Chemism of Streams Within the Siret and Prut Drainage Basins: Water Resources and Management

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This study aims to underline the importance of water reserves in the life of local communities and to quantify the value of certain basic elements that can affect their chemical properties. Most waters in eastern Romania are affected by a relatively high degree of salinity, they have high hardness, or are practically polluted. There is a positive relationship between geologic deposits and salt concentration. Additionally, there is a correlation between the salt waters (Mg and K salts) and an increase in the pH of rivers in the Carpathians and the Curvature Subcarpathians areas. The water salinity within the Moldavian Plateau is due to the dissolution of the salts within the marls and the clays of the geologic substrate and their transportation towards the topographic surface through the capillarity process. Freshwater is used for households and in the industrial sphere.

Key words: rivers, water quality, salinity, pH, geochemistry, underground deposits effects

This research analyses certain chemical parameters (salinity and pH) of the surface waters within the Siret and Prut drainage basins (Moldova – Romania). The connection between the geologic substrate (surface and underground deposits) and the chemical constitution of groundwater was traced. Additionally, this research examines how salt water (especially springs) has been exploited and used within human communities, especially rural communities.

The Siret and Prut drainage basins include the highest population densities in Romania. Under these circumstances, water resources must benefit from efficient management, as the regional climate does not allow for the runoff of a significant amount of water [1].

The Prut–Bârlad Water Basin Administration and the Siret Water Basin Administration annually assess the water resources and closely monitor their quality. Therefore, in the last twenty years (1990–2010), complex expedition campaigns for qualitative analysis of the most important hydrographic arteries took place. Unfortunately, most small rivers were not the object of such research, despite their important role for local communities [2, 3].

The most detailed analyses concern the degree of pollution for streams and stagnant waters. Some chemical parameters (pH or salinity) are neglected because they do not represent important indicators of pollution. Most springs are analysed only from a quantitative perspective, with direct reference to discharge and more rarely to their organoleptic qualities. The sole exception is that of mineral springs with a therapeutic role, but they are rare in the Moldavian Plateau and are more common in the mountain area.

The national and international research regarding salinity and pH is particularly rich and makes special references to very large areas [4-47]. In this study, the aim was to complete a detailed analysis for the most important hydrographic arteries in a small area that suffer from an acute lack of water. Though *p*H is not an indicator of water quality, it is related to the parameters of salinity and to the geologic substrate of the zone [48-51].

The Siret and Prut drainage basins occupy the historical region known as Moldavia (Romania). The left side of the Prut drainage basin is situated in the Republic of Moldova. Both rivers spring from Ukrainian territory, but, for the most part, they flow into Romanian territory [44, 52-54]. Within this area, there are many landform subunits: Eastern Carpathians, Curvature Carpathians, Suceava Plateau, Moldavian Subcarpathians, Curvature Subcarpathians, Moldavian Plain, Bârlad Plateau, and Lower Siret Plain.

The Prut drainage basin unfolds entirely within the Moldavian Plateau in Romanian territory. For this reason, it has a relatively low discharge compared to its length. It unfolds within a temperate–continental climate of transition. The Prut is a cross-border river between Romania, Ukraine, and the Republic of Moldova. The Siret drainage basin has an asymmetric development: the left side, within the Moldavian Plateau, is not well represented and includes small rivers with low discharges; the right side, with an important development in the Carpathian and Subcarpathian areas, includes rivers with significant discharges (Suceava, Moldova, Bistriţa, Trotuş, Buzău, etc.) [52, 55].

Experimental part

Materials and methods

The field measurements included summer campaigns in all landform units and drainage basins in eastern Romania, all within the historical region of Moldavia. They targeted the large drainage basins of Siret and Prut, both

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allochthonous, with springs in the Ukrainian territory [56, 57]. The sampling campaigns occurred in 2010–2011, in August, when the highest temperatures are registered in Romania and when the liquid discharges (of springs and streams) are at their lowest. The expeditionary measurements were taken with the HACH Multiparameter with the purpose of determining the salinity and pH of surface waters (streams, springs, and lakes).

The target area was represented by 108 hydrographic arteries of different sizes within the plateau or mountain areas. Most springs could be localised with the information provided by the inhabitants. Only a small part was localised based on cartographic information. Most springs have freshwater. Large freshwater springs are used in the drinking water supply or the industrial sphere. Salt springs – mostly those within the Carpathian area – are used in balneology or for the conservation of perishable foods [54, 58].

Some water samples with a high degree of salinity have also been analysed in the laboratory to determine their chemical composition. Most of the springs analysed belonged to the Carpathian and Subcarpathian zones, as these areas have been strongly influenced by Miocene salt deposits. The study also analysed the way in which the waters have been used by local communities, especially the rural communities. Ethno-management is an entirely operational concept given the high level of non-industrial uses of salt springs by the local communities. Therefore, the study also includes the preservation of – in the cultural, traditional patrimony of the rural communities – certain traditional activities that are not profitable from an economic perspective [54, 59].

We could only analyse the exploited springs of accessible areas. Spatial analysis specific to geographic research with applicability for the ethnoarchaeological field was tested. There is a plan to extend this method to the entire Carpathian and extra-Carpathian space in the future [58] 2011). Based on the geologic (Romanian Geologic Committee, 2010) and hydrogeologic data from qualified institutions and personal research [2, 3], original themed maps have been generated (geologic, hydrogeologic).

Results and discussions

The hydrographic network within the two basins is extremely rich, but most streams have a temporary character [60]. In this analysis, only the large hydrographic arteries, important for certain landform units or communities, have been analysed. To the same extent, springs with high discharges, which could have special importance in the supply for streams or for the economy of local communities, have been chosen.

As for salinity, there is a clear similarity between the rivers within the northern half of the Moldavian Plateau (Moldavian Plain and Moldavian Central Plateau) and the south–west of the Siret drainage basin (Curvature Subcarpathians). In the remaining basins – with only small exceptions – there are hydrographic arteries influenced by salinity (Soloneţ, Sărata, and Tazlău on the lower stream) (fig. 1). Most rivers are included in the freshwater category. They are also the biggest hydrographic arteries, with important liquid discharges.

Only the salinity of six rivers exceeds 0.5 mg/L: Volovăţ – 0.7 (tributary of the Prut), Roşu – 0.7 (tributary of the Prut), Cacaina – 0.6 (tributary of the Bahlui), Sărata – 7.1 (tributary of the Moldova), Sărata – 0.6 (tributary of the Şuşiţa), and Sărăţel – 0.8 (tributary of the Buzău). The brooks are strongly influenced by salinity because of the salt springs supply. Unfortunately, there have been frequent

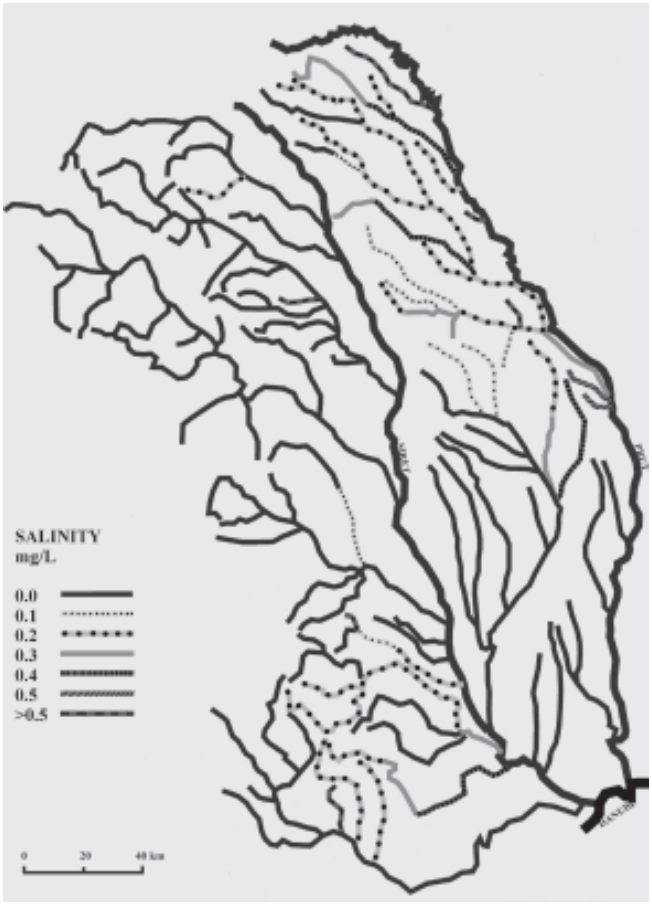

Fig. 1. Salinity of the main rivers within the Siret and Prut drainage basins

drying-out phenomena because of the continental climate of transition with long-term droughts. It is worth mentioning that salt springs only influence the salinity of small streams, which dry out most often. The only permanent brooks strongly influenced by salinity are the Sărata (from the area of the local therapeutic resorts of Oglinzi, Neamţ County) and the Sărata from the Soveja depression (Vrancea County) [54].

The *p*H of the large rivers with rich discharges ranges between 7.9 and 8.4 (Siret, Prut, Moldova, Suceava, lower Bistriţa, etc.). The pH of the small rivers within the drought-prone area of the Moldavian Plateau ranges between 8.5 and 9.0 (Bârlad, Tutova, Vaslui, Elan, etc.) (fig. 2). The streams with the highest *p*H can be found in the south–western sector of Moldavia, on the right side of the Siret drainage basin: Buzău, Râmnicu Sărat, Milcov, Râmna, Putna, Bâsca Chiojdului, Bâsca Mare, Bâsca Mică, etc. The rivers of the Valea Seacă (in the Bârlad basin) and the Săcrieş (in the upper Moldova basin) also have high pH levels.

Though the discharges of the two main streams are relatively high (compared to other streams in Romania), the water resource is low because it corresponds to the number of inhabitants. From this perspective, Moldavia is the most populated region with the highest population densities in Romania [1]. The climate in eastern Romania is characterised by a continentalism of transition, which makes the precipitation relatively low (500–800 mm) in high evapotranspiration conditions (700–500 mm). Therefore, the multiannual average discharges of the rivers are reduced, while the concentration of salts is high.

Most tributaries within the Moldavian Plateau are small, and the discharges are extremely low. Streams within the first, second, and third category of the Horton–Strahler ordering system dry out annually, often in the summer

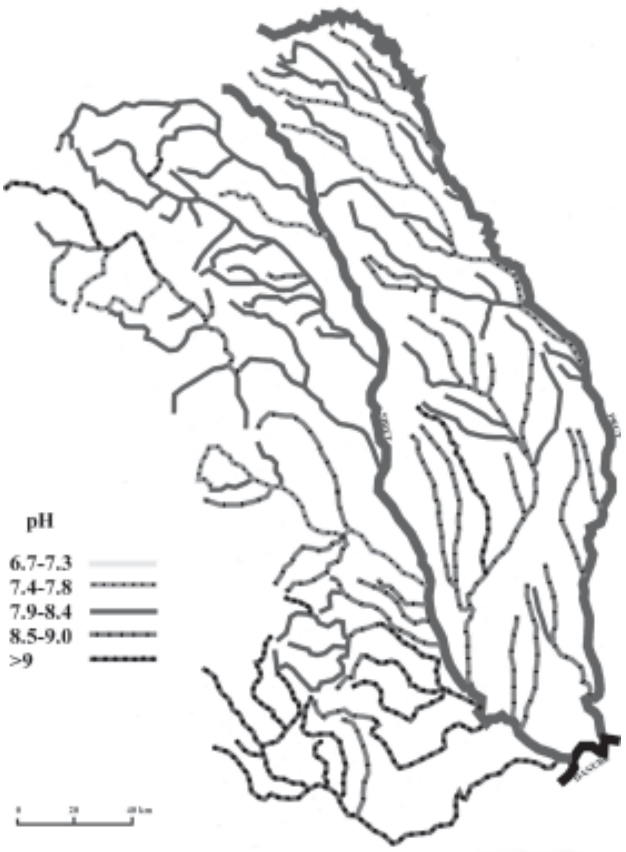

Fig. 2. The pH of the main rivers within the geographic basins of Siret and Prut

(because of the lack of precipitation and high evapotranspiration) and in the winter (because of the total frost). The fourth-order arteries have extremely low discharges ranging between 0.1 and 0.3 m^3/s. The water resources within most of the areas of the Moldavian Plateau are limited or completely absent. The need to preserve water led to the construction of ponds in Botoşani and Iaşi counties, situated in the hill–region of the Moldavian Plain (an element of the Moldavian Plateau). Though the two counties are among the poorest in water resources, they are in second and third place of the aquatic bodies in Romania. A quick look at a hydrographic map of the region can be misleading with regard to the water resources. Lakes have been built precisely because of the lack of water, not because there is too much of it [60].

Another deceiving factor is the density of the hydrographic network, which is extremely high in this particular case. This high level is due to the high friability of the geologic substrate and the massive deforestation in eastern Romania. Most small hydrographic arteries are dry or have streams only during heavy rainfalls. The permanent character of local rivers is given first by the groundwater supply. Most large hydrographic arteries have 30–50% groundwater supply [52, 53].

The dominance of groundwater supply and the low discharge of small hydrographic arteries lead to a substantial increase in the degree of water salinity. This category includes all of the rivers within the northern half of the Moldavian Plateau, where the substrate is mainly clayey–loamy (Jijia, Başeu, Bahlui, Bahlueţ, Miletin, Sacovăţ, Rebricea, Bohotin, Moşna, Vaslui, Lohan etc.).

The rivers within the Moldavian Plateau have high salinity because the salts rise to the surface during summer drought through capillarity. The salts follow two routes: ascendant in the soil, leading to the formation of a salt crust on the topographic surface; transportation through surface waters, caused by the washing off of the terrestrial surface.

The rivers within the Curvature Carpathians and the Curvature Subcarpathians owe their salinity to the dissolution and washing off of salt deposits, dominated by Mg and K salts. The salts deposits within the Transylvanian depression are dominated by NaCl, specific to large lagoons [13]. The deposits of Mg and K salts are an inheritance of the old intermediate lagoons that facilitated the passage of a sea current towards the Transylvanian depression through the Vrancea corridor. In arid climate conditions with significant sea currents, the deposition of magnesium and potassium salts has been favoured. The small, intermediate lagoons had waters with small depths and high temperatures. These favourable conditions led to the massive deposition of salts. In the Transylvanian depression – large, with cold, deep, and agitated waters – there have been favourable conditions for the deposition of Na and Cl salts.

There is a positive correlation between salinity and pH only in the south-western sector of Moldavia, in the areas of the Curvature Carpathians and the Curvature Subcarpathians. In this case, the Mg and K salts cause an increase in the *p*H exceeding 9.0. There is also a relatively good correlation for the rivers within the Moldavian Plateau, where the *p*H of most rivers ranges between 8.5 and 9.0. There are no correlations between salinity and the pH of the waters within the northern half of the Siret drainage basin. In this case, the rivers have high liquid discharges and a great dilution power (they come from the mountain sector with heavy precipitation).

The clay and loam deposits within the Moldavian Plateau lead to slow movement of groundwater. In this way, groundwater has enough time to significantly dissolve the salts within the geologic deposits and to acquire many chemical elements. The fine granulometry and drought (with high temperatures) favour the movement of groundwater towards the surface though capillarity, as well as the deposition of salts on the topographic surface as a salt crust that the locals call *chelitură* ("bald land", as the field is left empty, with no vegetation).

The coarse granulometry of the sand and gravel deposits in the south of the Moldavian Plateau causes low salinity of groundwater, but does not allow movement of groundwater through capillarity. In this case, the surface waters are often represented by freshwater. For the other rivers, loaded with high amounts of salts, the salt deposits that take the shape of massifs or compact salt cores – situated in the areas of the Carpathians and the Subcarpathians (the right side of the Siret drainage basin) – are the important ones. Some salt massifs reach the surface and are washed out by meteoric waters. The surface freshwater is used in all fields of activity: households (drinking water), industry, and agriculture. The management of freshwater (at the surface and in the ground) is modern and cannot be compared to the ancestral management of salt waters. Salt water sources – mostly the springs – have often been used by the rural populations throughout the entire region of Moldavia (in the mountains, on the hills, and in the plain) [58, 62, 63].

Salinity has a significant influence only on small rivers. The large rivers have freshwater (the high discharge creates great dilution power). The influence of salt deposits or of rock salt is dominant only in the case of groundwater, with relatively high amounts of salts [64, 65]. The high load is also determined by the weak circulation of the water underground (fine granulometry) or by the low pluvial supply.

People have used salt water from springs and more rarely from streams (the crust formed after the summer drought). The water within salt springs is significantly saltier than that within streams. They represent the main source for the rivers only in the upper course. The relatively low salt content within rivers in the middle and lower sectors is due to the reduced underground discharge and dilution by meteoric waters. The dilution power is obvious in the case of large hydrographic arteries.

The highly salinised streams are not proper for household use as their chemical qualities are not suitable for this sphere. Considering that they have high salinity levels in the upper sectors of the streams, near the springs, the latter are suitable. As for most streams, only the salt crusts left after the summer drought are used. From this perspective only, the salts within the streams of the Moldavian Plateau are used traditionally. Herds of sheep often graze on pastures littered with salts because they also eat salt-loving plants: *Sueda maritima* and *Salicornia herbaceea*. They obtain necessary salts by eating these plants.

The surface waters within the Moldavian Plateau are not often used for irrigation because of three shortcomings: they have variable discharges, they are slightly salinised, and they contain high solid load (fine alluvia in suspension, which ruin the soil structure and do not allow good water circulation). Therefore, in the central part of the plateau (Vaslui County), the best solution is to use groundwater. The highest amount of water destined for irrigation is taken from the Stânca–Costeşti reservoir on the Prut River (Botoşani County). Unfortunately, the infrastructure is limited only to supplying the area near the lacustrine basin.

The salt springs within the mountain area are exploited traditionally through ethno-management. Salt water is used for the conservation of perishable products or of vegetables for consumption during winter, to prepare cheese products, to conserve hay, etc.; such examples are also encountered in Africa, South America, and Asia [66-70]. Modern exploitation management relates only to the springs with national importance, around the large salt exploitations (Târgu Oca, Cacica).

For household use within rural settlements, only non-salinised, phreatic groundwater is used, but it is influenced by the substances used in agriculture. Unfortunately, most groundwater samples taken from wells are polluted (80%) by nitrates and nitrites. Even deep waters are often salinised or hard. These properties make them unusable, which is why their exploitation is not profitable.

To avoid diseases or deaths caused by the pollution of surface or groundwater, the state has defined the catchment for drinking water sources only [71, 72]. European funds have been accessed and all localities in Romania will be supplied with safe waters as soon as possible. Most deaths have occurred in infants up to one year of age who have been drinking water with nitrates and nitrites.

Though Romania is in the industrial–agrarian stage of development, there are many examples of persistent traditional behavioural patterns specific to salt water springs. This use is mainly encountered in the rural setting and has become almost extinct in the urban setting.

Conclusions

The two hydrographic arteries draining Moldavia from the north to the south – Siret and Prut – are the most important rivers in Romania. Because of high population densities, water resources are scarce. Most rivers are small and dry out in the summer. Small rivers are often highly salinised, so they cannot be used in economic activities. Large rivers with rich discharges (which spring from the mountain area) contain freshwater. All surface waters are alkaline. Salinity causes an increase in the *p*H value in the north–east of the Moldavian Plateau (the hill–region of the Moldavian Plain) and the south–west of the Siret basin (in the areas of the Curvature Carpathians and Curvature Subcarpathians).

The nature of the geologic substrate within the Siret and Prut drainage basins has a specific influence on the salinity of surface waters and groundwater. There is a similar influence on human activities related to the exploitation of salt resources as salt water sources. High salinity is specific only to springs. Small rivers with low discharges are highly influenced by salinity because their discharges are low in the summertime. Large streams contain freshwater because of the high dilution power of water.

Freshwater (mostly surface water) is exploited through modern means and has large-scale use in all economic fields. The population in eastern Romania uses river water and, more rarely, groundwater. Only the rural population uses groundwater on a large scale, and it is often contaminated with nitrates and nitrites. Over 80% of the water within Moldavian wells is not adequate for human consumption. Ethno-management is specific to the exploitation of salt springs within rural areas.

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