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Section: Environmental Protection

Development and functioning of riparian ecosystem (*Fraxino-Alnetum*) under the influence of human impact

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Abstract

The papers concerns the problem of the development and functioning of the alder ecosystem (*Fraxino-Alnetum*) forming along the anthropogenic watercourse in the area of the city of Zabrze (Silesian Upland, southern Poland). The vegetation community develops on the habitat of highly contaminated with heavy metals. The investigated riparian alder is supplied by rainwater (urban rainfall/waste water), conducted in artificial riverbed in a tube and targeting the forest area. Despite the high content of some oxides (Fe_2O_3, Al_2O_3, P_2O_5) and heavy metals (Cd, Pb, Fe, Cu, Ni, Co) in soil and the existence of an artificial ditch the functioning of the examined ecological system is proper. This might be explained by the presence of silt, claim and loam fraction which deposited on the bottom of channel and in from the surrounding environment, which helps to increase the water capacity of the soil. These situations allow the proper functioning of the alder community. A community has got the proper structure similar to the system of natural character, manifested both in species composition, as well as the vertical structure of the vegetation. Soil cover the study area was completely destroyed and the soil has lost its natural horizons. As mentioned above the soil cover has a high content of heavy metals in excess of the permissible standards. For this reason these soils are classified as *Anthrosols* in accordance with WRB standards.

Keywords: alder ecosystems; soil properties; heavy metals; anthropogenic impact.

1. Introduction

Ecosystems undergo dynamic processes, among which are regeneration and degeneration. These changes are the result of natural phenomena as well as human economic activity [1]. It is predominantly anthropogenic activities that cause significant changes to biocenotic systems and disturbances of ecological homeostasis. Therefore, knowledge of the rate and trend of the changes to flora and water-soil relationships that occur as a result of anthropopression as well as due to natural processes is very important for assessing their functioning under increased human pression [2-3]. Forest ecosystems which once existed within city limits were among the important elements influencing the functioning of urban ecosystems. Currently, due to the continous growth of urban areas, forests and other vegetation ecosystems are subject to continued degradation caused by the continous expansion of urban infrastructure [4]. In such ecosystems, the content of organic material of alien origin and of heavy metals exceeds the geochemical background [5]. Their concentration has significant influence on the development of vegetation ecosystems and of the chemism of the soil cover. Thus, the development of the lands situated on the upper boundary of catchment has decisive influence on the development of these ecosystems.

The phytocoenose of riparina forests is resistant to various stress factors of varied degrees of intensity. Such an ecological tolerance enables the development of similar phytocoenose on very polluted soil [3, 6]. Such areas are seldom the subject of scientific research due to their constant change. Despite intensive human activity, which causes changes in relations between water relationships, ecosystems of marsh forests develop well in urban areas. They function well along anthropogenic water courses in built-up areas, performing sanitary as well as biological functions.

The purpose of this study is to present the habitat conditions, soil propirties, content of heavy metals and the functioning of the ecosystems of riparian forests within heavily developed urban areas.

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2. Materials and methods

Study area – the Guido Trench is situated within the Silesian Insurgents Park in Zabrze and runs in an east to west direction. Within the park, the water flow is regulated and has an exceptionally anthropogenic origin, and its riverbed is covered with azure concrete plates. In addition, embankments of varying degrees of thickness lie on both sides of the canal, and the slopes thus created also serve as end points for pipes delivering sewage from the surrounding areas. The canal's "valley" has varied width reaching at most 200 metres in some places. This valley is covered with heavily transformed mixed forests and riparina forests that are about 70 years old

Vegetation and soil investigation – in order to assess and determine the nature of the vegetation and soil cover, research transects were set up in the last part of the Guido canal on some part of the riparian forest. Such transects run through the entire length of the "valley." Soil profiles was performed on the transects' surface, and a detailed description of the plant environment has been done. On the basis of ecological indicator values [7], species diversity was evaluated in terms of ecological parameter as soil trophy value.

The various sites of soil samples collection have been designated in the table and figures with the following letters: A – the bottom of the riverbed, B – the anthropogenic embankment on the channel, C – the ash-alder riparian, D – the mixed forest. Samples for laboratory analysis have been collected from selected humus horizons and from the residues at the bottom of the riverbed channel.Soil samples were submitted to standard physical and chemical analyses [8].

Soil pH was measured in a 1:5 soil:water suspension, using a Radiometer model PHM62 pH meter with a radiometer combined glass electrode. Organic carbon (OC) in soil samples was determined by means of Tiurin's method and total nitrogen (Nt) by means of Kjeldahl`s method. In soil material the contents of alkaline (Na^+, K^+, Mg^{2+}, Ca^{2+}) cations were also determined. Exchangeable alkaline were determined were determined in a solution of 1M CH3COONH4 of pH 7. Element contents were determined by means of atomic absorbance spectrometry AAS [9].The content of heavy metals in the soil samples was determined also by atomic absorption FAAS. Extracts in aqua regia (the mixture of concentrated acids $HCl:HNO_3$ in the proportion of 3:1).

3. Results an discussion

The subject of the study has an exceptionally anthropogenic environment. It should be treated as a canal transporting industrial sewage from nearby facilities away. This is because the riverbed has been straightened and was, for a certain period of time, rid of silty-sandy residues, which contain a stone and graver fraction. As for its granulometric composition, the sample material from the riverbed's bottom slightly differs from the samples from other parts of the canal This is because of stone and gravel fractions, most notably gravels and brick fragments, that have been found in the residues granulometric composition (Table 1.) which often have anthropogenic origin.

Table 1. The granulometric composition of soil

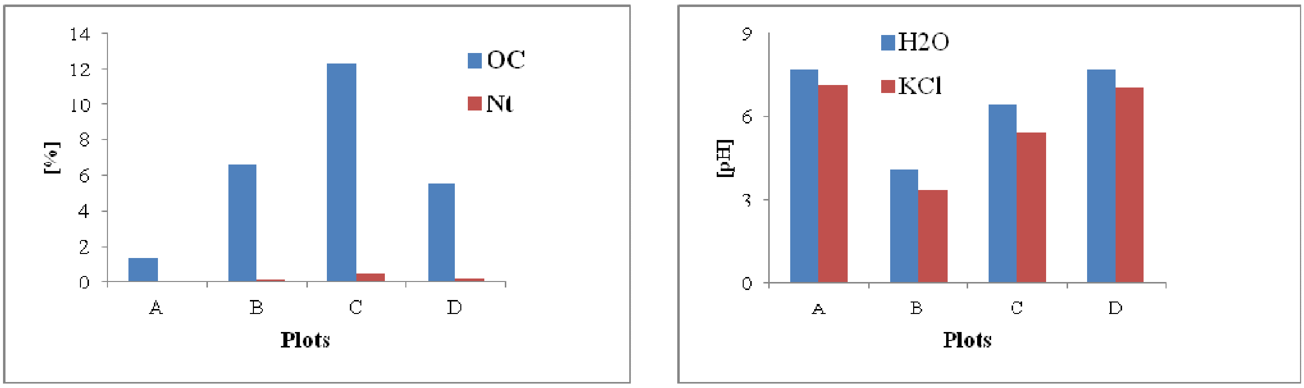
Samples	>10,0	10,0–5,0	5,0–2,0	2,0–1,0	1,0–0,8	0,8–0,5	0,5–0,25	0,25–0,1	0,1–0,05	<0,05
						[mm]				
A	1,6	4,9	6,8	6,9	6,7	17,7	45,9	8,4	1,1	–
B	–	–	–	10,6	9,1	16,2	37,5	18,0	4,4	4,2
C	–	–	–	1,0	0,9	4,3	26,4	30,0	16,7	20,7
D	–	4,3	5,1	1,9	1,9	4,7	30,0	28,9	12,4	10,9

There is a high content of organic carbon (OC) in all samples (from 1.28 to 12.3%), which is due to the highly anthropogenic soil cover in this part of the area under study. The concentration of OC has significance influence in content of total nitrogen (Fig. 1) where organic matter are suplied from ouotside. The C/N ratio is also evidence of very weak biological activity in this zone. Even though the humus horizons are thicker here, there are only small quantities of elements indispensable to plants.

This indicates a lack of any significant biological activities in the soils studied. Inside the mineral material found in the humus horizons are numerous artifacts which often have a significant influence on the overall organic material content in the soil.

The soil reaction of the canal varies considerably, from very acidic to weakly acidic and are present in the range of from 3.3 to 4.7. Considering the lack of $CaCO_3$ in samples A, such a reaction is a typical for this environment and is certainly not related to the limestone rocks found here, but rather to the chemical composition of the water flowing through the riverbed.

The thickness of the organic and humus horizons in this soil are up to 40 cm on average (n = 8) for the ash-alder riparian and riparian willow forests; however, in the ecocline/overlap zone, beneath artificially-created mixed forests, outside the zone of influence of the canal's waters, soil thickness reach only 15 cm on average. In these horizons significantly concentration of available P was observed. Its content was shaped in the range of 0.44 (in Plot A) to 11.16 mg/100 g (Plot D). It should be emphasized that the variation in the content of individual components and the chemistry of the environment here is strongly dependent on the range of water flooded on the valley surfaces with its contents (often high polluted).



a) b)

Fig. 1. The contents of organic carbon, total nitrogen (a) and soil reaction (b)

The content of alkaline cations in the studied soil samples can be said to be relatively low, despite a very low humus horizon and very low organic carbon (OC) content. This, however, does not indicate a biological activity (or lack there of) of the soil, or a significant argil material content; in fact, it is the result of the fine-grained residues brought about by the sewage being dumped into the canal by nearby industrial facilities and residential neighborhoods.

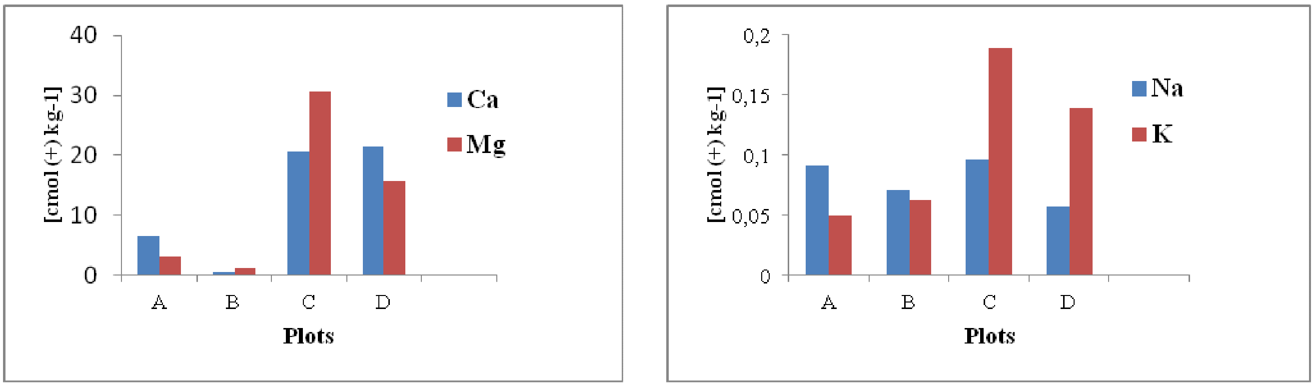


Fig. 2. The contents of exchangeable alkaline cations

The content of heavy metals varies greatly depending on the specific site of soil samples collection and corresponds, in terms of its chemical properties, to urban area soils [6].

Each of the materials studied exceeds the geochemical background for such soils. Moreover, it must be underlined that the cadmium (Cd) content detected is characteristical for heavily polluted soils and for residential and industrial sewage [5], [10]. It can therefore be said that the content determined is a product of the pollution resulting from the residues from the Guido Trench. Other heavy metal elements also exceed (several times) the normal levels for the geochemical background and thus also constitute evidence of a radical anthropogenic transformation of the soil environment in the area concerned. The most studied heavy metals (Co, Ni, Cu, Cd, Zn, Pb) exceed the standards for the region. It is a measure of the increased and uncontrolled human activities on neighboring ecosystems him. This is one of primary indicators of human impact on natural environment.

An the most important element and geochemical indicators is the total content of phosphorus (Pt) for determination human impact on modern and paleoenvironment. Its contents above 500 mg/kg already recognized as a human pressure. In the study area on each investigated plots(A, B, C, D) indicator is exceeded and such large quantities of this element is a anthropogenic. In environments not polluted the such amount of phosphorus is difficult to find [11].

The soil cover analised in the studied area can be classified as hydrogenic and semihydrogenic soil of the ground-gleying type with a profile structure of the O-A- C_{gg} type. It must be underlined here that these are soils heavily and anthropogenically transformed, and sometimes, soil horizon have been mixed up.The areas covered by artificial mixed forests are characterised by the development of podsolic soils. Some portions of them show a tendency to podsolize, whereas more moist fragments show signs of bottom gleying.

The vegetation community and their functioning – along the Guido Trench's riverbed, one observes the development of anthropogenic mixed forests that resemble hornbeam forests and which occupy areas directly neighboring the canal, with a moderate degree of soil moisture. These are artificial forests, and the average age of trees is around 50–60 years. The proportion of different tree species' representation in the forest in the area concerned is diverse. The forest consists of both native (*Quercus robur, Q. petraea, Acer platanoides, A. pseudoplationoides, Populus tremula, Tilia cordata, Carpinus betulus, Betula pendula, Fagus sylvatica, Larix decidua, Pinus sylvestris, Picea abies*) and alien (*Q. rubra, Acer negundo, Robinia pseudoacacia*) tree species.

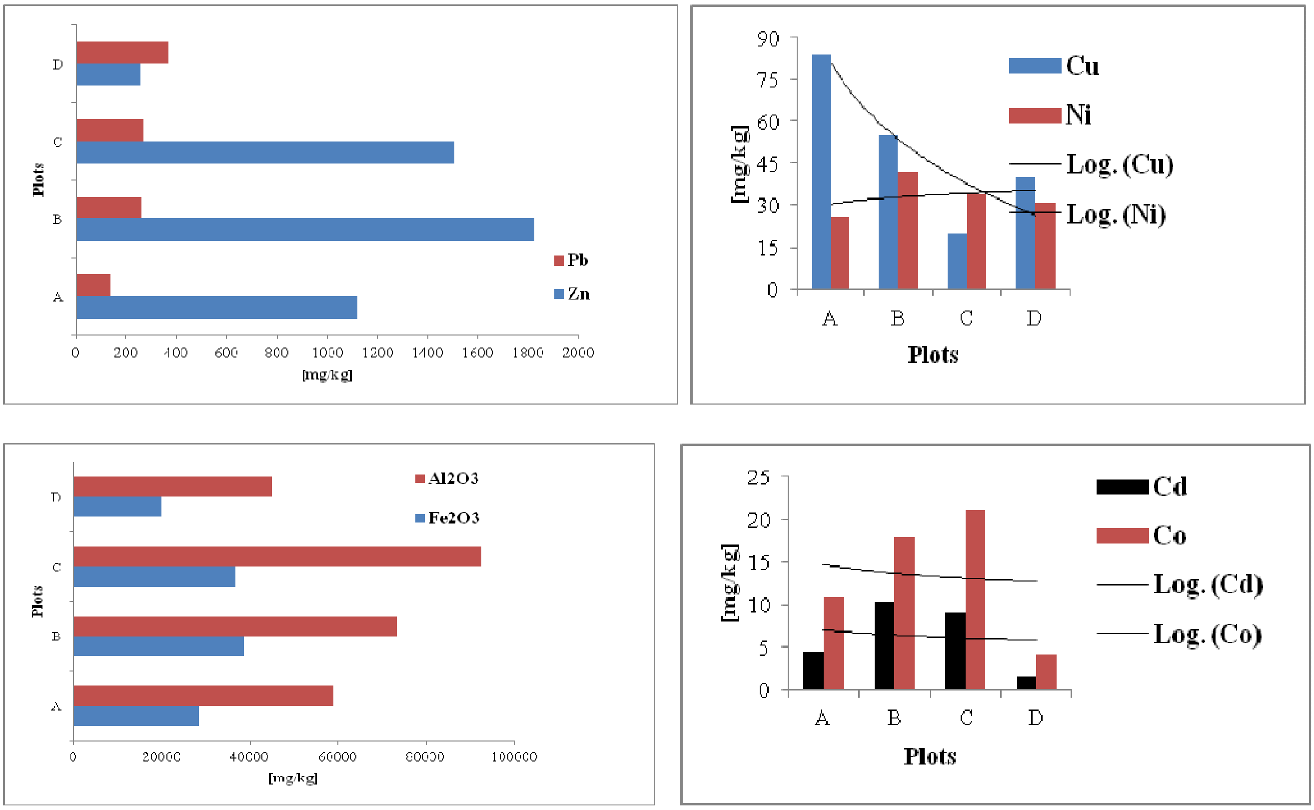


Fig.3. The content of heavy metals in humus horizons

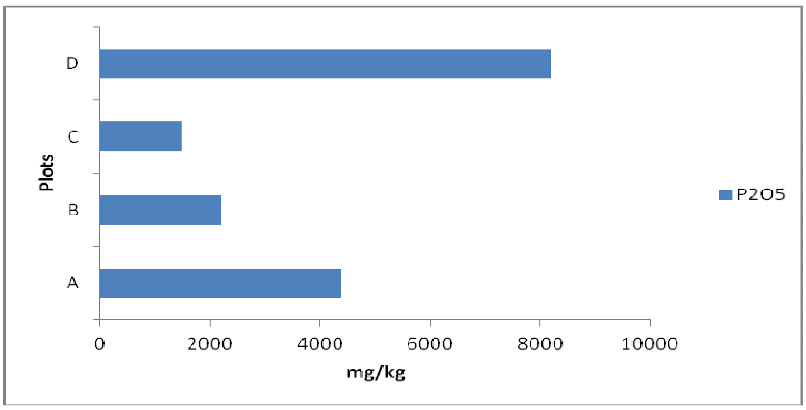


Fig.4. The total content of phosphorus in oxide form in humus horizons

In the shrub layer, there is a signicant presence of *Padus serotina*, which slows down the development of other plant species, as does *R. pseudoacacia* [12]. In the forest undergrowth, we can observe species of a wide range of ecological requirements, such as *Athyrium filix-femina*, *Dryopteris filix-mas*, *Vaccinium myrtillus*, *Solidago virgaurea*, *Aegopodium podagraria* and species of the *Rubus* genus. There are also acidophilous species, such as *Deschampsia flexuosa*, *Lusula pilosa*, *Oxalis acetosella*, and others in the forest undergrowth. *Fraxino-Alnetum*, which occur around the Guido Trench, developed as a plant vegetation related to moist habitats. Despite the anthropogenic nature of the canal's surroundings, phytocenosis characteristical for such habitats occur here. Also to be found here is a small part of the *Salicetum albae-fragilis* marsh which is transformed to the *Fraxino-Alnetum* phytocenose (Fig. 6).

The tree stand consists of *Alnus glutinosa* and accompanying single examples of *Quercus robur* and *Ulmus laevis*. *Alnus glutinosa* was artificially implanted into this phytocenose. This may be the reason why the tree stand is dominated by trees that are no more than 100 years old, except scant examples of alder trees that are older.

The tree stand's density is varied and reaches a maximum degree of 70% in its well-developed portions. The forest undergrowth is poorly developed (no more than 20–30% in some portions), and in some places is completely absent. In the forest undergrowth, we have observed only singular examples of *Fraxinus excelsior*, *Acer pseudoplatanus*, *Sambucus nigra*, *Evonymus europeae*, and *A. glutinosa* is scarce.

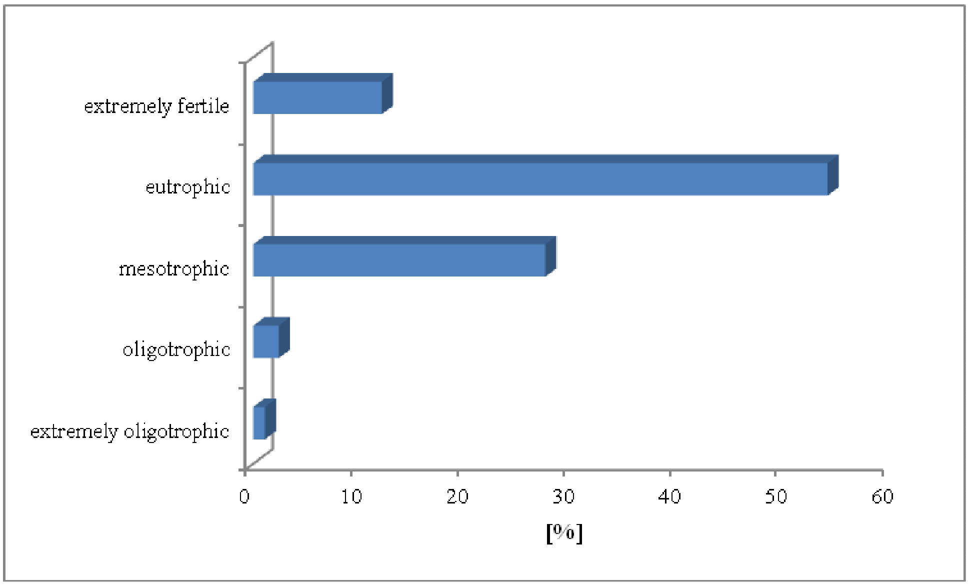


Fig. 5. The percentage share of flora in terms of organic matter content value

The composition of the flora in this area is similar to that of other parts of the Silesian Upland, especially those also affected by human impacts as surface mining and others [13]. In term of trophy requirements the plant species (Fig. 5) are significant diversity. They are spesies mainle prefering the deep and moderate shade habitats. These habitats also rich in organic and mineral both form natural and anthropogenic origin.

(a) (b)

Fig. 6. Alder riparin forest t with domination of *Athyrium filix-femina* (a) and mostly antropogenic sediment in valley (b)

The forest's groundcover is exceptionally luxuriant; it covers 100% of the forest and has two layers. It is dominated mainly by *Urtica dioica*; it is mostly this species that shapes the physionomy of this vegetation community. This may be caused by a steadily incoming stream of waters abounding in biogenic compounds. In the base of environmental impact assesment the area concerned was also characterized as a riparian forest with nitrophyllous species in the forest undergrowth [14], [15]. There is also a strong presence of species such as *Athyrium filix-femina*, *Carex remota*, *Lysimachia* *vulgaris*, *Poa palustris*, *Impatiens parviflora*, *Galium aparine*, *Lycopus europaeus*, *Festuca gigantea*, *Rubus idaeus*, *Galeopsis tetrahit,* and *Milium effusum*.

In some parts of the valley, in concaves where water accumulates, one noticed the following species: *Iris pseudoacorus*, *Deschampsia caespitosa*, *Equisetum limosum*, *Scirpus sylvatica,* and *Phalaris arundinacea*. The latter two species create the *Scirpetum silvatica Phalaridetum arundinaceae* vegetation communities which occur in small patches, on a surface which, with its physionomy, resembles an old riverbed.

In the final section of the Guido Trench, on a large part of its surface, the *Salicetum albae-fragilis* vegetation community occurs frequently, consisting of old examples of *Salix alba* and *S. fragilis*. It has preserved almost completely its original, typical structure and species composition despite occurring in a human-created habitat.

4. Conclusions

The most important element and geochemical indicator is the total content of phosphorus (Pt) for determination human impact on modern and paleoenvironment. In the study area on each investigated plots indicator is exceeded and such large quantities of this element is a results of high human impact on environment.

The investigated riparian alder is supplied by rainwater (urban rainfall/waste water), conducted in an artificial riverbed, in a tube, and targeting the forest area. Nonetheless, despite the high content of heavy metals (Co, Ni, Cu, Cd, Pb, Fe, Al) in soil and the existence of an artificial ditch, the examined ecological system in the area concerned is functioning properly.

The soil covering the area concerned has been completely destroyed by human activity, and it has lost its natural horizons. The soil is polluted and has a high content of heavy metals in excess of the permissible standards and of the normal geochemical background. For this reason these soils are classified as *Anthrosols* in accordance with WRB standards.

The vegetation community develops in a habitat highly contaminated with heavy metals. Even though the *Fraxino-Alnetum* ecosystems develop in a habitat dramatically changed by humans, they retain a very similar floristic composition, and a vertical and horizontal floristic structure typical of natural phytocoenoses. In geobotanic terms, the vegetation communities discussed here lack the majority of the species that are typical and characteristical of them. It must also be underlined that the vegetation communities of the studied area's flora are, in general, poorly developed as a whole.

The straightening of the riverbed and its purification and dredging is causing changes in water system relations. Because of this, the water flowing in the riverbed cannot flood the innundation terrace, and the riverbed is located in an isolated argil and clay zone.

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