Estimating indium concentrations in Zn-rich deposits in Finland: a multivariate approach to predict critical raw material contents

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Probabilistic estimation of critical raw materials (CRM) contents in mineral ores containing copper, zinc, lead, and tin can increase profitability and remining. CRMs are considered of strategic importance at country level and globally, given supply security issues due to their sourcing concentration (China's control on REEs oxide production) and the expectation of a gradual or sudden increase in their demand due to digitalization and the green transition—the most prominent economic and sustainability related trends affecting policy on natural resources. For specific CRMs it is still difficult to map resource potential and compile comprehensive inventories, reporting abundances and tenor. These CRM may occur as a byproduct metal of main commodities, thus are seldom reported. This study reviews present knowledge on the estimation of indium, proposing some examples of multivariate regression modelling applied to indium global ore deposit data and extending their application to Finnish ores. Earlier research on indium estimation defines the importance of developing numerical proxies to infer CRM contents. For instance, statistical linkages between indium tonnage and global production figures for Zn are well established; however, the implication of specific regression approaches has not been fully characterized. We consider five regression methodologies of data imputation to improve current CRM estimation approaches exploiting covariance and other statistical properties of mineral resource data connected to missing information patterns, to better constrain mineral grade estimates. The results obtained are then compared with known indium contents in global and Finnish data. Initial evaluations on a global indium database of 101 deposits mostly representative of Bolivia, China, Russia, Canada, and Japan show significant data heterogeneity and clustering of indium grades suggesting that regression analysis should consider disaggregation of the data into sub-groups accounting for deposit-type, mineralogy, and processing stage in the value chain. Identified indium resources in known Finnish mines, deposits and occurrences show variable grades ranging from 0.2 and up to 994 ppm indium (observed in skarn-type mineral occurrences). These data are in most cases consistent with global averages of indium grade (ranging from 1 to 100 ppm) suggesting that regression and other proxies could be effective in predicting indium resources in Finland.