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Ilia Tamburadzhiev[1]*, Ahinora Baltakova*, Dimitar Krenchev*

**Sofia University „St. Kliment Ohridski“, Faculty of Geology and Geography, Department of Climatology, Hydrology and Geomorphology*

SEDIMENT CHARACTERISTICS OF THE LUDA YANA RIVER, BULGARIA

Abstract: This paper presents the results of an investigation into the physical properties of fluvial deposits within the channel of the Luda Yana River and its major tributaries. Sediment samples were collected from the riverbeds of the Panagyurska Luda Yana and Strelchanska Luda Yana rivers, as well as from the middle and lower courses of the main Luda Yana River, and were subjected to sedimentological (grain-size) analysis. Based on the results obtained, a qualitative assessment of erosion intensity and of the dominant sediment transport and depositional processes was performed for the upper, middle, and lower courses of the Luda Yana River. The findings indicate that the Strelchanska Luda Yana River is characterized by a high potential for strong currents. Despite the commissioning of the Luda Yana Dam on a tributary of the Panagyurska Luda Yana River, the occurrence of torrential processes within the studied drainage basin remains likely, primarily due to the high erosion potential of the Strelchanska Luda Yana River.

Keywords: Luda Yana River, drainage basin, fluvial processes, fluvial deposits, grain size

Introduction

The present study analyzes the physical properties of the fluvial deposits of the Luda Yana River and its major tributaries - Panagyurska Luda Yana and Strelchanska Luda Yana rivers, located in the central part of Bulgaria, Sredna Gora Mountains. The drainage basin

[1] tamburadzhiev@gea.uni-sofia.bg (corresponding author)
Ilia Ivanov Tamburadzhiev (https://orcid.org/0000-0001-8192-558X)
Ahinora Baltakova (https://orcid.org/0000-0001-6973-9688)
Dimitar Krenchev (https://orcid.org/0000-0003-0231-2481)

covers mountainous, hilly and flat relief with different geological, geomorphological, climatic and hydrological conditions. Fluvial deposits are an indicator of erosion, transport and deposition processes within the river channels. The particle-size composition of deposits forming fluvial landforms is a key structural characteristic reflecting the conditions under which deposition and subsequent transformation occurred (Baltakov & Kenderova, 2003). Grain size within sedimentary deposits serves as an indicator of the river's hydrological and hydraulic regime, as well as sediment supply conditions (Jacobson et al., 2016). Substrate composition controls the resistance of the river channel to erosive forces and influences boundary roughness, thereby affecting flow resistance (Charlton, 2007). In addition, grain size directly governs sediment mobility (Knighton, 2014), as different particle-size fractions are transported by distinct mechanisms (Middleton, 1976). The analysis of the size and shape of deposits is an important stage in the overall process of studying the potential for the formation and development of hazard natural phenomena, including risk processes - floods, debris flows, mudflows, etc.

Studies of the physical properties of fluvial deposits in various drainage basins in Bulgaria have been conducted as part of the analysis of already occurring debris flows by Kenderova and Baltakova (2013), Kenderova et al. (2013; 2014), Krenchev et al. (2021), Kenderova and Rachev (2021), Dobrev et al. (2023), as well as as part of combined climatic, hydrological and geomorphological studies of a given drainage basin (Rachev et al., 2017; Krenchev et al. 2018; Stoyanova et al., 2019).

The aim of this study is to relate the physical properties of fluvial deposits formed by permanent flows in the Luda Yana River drainage basin and to address them to its specific geological, geomorphological, climatic and hydrological conditions. In this way, an assessment of the potential of the main river and its tributaries for the formation and development of torrential processes can be achieved. The present study focuses not only on the comparative analysis of the physical properties of fluvial deposits of the individual tributaries of the main river, but also between pools and riffles sections of the river bed of the mountainous tributaries. The fluvial deposit samples from the main river and its tributaries were collected prior to the commissioning of the Luda Yana Dam. The dam was constructed on one of the tributaries of the Panagyurska Luda Yana River and has been in operation since December 2025. The operation of this facility is expected to alter the erosional, transport, and depositional dynamics not only of the affected tributary but also of the main Luda Yana River, thereby influencing the potential for the initiation and development of torrential processes. This study provides data on the physical properties of fluvial deposits from the Luda Yana River and its major tributaries prior to the dam's commissioning. Accordingly, an additional objective of the study is to collect and interpret quantitative and qualitative information on the physical properties of fluvial deposits across the Luda Yana River drainage basin for the pre-dam period a task not previously undertaken for the entire basin. This dataset establishes a baseline for future monitoring of changes in sediment physical properties and, consequently, for assessing changes in the potential for the formation and development of torrential processes within the studied drainage basin.

Taking into account the fact that a number of settlements (towns and villages) are located in the studied territory, including along the Luda Yana River and its main tributaries Panagyurska Luda Yana and Strelchanska Luda Yana, this study is relevant in terms of the preliminary analysis of the risk of torrential processes. The relevance of the topic is also predetermined by the catastrophic event (debris flow) that occurred in 2022 in the northeastern foothills of Sashtinska Sredna Gora Mountain (Bozhkov, 2022) near the studied area.

Methodology of the Research

Study area

The study area encompasses the drainage basin of the Luda Yana River. This basin, or parts of it, has previously been the subject of geomorphological and hydrological investigations (Petrov & Mitev, 2012; Hristova & Petkanski, 2014; Baltakova & Baltakov, 2016).

From a hypsometric perspective, the drainage basin can be conditionally subdivided into three sectors: upper, middle, and lower, corresponding respectively to mountainous, hilly, and lowland terrains. The upper sector is situated within the Sashtinska Sredna Gora Mountain, the middle sector occupies the southern foothills of the mountain, and the lower sector extends into the Pazardzhik Plovdiv Lowland. This spatial differentiation encompasses contrasting hypsometric, geological, and lithological conditions that control the formation, transport, and accumulation of channel alluvium along the main river channel and its tributaries. Within the mountainous and hilly sectors lie the sub-basins of the Banska Luda Yana, Panagyurska Luda Yana, and Strelchanska Luda Yana rivers. The Banska Luda Yana sub-basin was excluded from the present study due to significant anthropogenic alteration, which does not allow the acquisition of representative data on channel-alluvium composition and dynamics.

From the point of view of morphostructural features, the study area belongs to the Srednogorie morphostructural zone (Central Srednogorie region) and the Upper Thracian morphostructural zone (Kanev, 1989). The mountainous sector of the basin partially overlaps the Panagyurishte Medet fault-flexure zone (Zagorchev & Chunev, 1974; Dabovski, 1988).

The upper (mountainous) part of the basin is dominated by intrusive igneous rocks, whereas volcano-sedimentary formations and Neogene sediments prevail in the middle sector. The lower sector is composed mainly of Quaternary deposits (Iliev & Katskov, 1990; Kozhuharov et al., 1990).

In terms of hypsometry, the Luda Yana River drainage basin ranges from 191 m to 1604 m a.s.l., extending from the main ridge of Sashtinska Sredna Gora where the highest peak of the mountain (Mt. Bogdan) is located to the confluence of the Luda Yana River with the Maritsa River in the Pazardzhik Plovdiv Lowland. The mountainous part of the basin includes a mid-altitude mountain belt (1000/1200–1600 m), a low-altitude mountain belt (600–1000 m), and a hilly belt (350–600 m). The upper boundary of the mountain foothills is situated at elevations of approximately 400–450 m (Kanev, 1989).

Within the mountainous sectors along the valleys of the Strelchanska Luda Yana, Panagyurska Luda Yana, and Banska Luda Yana rivers, small intramountain basins have developed in accordance with the underlying geological structures. The foothills of the slopes are covered by alluvial fans (Kanev, 1989). Along the course of the Luda Yana River, a sequence of five erosion terraces has been identified (Kanev, 1989), predominantly within the middle course of the main channel and its mountainous tributaries.

The study area lies within the transitional climatic region, characterized by warm summers, mild winters, a relatively small annual temperature amplitude, bimodal precipitation maxima (May–June and November–December), and minima in August and February. Precipitation amounts decrease from west to east, and snow cover is annual but unstable (Velev, 2010).

Soil distribution varies along the basin: Cambisols and Luvisols dominate the upper course, Leptosols prevail in the middle course, while Fluvisols, Vertisols, Luvisols, and Planosols are characteristic of the Pazardzhik–Plovdiv Lowland (Ninov, 2002).

The Panagyurska Luda Yana River flows through the town of Panagyurishte, whereas the Strelchanska Luda Yana River passes through the town of Strelcha. In its middle and especially in its lower course downstream of the confluence of the Panagyurska and Strelchanska Luda Yana rivers the Luda Yana River traverses numerous settlements and cultivated agricultural lands.

A map of the studied drainage basin is shown in Figure 1.

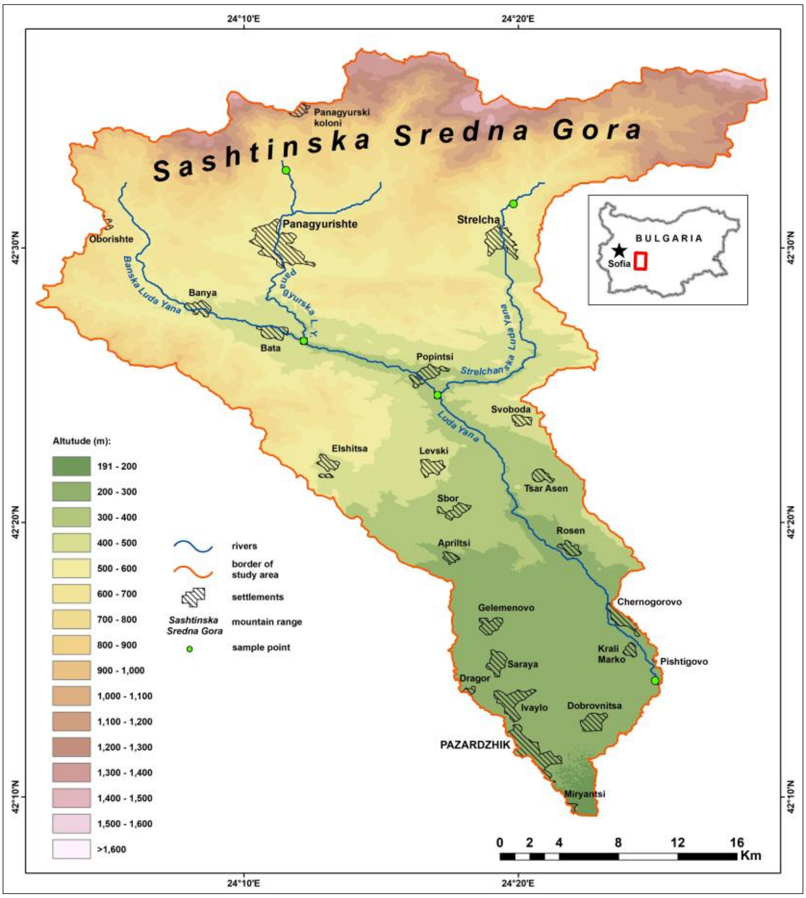

Fig 1. Map of the Luda Yana River drainage basin

Materials and Methods

The present study focuses on the analysis of the physical properties of fluvial deposits. For this purpose, eight surface alluvial channel samples were collected from five locations: two samples from the Strelchanska Luda Yana River; three samples from the Panagyurska Luda Yana River; one sample from the confluence of the Banska and Panagyurska Luda Yana rivers; one sample from the confluence of the Panagyurska and Strelchanska Luda Yana rivers; and one sample from the lower course of the main Luda Yana River, near its mouth (Table 1).

Table 1. Location (toponym), name and number of samples taken for sedimentological (grain-size) analysis

Direct (manual) measurement of individual clasts		Sieving and pipette analysis	
location (toponym) and name of the samples	number	location (toponym) and name of the samples	number
Strelchanska Luda Yana River (SLY2)	1	Strelchanska Luda Yana River (SLY1)	1
Panagyurska Luda Yana River (PLY1 and PLY3)	2	Panagyurska Luda Yana River (PLY1 and PLY2)	2
confluence of Banska Luda Yana River and Panagyurska Luda Yana River, (BPLY)	1	lower course of Luda Yana River (LYO)	1
confluence of Panagyurska Luda Yana River and Strelchanska Luda Yana River (PSLY)	1		

* Sample PLY1 was used for both direct (manual) measurement and sieving and pipette analysis due to the various size of the particles.

Sample SLY1 was taken from a sand bar located in the mid-channel section of the river, in the upper part of the Luda Yana Basin (Strelchanska Luda Yana River). The river channel in this section is step-pool type. In the sections with the steps and rapids, deposition of coarse gravel (from which sample SLY2 was taken for direct (manual) measurement of individual fragments) and sand on the bedrock is observed. In this section of the Strelchanska Luda Yana River, the river channel is incised directly into the bedrock (Fig 2).

Samples PLY1 and PLY2 were also taken from the upper course of the Luda Yana Basin (Panagyurska Luda Yana River), respectively from a section with a shallower rapid and from a sand bar. Sample PLY3 was taken from the same tributary from a section with a deeper rapid (Fig 2).

Samples BPLY and PSLY were taken from the confluences of Banska Luda Yana River and Panagyurska Luda Yana River, and of Panagyurska Luda Yana River and Strelchanska Luda Yana River in the middle course of the Luda Yana River, respectively. Sampling was carried out in the contact zone of the riverbed and the river bank.

Sample LYO was taken from the right bank along the lower course of the Luda Yana River before its confluence with the Maritsa River. After the sampling site, the river channel towards the mouth of the river is strongly transformed and has numerous corrections (canals and about 4 m high embankments).

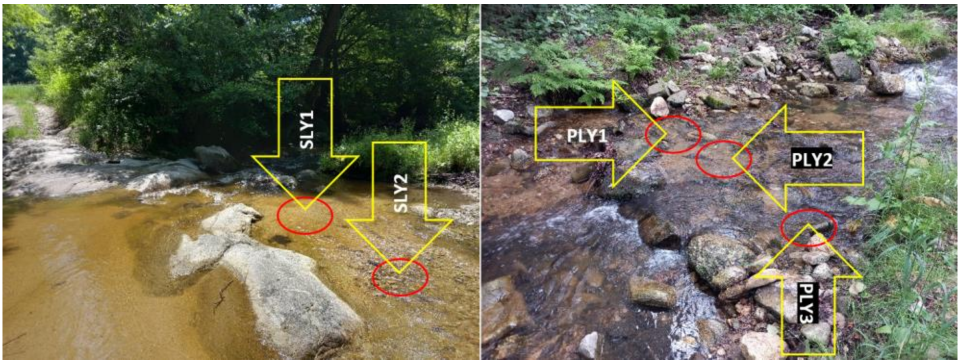

Fig. 2. Locations of the samples taken from the Panagyurska Luda Yana River and the Strelchanska Luda Yana River

The physical properties of the fluvial deposits were studied by sedimentological methods - direct (manual) measurement of individual fragments of the gravel and grain-size analysis (Baltakov & Kenderova, 2003), for which a sieving method (dry and wet sieving) and a pippette analysis were used (Pettijohn et al. 1972, 1987; Boggs, 2014). The total number of measured pieces for direct (manual) measurement in the five samples is 136.

Previous studies on a similar topic (Kenderova et al., 2024) confirmed that gravel and sand predominate in alluvial deposits, and the silt and clay fractions are generally washed away by the river flow. As a result, in the mentioned study, no separation of fractions smaller than fine silt and clay was performed, and the washed part of the samples was defined as fine silt and clay in the fraction < 0.016 mm and was calculated by subtracting the measured fractions from the total weight of the sample (Kenderova et al., 2024). In the present study, the pipette analysis was used to separate even the finest fractions. Wentworth's (1922) classification was used to determine the type of deposits by their size. Four main fractions were distinguished – gravel (>2.000 mm), sand (2.000-0.062 mm), silt (0.062-0.004 mm) and clay (<0.004 mm). The sample type was determined by the different modes of grain size distribution (unimodal, bimodal, trimodal and polymodal) using GRADISTAT software (Blott & Pye, 2001), as well as the sorting of the samples based on the method of Folk and Ward (1957). Bimodal, trimodal and polymodal sediments are the result of mixing of sediment from different sources, or of mixing sediment carried by different agencies, and represent different transport or depositional processes (Tanner, 1964; Ashley, 1978; Sun et al., 2002). Sorting is an indicator of the energy conditions during sediment transport and deposition, as well-sorted sediments usually indicate more uniform energy conditions, while poorly sorted sediments suggest fluctuating energy environments (Fournier-Sowinski, 2024). In this study, the analysis of sorting is based on the grain size and is considered as an indicator of the degree of transport of materials - for example, coarse sediments, gravels and conglomerates, and fine sediments, silts and clays, generally are more poorly sorted than sand-sized sediments, which are more easily transported and therefore sorted by wind and water (Tucker, 2001).

The direct (manual) measurement of individual fragments (clasts) carried out in the present study includes measuring the dimensions of the large fragments along their three axes "a", "b" and "c", calculating the elongation ratio and the flatness ratio. The dimensions of the large fragments are an indicator of the degree of processing of the material and the length of transport (Baltakov & Kenderova, 2003). The elongation ratio (b/a) and flatness ratio (c/b) were calculated using the method of Zingg (1935), cited by Krumbein (1941). The indicated coefficients were used to determine the shape of the fragments, and through it - the type and degree of transport of the fluvial deposits. Shape may play an important role in the selective transportation of the particles (Krumbein, 1941). Four types of shapes have been differentiated – disks, spherical, blades, rod-like (Zingg, 1935; Krumbein, 1941). Spherical and rod-like particles tend to roll along the channel, while discoid and bladed particles tend to remain behind (Krumbein, 1942; Sneed & Folk, 1958; Schmidt & Ergenzinger, 1992; Tuncer, 2000), although there are studies that refute the connection between the spherical and elongated shape of the particles and their faster transportability downstream (Bradley et al., 1972). The spherical and rod-like shapes of the fragments are primarily associated with saltation (overturning) transport, while the discoid and blades shapes are associated with dragging (Baltakov & Kenderova, 2003).

Comparisons of the grain size and shape were made both between the individual tributaries of the main river and between pools and riffles sections of the river bed. Based on the obtained results, a qualitative assessment of erosion intensity and of the dominant transport and depositional processes was conducted for the upper, middle, and lower courses of the Luda Yana River.

For the purpose of this study Shuttle Radar Topography Mission (SRTM 1 Arc-Second Global) Digital Elevation Model (DEM) (30 m), n42_e024_1arc_v3 (United States Geological Survey [USGS], Earth Resources Observation and Science [EROS] Center, 2018) was used. The map of the studied drainage basin was made in GIS environment.

Results and Discussion

Grain-size analysis (Sieving and pipette analysis)

Despite the relatively uniform petrographic composition of the rocks in the upper course of the Luda Yana River, certain differences in the mechanical composition of the studied fluvial deposits are observed both between individual tributaries and within a given river channel (Fig 6, Table 2).

The mechanical composition of sample PLY1 is represented by gravel (53.88%) and sand (39.95%). The sample is trimodal (Blott & Pye, 2001), very poorly sorted (Folk & Ward, 1957). In the finer fractions, the clay content (5.33%) predominates (Fig 3).

The mechanical composition of sample PLY2 is represented by sand (73.76%) and gravel (22.59%). The sample is unimodal (Blott & Pye, 2001), poorly sorted (Folk & Ward, 1957). The silt content (3%) is higher than the clay content (0.65%). The differences between the ratio of individual fractions in the two samples from the studied section of the Panagyurska Luda Yana River are due to the specificity of the sampling points. Sample PLY1 was taken from a section located closer to the river bank, and sample PLY2 was taken from a section located closer to the river thalweg, which suggests a more intensive processing of the sediments by the water flow compared to the peripheral parts of the river bed. In this regard, finer sediments prevail in sample PLY2 (Fig 4).

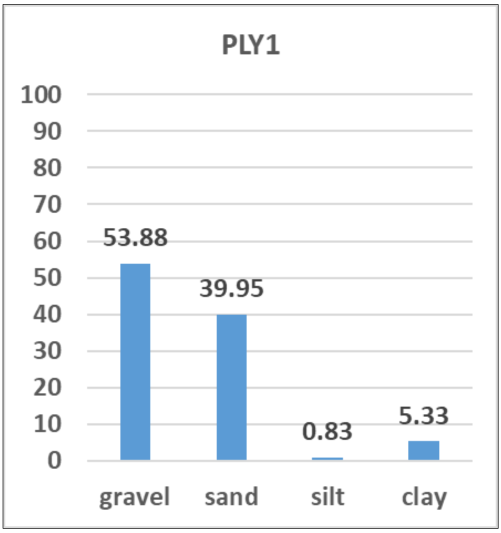

Fig. 3. Mechanical composition of sample PLY1

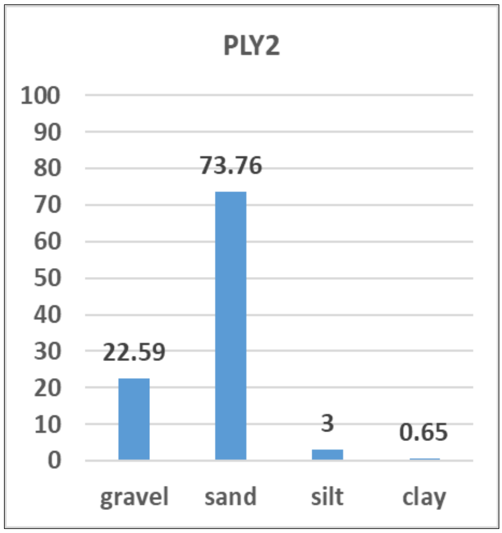

Fig. 4. Mechanical composition of sample PLY2

Sample SLY1 is bimodal (Blott & Pye, 2001), poorly sorted (Folk & Ward, 1957). The coarser fragments (gravel) have a higher content (9.12%) than the fine fractions silt (0.65) and clay (2.88), but with a significantly lower content than sand (87.35%) (Fig 5).

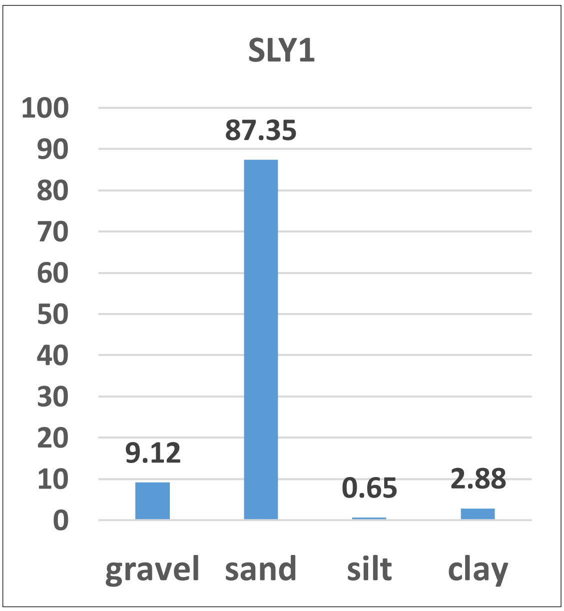

Fig 5. Mechanical composition of sample SLY1

It has been established that the motion of fluids may be either of two kinds - laminar (usually slow and steady) or turbulent (usually more rapid than laminar flow). Turbulent flow does not occur in uniform sands finer than very coarse sand (Smith & Sayre, 1964). The concentration of the coarse sediments increases as discharge increases, principally because velocities tend to be faster and flow more turbulent at high discharges (Colby, 1963).

In addition, based on the fact that erosion and transportation of coarse-grained materials cannot occur in laminar flow (Strahler, 1952), we can associate the significant portion of coarser material in sample PLY1 with the manifestation of more intense or turbulent flows and therefore with a higher erosion and transport potential. The percentage of gravel in sample PLY2 is also higher compared to its percentage in sample SLY1. The indicated results could be due to the quantity and transporting force of the water flow in the places of the specific sampling. For a more detailed picture, it is necessary to analyze the results of the direct (manual) measurement of the large fragments from the two tributaries. On the other hand, the relatively smaller portion of the larger fragments (gravel) and the larger portion of sand in sample SLY1 is an indicator of the manifestation of greater stability over time of the water flow of the Strelchanska Luda Yana River, which is also proven by the cutting of the river into the bedrock.

Leopold et al. (1995) indicate that erodibility is a function of a number of factors - intensity of the rain, the infiltration capacity (permeability) of the surface, the chemical and physical properties that control the disintegration of the rocks and determine the cohesiveness of the soil, etc. Therefore, in the upper course of the Luda Yana River - in the drainage basins of the Panagyurska Luda Yana and Strelchanska Luda Yana rivers, we can argue that the prevailing intrusive rock complexes predetermine a low degree of water permeability (Leopold et al., 1995) and as a result, the formation of torrential processes in conditions of intense precipitation and the generation of a significant amount of surface runoff is possible (Fig 6, Table 2).

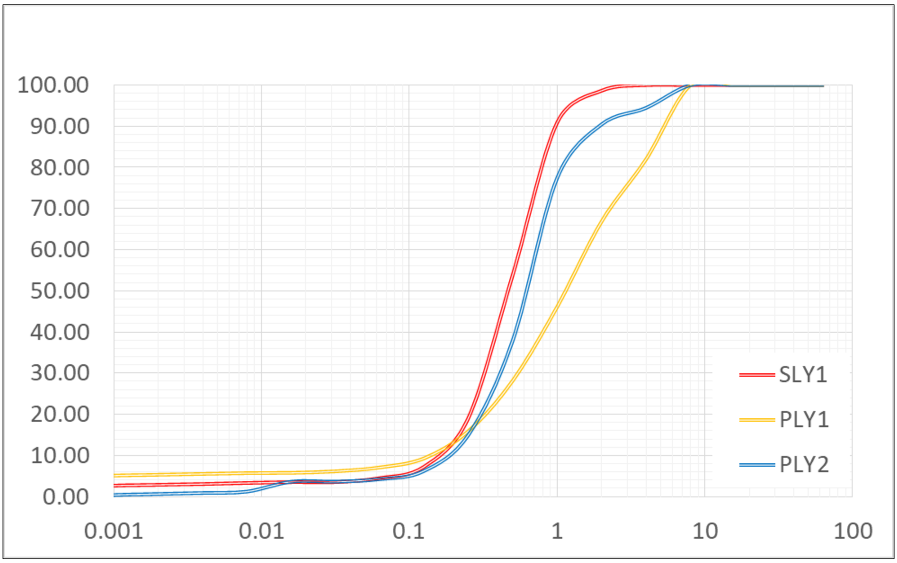

Fig 6. Mechanical composition of samples PLY1, PLY2 and SLY1

The LYO sample is polymodal (Blott & Pye, 2001) with a minimal predominance of sand (50.6%) over gravel (48.1%), poorly sorted (Folk & Ward, 1957). The high percentage of gravel is striking (Fig 7, Table 2). As a general rule, the quantity of coarse-grained material (cobbles, gravel, coarse sand) in the sediment load is transport limited (Sear et al., 2010). Coarse fragments are mainly associated with erosion in the upper course of the rivers. For the lower course of the rivers, deposition processes prevail. Moreover, during transport, sediment grains are subject to fracture, abrasion, weathering and dissolution, contributing to widely observed downstream decreases in grain size and shifts in particle composition (Reid & Dunne, 2016). This is also confirmed by Tucker (2001) that sediment grain size generally decreases downstream, and sorting improves. Therefore, the significant presence of larger fragments (gravel) in the studied sample is an indicator of high flows (Charlton, 2007) in the lower course of the Luda Yana River. It is precisely high flows that are a possible reason for the transport of fragments from the upper and middle to the lower course of the river. Evidence of high waters is also the traces of the river water level, which are visible on the embankments at a height of about 3.5 m.

In general, the presence of larger fragments in the studied samples is an indicator of weaker erosion resistance of the river channel boundaries (Charlton, 2007) of the main river and its larger tributaries.

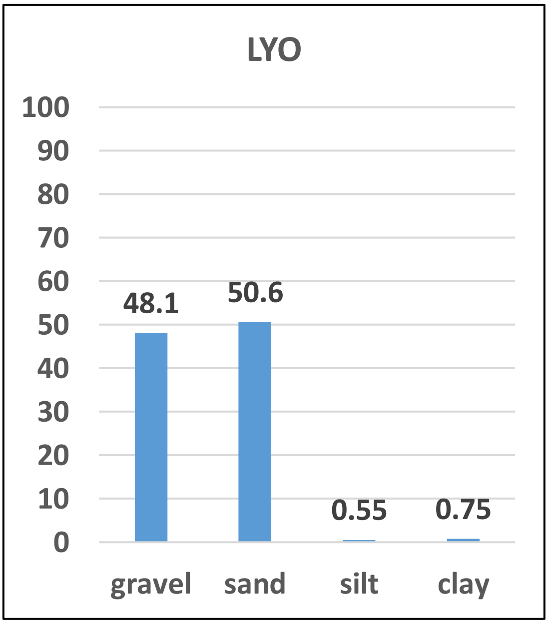

Fig 7. Mechanical composition of sample LYO

Table 2. Mechanical composition of the fluvial deposits

Sample	Fractions			
	gravel (>2.000 mm)	sand (2.000-0.062 mm)	silt (0.062-0.004 mm)	clay (<0.004 mm)
SLY1	9.12 %	87.35 %	0.65 %	2.88 %
PLY1	53.88 %	39.95 %	0.83 %	5.33 %
PLY2	22.59 %	73.76 %	3.00 %	0.65 %
LYO	48.1 %	50.6 %	0.55 %	0.75 %

The results of the grain size analysis show that in three out of the four samples studied, a mode is observed for grain, indicating more than one agent of transport and deposition of materials. We could assume that this is due to the manifestation of different types of flows – different in quantity (high and low waters), intensity and flow pattern (laminar and turbulent flow). The presence of several modes of deposits points to the probable possibility of the manifestation of different in intensity and duration torrential processes both in the upper course of the Luda Yana River and in the lower course. An exception is sample PLY2, in which the presence of one mode and the smaller amount of larger fragments suggest relatively more constant conditions of transport of materials in the thalweg of the Panagyurska Luda Yana River.

In terms of sorting, it is striking that sample PLY1 is the least sorted compared to the other samples, which indicates that the sediments in the studied section with a shallow rapid of the Panagyurska Luda Yana River are more easily transported. Based on the sorting of the deposits, we can also say that the sediments of the Luda Yana River, both in the upper and lower course, are texturally immature (Tucker, 2001).

In grain-size analysis, it is important to note that a basic distinction exists between non-cohesive and cohesive materials (Knighton, 2014). In general, decrease in particle size and an increase in clay content, organic content increases the cohesivity of sediments (Lick, 2009), and cohesive sediments are more resistant to erosion and thus reduce erosion rates (Brierley & Fryirs, 2005; Charlton, 2007; Lick, 2009). In the studied fluvial deposits, the portion of clay is insignificant.

Grain-size analysis (Direct (manual) measurement of individual clasts)

The results of the direct (manual) measurement of the individual fragments of the fluvial deposits show relative similarity in the average, maximum and minimum sizes of the pieces in the five studied samples. The average sizes of all five studied samples fall into the category of pebbles. The maximum, but also the minimum sizes of the fragments of both mountain tributaries are in the fractions of cobbles and pebbles. At the confluence of Panagyurska Luda Yana River and Strelchanska Luda Yana River, the average sizes of the fragments are larger compared to the confluence of Banska Luda Yana River and Panagyurska Luda Yana River. This is probably due to the fact that the erosion and transport potential of the water flow of the Banska Luda Yana River are limited and regulated by anthropogenic reservoir facilities located in the upper course of the tributary. Also, the predominantly higher values of the average and maximum sizes of the fragments of the Strelchanska Luda Yana River compared to the values of the same indicator for the Panagyurska Luda Yana River contribute to some higher values of the same indicators at the confluence of the Panagyurska Luda Yana River and the Strelchanska Luda Yana River. On this basis, we can assume that the Strelchanska Luda Yana River has a greater erosive power of the flow and a relatively greater potential for the manifestation of torrential processes compared to the Panagyurska Luda Yana River. This may be due to a greater intensity and quantity of the water flow of the Strelchanska Luda Yana River, determined by certain climatic (amount of precipitation) and topographic (slope grade) factors, since both tributaries have an uniform type of petrographic composition of the rocks that make up the river channel. The roughness of the river bed is also important (Table 3).

Larger fragments are observed in sample PLY1 compared to sample PLY3. Although sample PLY1 was taken from a shallower rapid, it is likely that a more intense flow passes through it, which, although intermittent, leads to the transport of larger fragments. The latter is also confirmed by the grain-size analysis.

Table 3. Results of the direct (manual) measurement of the individual fragments of the fluvial deposits

Sample	PLY1	PLY3	SLY2	BPLY	PSLY
Number of fragments measured	25	30	30	21	30
Average sizes (mm)	"a"-37.8 "b"-27.4 "c"-13.8	"a"-33.2 "b"-22.3 "c"-12.9	"a"-38.6 "b"-26.8 "c"-19.6	"a"-34.5 "b"-26.1 "c"-14.3	"a"-39.7 "b"-27.3 "c"-15.7
Maximum sizes (mm)	"a"-67 "b"-44 "c"-26	"a"-57 "b"-41.5 "c"-25	"a"-82 "b"-46 "c"-38	"a"-61 "b"-56 "c"-40	"a"-93 "b"-48 "c"-30
Minimum sizes (mm)	"a"-21 "b"-15 "c"-7	"a"-13.5 "b"-8.5 "c"-4.5	"a"-9 "b"-8 "c"-6	"a"-14 "b"-12 "c"-4	"a"-22 "b"-17 "c"-6
dragging:saltation	80:20	60:40	30:70	71:29	67:33

In four of the five samples examined for direct (manual) measurement of the fragments, dragging prevails over saltation. The exception is sample SLY2, taken from the Strelchanska Luda Yana River, in which the fragments are moved by saltation. In connection with the statement that saltation of deposits occurs at very strong currents (Huggett, 2011), we can assume that the Strelchanska Luda Yana River is prone to the formation of very strong currents.

Conclusions

The differences in the mechanical composition of the samples taken from the individual sections of the riverbed of the Panagyurska Luda Yana River are an indicator of the different dynamics and intensity of the water flow in the individual sections of the riverbed. In the sections with a more constant manifestation of water flow, the erosion and transport capacity of the flow are greater. This leads to a more intensive transport of the fragments downstream of the river. In conditions of an unstable flow, but with a larger amount of flowing water, the transport of fragments downstream is also more intense. At the same time, in the shallower sections of the riverbed of the Panagyurska Luda Yana River, a deposition of larger fragments is observed, which in conditions of intense precipitation and high water could participate in the formation of torrential processes such as debris flows, for example.

The results of grain-size analysis and of direct (manual) measurement of individual clasts show that the Strelchanska Luda Yana River is characterized by a relatively constant water flow in quantity and intensity over time and a relatively large erosive power of the flow. Therefore, the Strelchanska Luda Yana River is prone to the formation of strong currents.

The finest fractions (silt and clay) are low in the studied fluvial deposits of the Luda Yana River and its tributaries. The significantly higher content of sand and gravel compared to silt and clay is an indicator of high flows and of weaker erosion resistance of the river channel boundaries of the Luda Yana River and its tributaries. The insignificant portion of the finest deposits in the studied samples, as well as the low content of clay, are a prerequisite for weak cohesion of the river sediments and therefore also prove weaker erosion resistance.

In the lower course of the Luda Yana River, a significant amount of gravel is observed, which is an indicator of the torrential nature of the river not only in its upper course, but also in its lowland part. Despite the commissioning of the Luda Yana Dam on a tributary of the Panagyurska Luda Yana River, the occurrence of torrential processes within the studied drainage basin remains likely, primarily due to the high erosion potential of the Strelchanska Luda Yana River.

Given the fact that the Luda Yana River and its larger tributaries pass through a number of settlements and in accordance with the specifics of economic activity in the region, it is necessary to pay special attention to the maintenance and improvement of the strengthening facilities in the studied drainage basin. Of great importance is also the cleaning of the river channels in order to facilitate the passage of a water flow loaded with larger fragments.

The mode of most samples and the relatively poorly sorting of all studied samples indicate the presence of different types of flows transporting the deposits – different in quantity (high and low waters), intensity and flow pattern (laminar and turbulent flow). It is striking, however, that the relatively uniform mechanical composition of the deposits of the sample from the Strelchanska Luda Yana River and partly of the sample from the Panagyurska Luda Yana River, taken from a section with a constant water flow, contrasts with the results of the analysis of the mode and sorting of the deposits. This requires detailing and precision of the analysis of the mode and sorting of the deposits from the point of view of the application not only of specialized software (in this case GRADISTAT), but also of additional field and laboratory research methods.

The results of this study prove the importance of this type of scientific research from the perspective of risk management for the formation and development of torrential processes (debris flows flash floods, etc.) in the conditions of modern climate change. It is necessary to involve a wider range of researchers and specialists in order to collect more and more accurate data and obtain more in-depth results revealing the risk of torrential processes in the scope of other drainage basins in the country.

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