

## CHEMICAL, GRANULOMETRIC AND MINERALOGICAL CHARACTERIZATION OF TECHNOGENIC WASTE FROM THE CHODAK GOLD-PROCESSING PLANT

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**Abstract.** This study investigates the chemical, granulometric, and mineralogical characteristics of technogenic waste generated at the Chodak gold-processing plant. Representative samples were collected from different depths and waste layers and analyzed to determine the distribution of valuable components. Gold concentrations ranged from 0.60 to 1.68 g/t, while silver concentrations varied from 4.35 to 28.89 g/t. The study showed that approximately 60.6% of gold occurs in free and intergrown forms, whereas 25.64% is associated with rock-forming minerals and sulfides. Granulometric analysis revealed a predominance of fine particles. The obtained results provide a basis for developing appropriate beneficiation methods for recovering gold and silver.

**Keywords:** Chodak deposit; technogenic waste; gold; silver; granulometric analysis.

### INTRODUCTION

The accumulation of waste generated during gold ore processing has become an important issue in the sustainable use of mineral resources. Although the primary processing of gold ores is aimed at recovering the valuable metal, a part of gold and associated silver may remain in the solid residue after beneficiation and cyanidation. Such residues can therefore be considered as a secondary mineral resource rather than only as waste. Their further utilization requires a detailed assessment of chemical composition, particle-size characteristics, and the forms in which valuable components occur.

The Chodak gold-processing plant treats ore through a sequence of crushing and grinding operations followed by cyanidation. According to the available data, the ore is subjected to three stages of crushing and is subsequently ground so that approximately 80% of the material passes a particle size of 0.074 mm. The prepared material is then subjected to cyanide leaching. However, not all of the gold and silver is transferred into the solution during this operation, resulting in the accumulation of metal-bearing residues in the plant's waste-storage areas.

The composition of the Chodak technogenic waste is characterized by considerable variation in the concentrations of precious metals. Samples collected from different depths of the waste dump showed gold concentrations between 0.60 and 1.68 g/t, whereas silver concentrations varied from 4.35 to 28.89 g/t. Sampling at different depths, including 1, 3, 5 and 7 m, demonstrated that the distribution of valuable components is not uniform throughout the accumulated material. Such variation is important when selecting a processing strategy because the efficiency of subsequent recovery operations depends strongly on the composition and physical characteristics of the feed material.

Another important characteristic of the Chodak waste is the mode of occurrence of gold. The available investigation indicates that about 60.6% of the gold occurs in relatively free or intergrown

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forms, while 25.64% is associated with rock-forming minerals and sulfides. Smaller proportions are related directly to sulfide minerals and other waste components. Gold has also been identified as microscopic inclusions within pyrite and as finely disseminated particles in the non-metallic mineral matrix. This heterogeneous occurrence can significantly influence the response of the material to different separation and concentration methods.

Particle-size characteristics provide additional information for evaluating the processing potential of the waste. Granulometric investigations of samples from different layers showed a predominance of fine material after crushing. In several crushed samples, the fraction finer than 0.071 mm accounted for approximately 85–87% of the total mass. At the same time, chemical analysis of individual size fractions demonstrated differences in gold and silver concentrations. Gold contents reached 1.33 g/t in the investigated fractions, while the corresponding silver concentration reached 13.11 g/t.

These characteristics demonstrate that the effective utilization of Chodak technogenic waste requires an integrated assessment of its chemical composition, mineralogical associations and granulometric distribution. Therefore, the present study focuses on evaluating the distribution of valuable components in the waste and establishing the technological prerequisites for their further recovery. The obtained characteristics can be used as a basis for selecting suitable concentration and separation methods and for developing a more efficient approach to the processing of accumulated gold-bearing technogenic waste.

**MATERIALS AND METHODS**

The study was conducted using technogenic waste accumulated at the Chodak gold-processing plant. Representative samples were collected from different layers and depths of the waste dump, including approximately 1, 3, 5, and 7 m, in order to assess the variability of the material composition. For detailed investigation, samples from the upper (1–2.5 m), middle (4.0–5.5 m), and lower (6.0–7.0 m) layers were examined. The collected material was prepared and, where required, crushed prior to laboratory analysis.

The granulometric composition was determined by sieve analysis, with the mass percentage of individual size fractions calculated for each sample. Chemical analyses were subsequently performed on the separated fractions to determine the concentrations of gold (Au), silver (Ag), palladium (Pd), and platinum (Pt). The obtained data were used to evaluate the distribution of valuable components as a function of particle size. The investigation also considered the mineralogical occurrence of gold, including its relatively free and intergrown forms, association with rock-forming and sulfide minerals, and occurrence as microscopic inclusions in pyrite and as finely disseminated particles in the non-metallic matrix.

The analytical results were compared across sampling depths and granulometric fractions to identify variations in precious-metal concentrations and determine the material characteristics relevant to subsequent processing. Thus, the methodological approach combined representative sampling, sample preparation, sieve-based granulometric analysis, chemical determination of valuable metals, and evaluation of their distribution and occurrence forms. These results were used as the basis for assessing the processing potential of the Chodak technogenic waste and selecting appropriate technological approaches for the recovery of valuable components.

**RESULTS AND DISCUSSION**

The chemical and granulometric investigations showed that the Chodak gold-processing waste is heterogeneous in terms of both particle-size distribution and the concentration of valuable components. Analysis of samples collected from different depths revealed noticeable variations in gold and silver contents. Gold concentrations ranged from 0.60 to 1.68 g/t, while silver concentrations varied from 4.35 to 28.89 g/t. The highest gold concentration was recorded in sample 4a (1.68 g/t), whereas the highest silver concentration was also observed in this sample (28.89 g/t). These variations indicate that the distribution of precious metals within the waste dump is non-uniform and depends on the sampling depth and location.

The investigation of the gold occurrence forms provides an additional explanation for the observed variability. Approximately 60.6% of the gold was identified in free and intergrown forms, while 25.64% was associated with rock-forming minerals and sulfides. Smaller proportions were related to sulfide minerals and other waste components. Gold was also identified as microscopic inclusions in pyrite and as finely disseminated particles within the non-metallic matrix. Such a heterogeneous mode of occurrence indicates that a single processing operation may not provide sufficiently effective recovery and that the material characteristics should be considered when selecting a recovery technology.

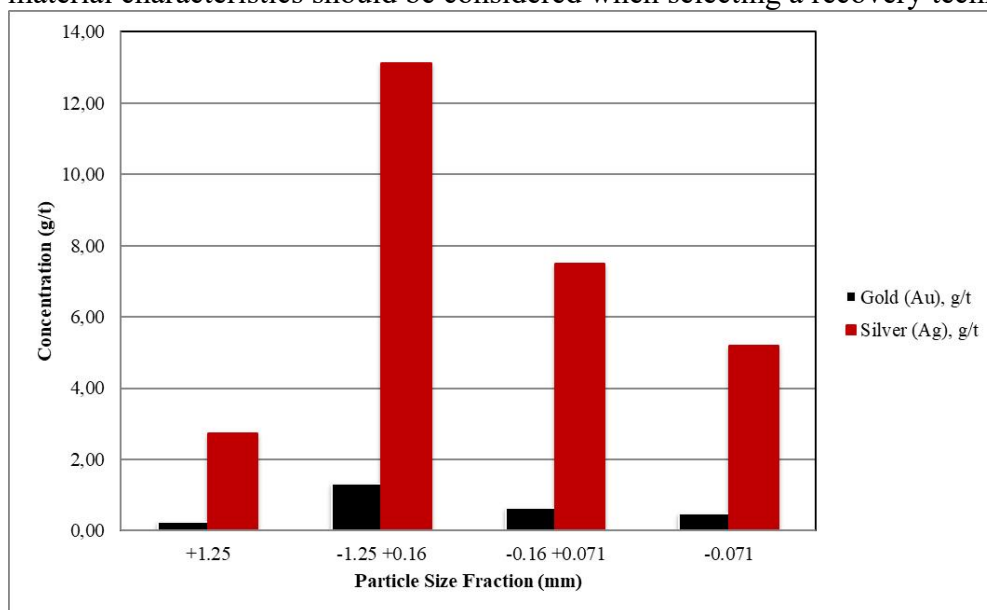


**Figure 1. Variation in gold and silver concentrations as a function of particle-size fractions in Chodak technogenic waste**

The granulometric analysis demonstrated a pronounced predominance of fine material after crushing. In the crushed upper layer, the fraction below 0.071 mm accounted for 85% of the total sample mass. Similar results were obtained for the middle and lower layers, where this fraction represented approximately 87% and 85.3%, respectively. This distribution confirms that the technogenic waste contains a substantial proportion of fine particles, which may affect the efficiency of subsequent separation processes.

Chemical analysis of the individual granulometric fractions showed that the concentration of valuable components changes with particle size. Gold contents varied from 0.25 to 1.33 g/t, while silver concentrations ranged from 2.73 to 13.11 g/t. The maximum gold concentration of 1.33 g/t and the

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maximum silver concentration of 13.11 g/t were recorded in the  $-1.25+0.16$  mm fraction. Other fractions also contained measurable amounts of gold and silver, demonstrating that the valuable components are distributed over a relatively wide particle-size range rather than being concentrated exclusively in one fraction.

The established variability in precious-metal concentrations across granulometric fractions, together with the predominance of fine material and the heterogeneous forms of gold occurrence, indicates that the efficiency of subsequent processing is strongly dependent on the physical and mineralogical characteristics of the feed. Therefore, preliminary classification of the material according to particle size may be considered an important preparatory stage for subsequent concentration processes. Such an approach makes it possible to account for differences in the distribution of gold and silver among individual fractions and to establish more appropriate conditions for their selective recovery.

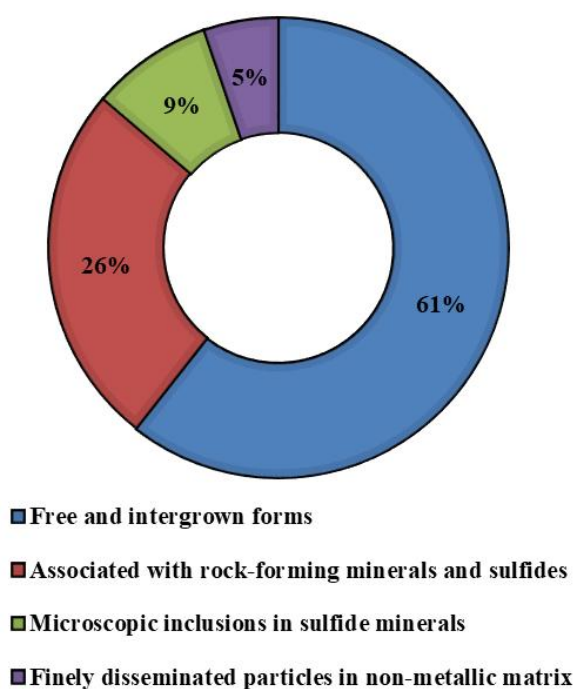


**Figure 2. Mineralogical distribution of gold in Chodak technogenic waste**

The combination of chemical, granulometric, and mineralogical characteristics demonstrates the technological potential of the Chodak waste as a secondary source of gold and silver. However, the non-uniform distribution of valuable components and their occurrence in both liberated and mineral-associated forms require a differentiated processing approach rather than the application of a single separation operation. The results obtained in this study can consequently serve as a scientific basis for further experimental investigation of combined beneficiation methods, with particular emphasis on the relationship between particle-size characteristics, mineralogical association, and recovery of valuable components from technogenic waste.

## CONCLUSION

The results of the study demonstrate that the technogenic waste of the Chodak gold-processing plant contains residual concentrations of valuable components and can be considered a potential secondary source of gold and silver. Gold and silver concentrations varied considerably with sampling depth, reaching 1.68 g/t Au and 28.89 g/t Ag, respectively. The mineralogical analysis showed that approximately 60.6% of gold occurs in free and intergrown forms, while 25.64% is associated with rock-forming minerals and sulfides. In addition, a substantial proportion of the material consists of fine particles, with the fraction below 0.071 mm accounting for approximately 85–87% after crushing.

The granulometric analysis further established that gold and silver are distributed across a relatively wide range of particle sizes, with maximum concentrations of 1.33 g/t Au and 13.11 g/t Ag observed in the  $-1.25+0.16$  mm fraction. The combined chemical, granulometric, and mineralogical characteristics indicate that the processing efficiency of the Chodak technogenic waste depends on both particle-size distribution and the mode of occurrence of gold. Therefore, preliminary classification followed by an appropriately selected concentration process can be considered a scientifically justified approach for further technological investigation. The obtained results provide a basis for developing and experimentally evaluating combined beneficiation methods aimed at increasing the recovery of valuable components from accumulated technogenic waste.

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