium flows along the main arms and partly on the gangways and canals inside the Danube Delta. The less researched knowledge of the transit of water and alluvium through the hydrographic units within the Danube Delta remained. For this reason, the purpose of this paper is the determination of this insufficiently known component of the Danube Delta hydrological regime so far.

## RESULT AND DISCUSSIONS

**Presentation of the characteristics of the water transit through the Danube Delta.**
Part of the Danube's water that runs through the Black Sea to the Danube Delta's main rivers, enters various rivers (canals, gorges, and river spills) into the Danube Delta and the Razelm-Sinoe Lagoon Complex, Black.
The measurements showed that the Danube River's access to the Delta is on the upward half of the arms, and the evacuation takes place halfway downstream.

The number of access and evacuation routes of the Danube waters in Danube Delta's hydrographical units, with the surfaces and average volumes of the hydrographic units, is presented below:
• **Sireasa-Sontea** hydrofoil unit (sofo) with 10 access and evacuation water outlets, with an average surface area of about 48709 ha and an average water volume of about 0.264 km$^3$;

• The **Matita-Merhei** hydrographic unit with 13 access and evacuation paths, with an average surface area of about 61140 ha and an average volume of about 0.556 km3.
• The **Gorgova-Uzlina** hydrographic unit with 7 access and exhaust water outlets, with an average surface of about 32060 ha and an average water volume of about 0.527 km.
• The **Puiu-Rosu** hydrographic unit with 7 access and evacuation water outlets, with an average surface area of about 47.100 ha and an average water volume of about 0.322 km.
• **Dranov-Razelm** (drrz) hydrographic unit with 5 access and evacuation water outlets, with an average surface of about 139840 ha and an average water volume of about 2.206 km$^3$.
Based on a hydrological model elaborated by the author, the water flows and the volumes of water entering and leaving the Danube Delta hydrographic units were determined. Table 1 presents the results obtained with the hydrological model.

**Table 1.** Stationary data of the annual average water flows, discharged and transited through Danube Delta hydrographic units, as well as the annual average values of water mirrors (Z), water mirror surfaces (S) and water volumes (V) at the annual average (H) levels of the Danube at Tulcea of 0, 100, 180, 300 and 430 cm.

1.1. The Sontea-Furtuna hydrographic unit

| Tulcea level (H) cm | Flow of water tributari (Qaf) mc/s | Water flow effluent (gef) mc/s | Water flow transmited (Qtr) mc/s | Tulcea Level (H) cm | Water mirror ration (Z) cm | Surface water mirror (S) $10^{-3}$ ha | Volume water mirror (V) $10^3$ kmc |
|---|---|---|---|---|---|---|---|
| 0 | 20 | 24 | 22 | 0 | 54 | 20.57 | 88.5 |
| 100 | 65 | 133 | 99 | 100 | 111 | 34.36 | 181.1 |
| 180 | 162 | 269 | 215 | 180 | 161 | 48.71 | 264.1 |
| 300 | 416 | 561 | 489 | 300 | 241 | 77.33 | 528.5 |
| 430 | 1144 | 1050 | 1097 | 430 | 335 | 120.83 | 860.9 |

1.2. The Matita-Merhei hydrographic unit

| Tulcea level (H) cm | Flow of water tributari (Qaf) mc/s | Water flow effluent (Qef) mc/s | Water flow transmited (Qtr) mc/s | Tulcea Level (H) cm | Water mirror ration (Z) cm | Surface water mirror (S) $10^{-3}$ ha | Volume water mirror (V) $10^3$ kmc |
|---|---|---|---|---|---|---|---|
| 0 | 10 | 84 | 47 | 0 | 46 | 50.19 | 252.2 |
| 100 | 65 | 133 | 99 | 100 | 83 | 56.28 | 389 |
| 180 | 243 | 289 | 266 | 180 | 117 | 61.14 | 556.3 |
| 300 | 516 | 473 | 494 | 300 | 175 | 67.52 | 905.3 |
| 430 | 971 | 906 | 939 | 430 | 248 | 71.22 | 1384.9 |

1.3. The Gorgova-Uzlina hydrographic unit

| Tulcea level (H) cm | Flow of water tributari (Qaf) mc/s | Water flow effluent (Qef) mc/s | Water flow transmited (Qtr) mc/s | Tulcea Level (H) cm | Water mirror ration (Z) cm | Surface water mirror (S) $10^{-3}$ ha | Volume water mirror (V) $10^3$ kmc |
|---|---|---|---|---|---|---|---|
| 0 | 8 | 20 | 14 | 0 | 38 | 15.61 | 197.6 |
| 100 | 12 | 60 | 36 | 100 | 100 | 26.57 | 301.4 |
| 180 | 40 | 75 | 57 | 180 | 150 | 32.06 | 427.3 |
| 300 | 108 | 82 | 95 | 300 | 226 | 36.37 | 670 |
| 430 | 206 | 157 | 183 | 430 | 309 | 38.22 | 977.2 |

1.4. Puiu-Rosu hydrographic unit

| Tulcea level (H) cm | Flow of water tributari (Qaf) mc/s | Water flow effluent (Qef) mc/s | Water flow transmited (Qtr) mc/s | Tulcea Level (H) cm | Water mirror ration (Z) cm | Surface water mirror (S) $10^{-3}$ ha | Volume water mirror (V) $10^3$ kmc |
|---|---|---|---|---|---|---|---|
| 0 | 6 | 3 | 4.5 | 0 | 19 | 39.9 | 177.1 |
| 100 | 70 | 15 | 57 | 100 | 39 | 44.28 | 237.6 |
| 180 | 103 | 83 | 89 | 180 | 58 | 47.1 | 322.5 |
| 300 | 150 | 141 | 145 | 300 | 89 | 52.71 | 531.1 |
| 430 | 198 | 224 | 211 | 430 | 128 | 56.64 | 900.2 |

1.5 Dranov-Razelm hydrographical unit

| Tulcea level (H) cm | Flow of water tributari (Qaf) mc/s | Water flow effluent (Qef) mc/s | Water flow transmited (Qtr) mc/s | Tulcea Level (H) cm | Water mirror ration (Z) cm | Surface water mirror (S) $10^{-3}$ ha | Volume water mirror (V) $10^3$ kmc |
|---|---|---|---|---|---|---|---|
| 100 | 47 | 39 | 43 | 100 | 59 | 135.16 | 2019.8 |
| 180 | 86 | 69 | 77 | 180 | 74 | 139.84 | 2206 |
| 300 | 163 | 127 | 145 | 300 | 91 | 144.04 | 2449 |
| 430 | 277 | 211 | 244 | 430 | 104 | 146.22 | 2631.7 |

Further, in Table 2 are presented the data of the average annual flows of water flowing through the Danube Delta through the hydrographic units between Chilia-Tulcea-Sulina, Sulina-Sf. Gheorghe and the southern part of the Sf. Gheorghe branch, under conditions of stationary regime with Danube levels in Tulcea of 0, 100, 180, 300 and 430 cm.

**Table 2** The balance of annual average water flows through the Danube Delta through the hydrographic units between Chilia-Tulcea-Sulina, Sulina-Sf. Gheorghe and the southern part of the Sf. Gheorghe branch, under conditions of stationary regime with Danube levels in Tulcea of 0, 100, 180, 300 and 430 cm.

| Danube level of Water | Danube transit water flow | Danube transit Water flow | Average throughput flow | Danube transit water flow | Danube transit water flow | Average throughput flow | Danube transit water flow | Total Danube transit flow |
|---|---|---|---|---|---|---|---|---|
| Tulcea | Sontea-Furtuna | Matita-Merhei | Sontea-Merhei | Gorgova-Uzlina | Puiu-Rosu | Gorgova-Rosu | Dranov-Razelm | Danube-Delta |
| H(cm) | Qtr-sofo mc/s | Qtr-mate mc/s | Qm-Some mc/s | Qtr-Gouz mc/s | Qtr-Puro mc/s | Qm-Goro mv/s | Qtr-Drrz mc/s | Qtr-Dd mc/s |
| 0 | 22 | 47 | 34.5 | 14 | 4.5 | 0.25 | 19 | 62.8 |
| 100 | 99 | 99 | 99 | 36 | 57 | 46.5 | 43 | 188.5 |
| 180 | 215 | 256 | 240.5 | 57 | 89 | 73 | 77 | 390.5 |
| 300 | 489 | 494 | 491.5 | 95 | 145 | 120 | 145 | 756.5 |
| 130 | 1097 | 939 | 1015 | 183 | 211 | 197 | 244 | 1456 |

Based on the data from Table 2, the graphs of the correlations between the Danube average annual rainfall levels at Tulcea hydrometer and annual average water flows through the Danube Delta hydrographic units are shown in Figure 2.

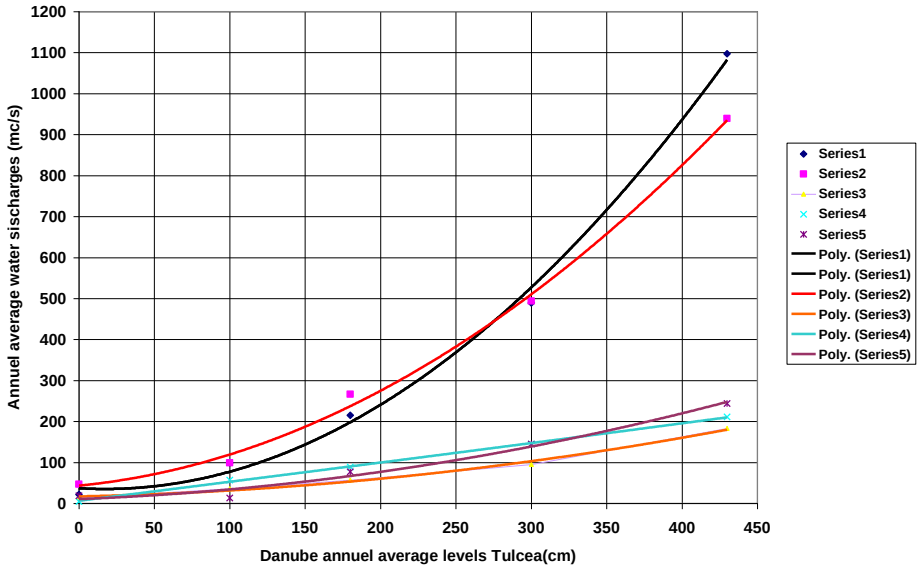


**Figure 2.** The graphs of the correlations between the Danube's annual average annual rainfall at the Tulcea hydrometric mirage and the annual average water flows through the Danube Delta (1 Sontea-Furtuna, 2 Matita Merhei, 3 Gorgova-Uzlina, 4 Puiu-Rosu and 5 Dranov -Razelm).

From the comparison of the graphs in Figure 2, it results that the largest water transit through the Danube Delta takes place through the hydrographic units Sontea-Furtuna and Matita-Merhei, followed by Gorgova-Uzlina, Puiu-Rosu and Dranov-Razelm.
A proof of this finding is also expressed by the way the Danube Delta surface is distributed on the water reflections on the Danube's average level (Figure 3). Figure 3 shows large gradients of variation of the slopes of the water mirror at the entrance to the Danube Delta and their diminution towards the flowing into the Black Sea. Thus, the penetration of Danube waters into the Danube Delta is particularly intense upstream to the Delta.

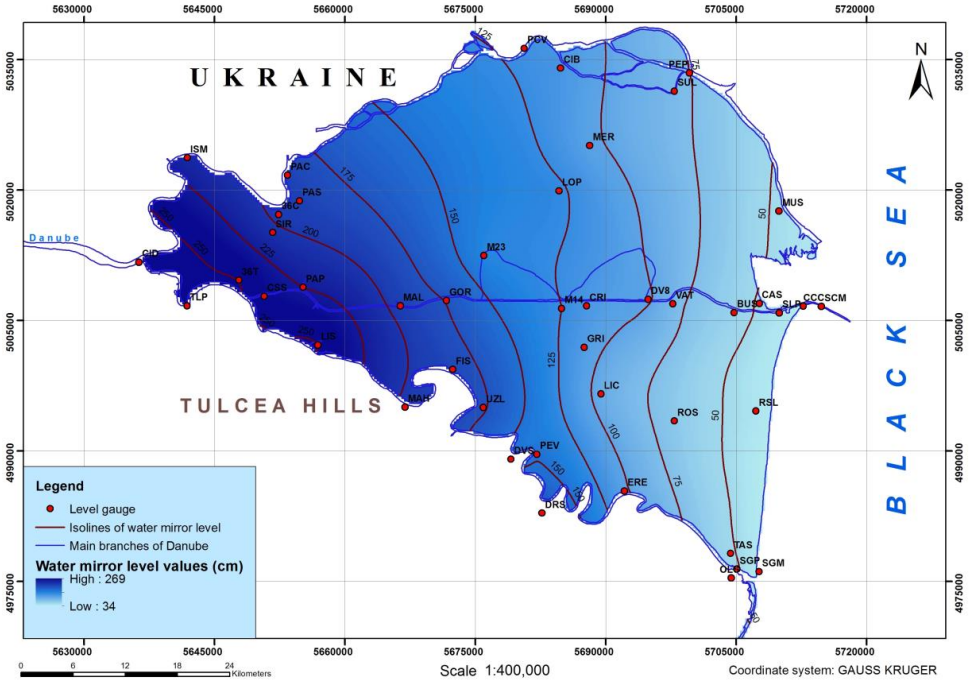


**Figure 3.** Map of the water mirror relief on the surface of the Danube Delta at the average Danube level in Tulcea (Nichersu, 2000).

**Presentation of the characteristics of alluvial transit through the Danube Delta.**
A satellite map of the Danube Delta, shown in Figure 4, shows that the penetration of the Danube's waters into the Delta occurs by dispersing the masses of water over the access ways in the Delta.
The map shows the large inflow of river waters with alluviums in Sireasa-Sontea-Furtuna hydrographic units, Carasu-Gorgova-Uzlina and Dranov-Razelm, because in the Maritime Delta the Matita-Merhei and Puiu-Rosu hydrographic units are less under the influence of the waters river. This characteristic of the spread of river waters in the Danube Delta allows simplified assessment of the Danube Delta.
Thus, only the hydrographic units Sireasa-Sontea-Furtuna and Carasu-Gorgova-Uzlina remain under the influence of climbing.
According to the map of Figure 4, although the color of the lagoon complex Razelm-Sinoe indicates the presence of fluvial alluviums, the hydrodynamic processes in this complex under the action of the waves do not allow the collimation of the nature of the fluvial Delta. Data of long-term hydrological observations and observations made in the Razelm-Sinoe Lagoon Complex confirm these findings.

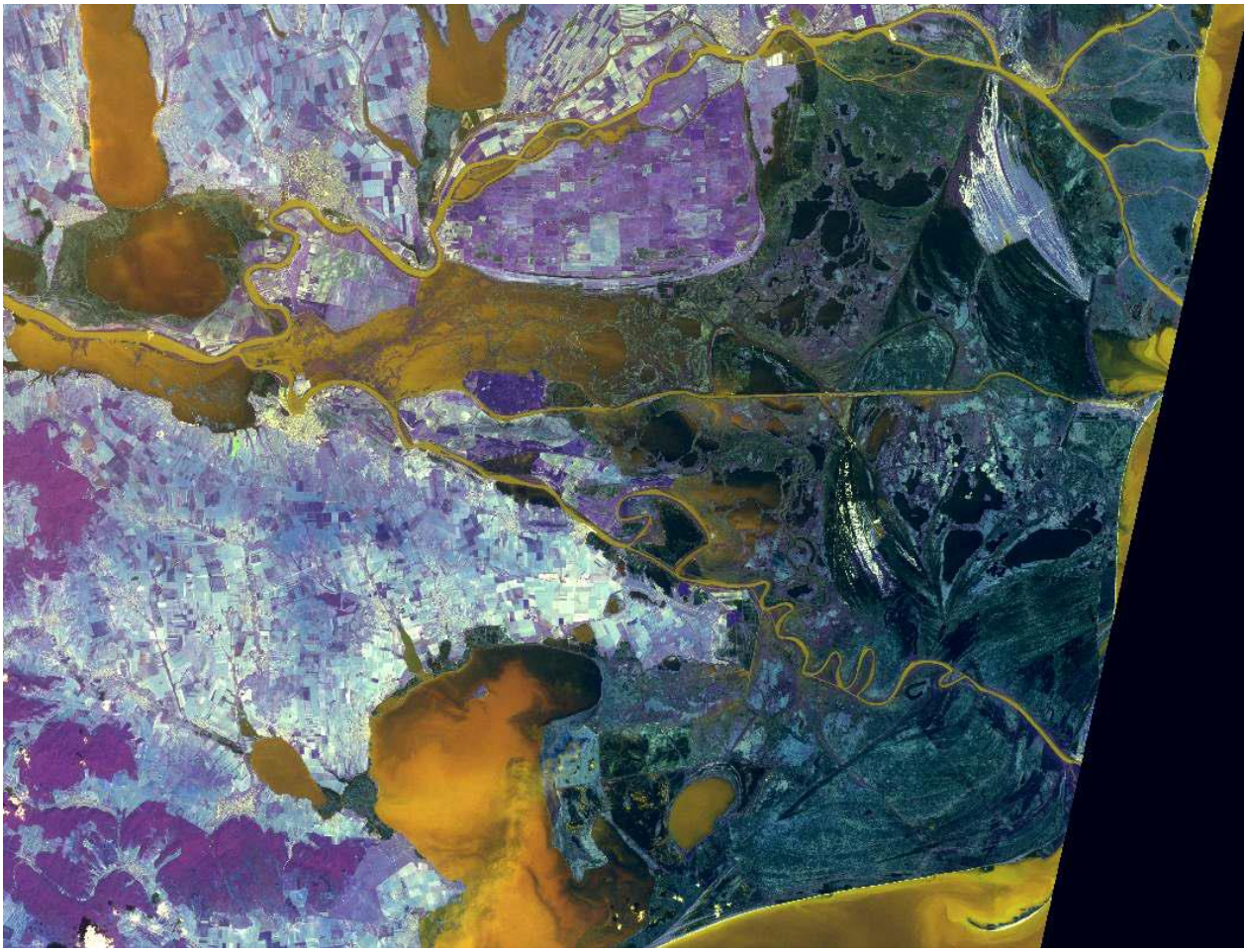

**Figure 4.** The satellite map of the Danube Delta on large waters in May 2006, with the presentation of the way of spreading inside the Delta of the Danube water masses in the Delta (Cioaca.2017).

**Evaluation of fluvial climbing of the hydrographic units Șontea-Furtuna and Gorgova-Uzlina.**
The data of the measurements of the Danube alluvial flows, carried out in the past and to this day, allowed to know the evolution of the concentration of the suspended alluviums at the entrance to the Danube Delta, expressed in **Figure 5**. The graph shows the decrease in average annual concentrations of Danube sludge concentrations from average values of about 300 mg/m$^3$ in 1840 to about 80 mg/m$^3$ in 2014.

The general tendency to diminish the concentration of Danube sludge concentrations over time was mainly due to the hydro-technical arrangements made over time in the Danube river basin and was accentuated after the barrage of the Danube bed at Iron Gates 1 and 2 in 1971 and 1984.
The fluctuation in time of Danube delta concentrations in the Danube Delta has led to a diminishing in time of the fluvial access in the Danube Delta and the diminishing of the Danube Delta between the arms.

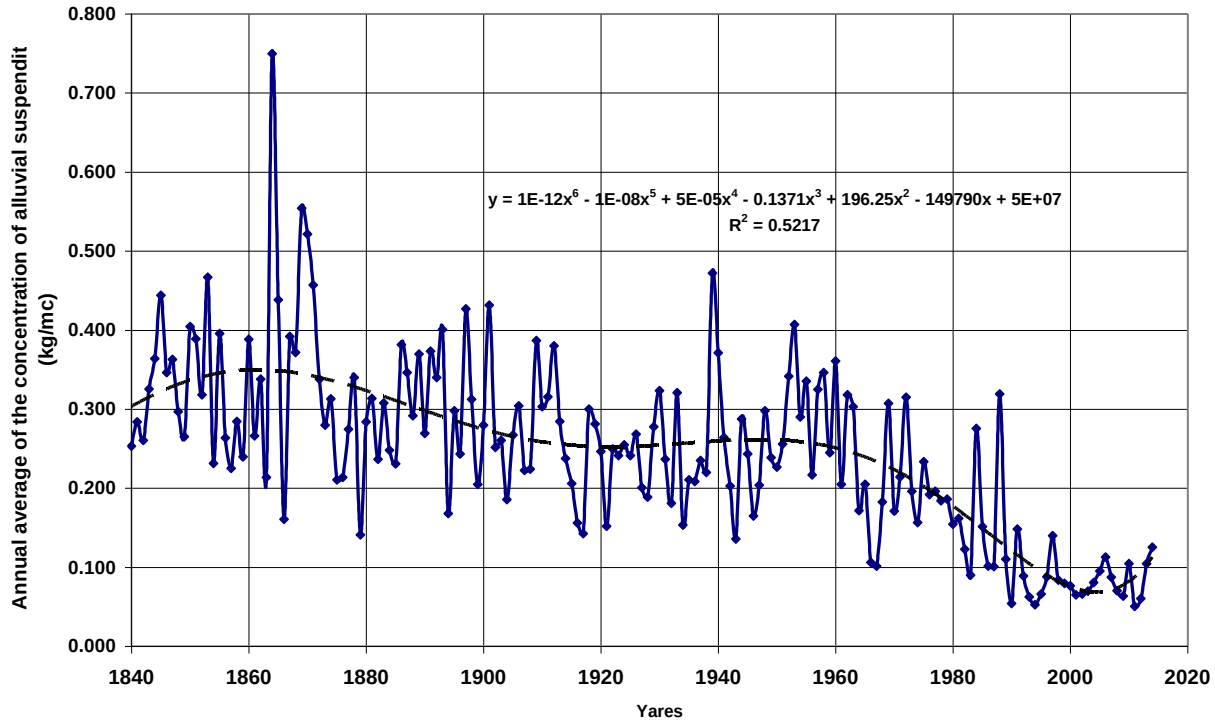


**Figure 5.** Chart of time variation, between 1840 and 2014, of the average annual concentrations of Danube alluvial sediments (kg/mc) at entry into the Danube Delta.

The evaluation of access and clogging of the Danube Delta's interior will be done taking into account the data in Table 2 and the graph in Figure 5. The calculation data are shown in Table 3.

**Table 3.** Calculation data of water access assessment and annual deposition of alluviums in hydrographic units subject to clogging in the year with a multiannual average of the Danube at the Tulcea hydrometric miter of 180 cm.

| Transit water flow through the hydrographic units ($m^3/s$) | Average mean of the alluvial accessed ($kg/m^3$) | Average quantity in the annual alluvial accessed (t/year) | Surface of alluvial deposit (ha) | Mean thickness of the annual alluvial deposit (mm/year) |
|---|---|---|---|---|
| **Șontea-Furtuna** | | | | |
| 215 | 0.246 | 1011564.524 | 48710 | 1.26 |
| **Gorgova - Uzlina** | | | | |
| 57 | 0.246 | 268182.222 | 32060 | 0.507 |

Thus it results that the process of clogging of hydrographic units subjected to alluviary is very slow, equal to about 1.26 mm/year in the hydrographic unit Sontea - Furtuna and 0.51 mm/year in the hydrographical unit Gorgova - Uzlina.

## CONCLUSIONS

A part of the Danube's water that runs through the Black Sea to the Danube Delta's main rivers, enters a variety of ways (canals, gorges, and river spills) inside the Danube Delta and the Razelm-Sinoe Complex.

As a result of the measurements, the access of the Danube water into the Delta has halfway upstream of the arms, and the evacuation takes place on the downstream side.

Knowing the transit of water and alluviums through the hydrographic units within the Danube Delta is of particular importance for the Delta habitat. The complex scientific researches carried out in the last two centuries in the Danube Delta responded to the deep knowledge of the biological and physical processes in the Delta
The Danube water transits the Danube Delta's interior through the hydrographic units Sontea-Furtuna, Matita-Merhei, Gorgova-Uzlina, Puiu-Rosu and Dranov-Razelm.

Based on a hydrological model elaborated by the author, the water flows and the volumes of water entering and leaving the Danube Delta hydrographic units were determined. The results of the calculations show that the largest water transit through the Danube Delta is through the hydrographic units Sontea-Furtuna and Matita-Merhei, followed by Gorgova-Uzlina, Puiu-Rosu and Dranov-Razelm.

The data of the measurements of the Danube alluvial flows, carried out in the past and up to the present, allowed to know the evolution of the concentration of the suspended alluviums at the entrance to the Danube Delta.
Data processing results in a decrease in average annual concentrations of Danube sludge concentrations from average values of about 300 mg/m$^3$ in 1840 to about 80 mg/m$^3$ in 2014. The overall trend of the decrease in time of concentrations of Danube alluvial sediments was mainly due to the hydrotechnical arrangements made in time in the Danube river basin and was accentuated after the barrage of the Danube bed at Iron Gates 1 and 2 in the years 1971 and 1984.

The hidrological fluctuations in the Danube caused time to diminish the access of the river valleys within the Danube Delta and to diminish the Danube Delta between the arms.

Thus it results that the process of clogging of hydrographic units subjected to alluvial is very slow, equal to about 1.26 mm/year in the hydrographic unit Sontea - Storm and 0.51 mm / year in the hydrographical unit Gorgova - Uzlina.

## REFERENCES

Banu A.C., Rudescu l., 1965. The Danube Delta. Technical Publishing House, 1-295 pp.
Diaconu C., Nichiforov J, Iacov D (eds), 1963. Zona de varsare a Dunarii – Monografia Hidrologica [Region of the Danube Delta – A hydrologic monograph]. Institutul de Studii si Cercetari Hidrotehnice, Bucuresti1-396 pp.
Petrescu I.G. 1957. The Danube Delta. Genesis and Evolution. Scientific Publishing House, Bucharest, 1-233 pp.
Cioaca E., 2015-2017. Project Restoration of aquatic ecosystems in the Sontea-Fortuna area- component of Natura 2000 sites ROSPA0031 and ROSCI0065 of the Danube Delta Biosphere Reserve [RESTORATION-DD] “,EEA Grants 2009-2014, RO 02 Biodiversity and Ecosystem Services Programme, Project call no. 3 “Large Ecosystems Restoration Scheme”
Constantinescu A.C., Trache G., 2000. Hydrological models of aquatic complexes Sontea-Fortuna and Gorgova-Uzlina, Scientific Annals of Danube Delta Design Research Institute, vol.VI / 2, Romania
Nichersu I., 2000. PhD thesis “Using Geographic Information Systems in achieving Atlas of Danube Delta Biosphere Reserve

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