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# Anthropogenic impact on environmental strontium isotope signatures ($^{87}Sr/^{86}Sr$) in Poland: implications for archaeological provenance and migration research

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Spatial variation in $^{87}Sr/^{86}Sr$ signatures has been investigated in various components of the natural environment of Poland (Central Europe) including rocks and sediments, surface waters, and flora. The geological substrate is characterized by a very wide range of Sr isotope ratios, from 0.7023 to 1.1486. High $^{87}Sr/^{86}Sr$ values (above 0.72), related to the Pleistocene glacial deposits, are omnipresent throughout the country and occur also in the Sudetes and the Holy Cross Mountains, where igneous and clastic Palaeozoic rocks are widely exposed. Low $^{87}Sr/^{86}Sr$ signatures (below 0.71) are recorded predominantly in Palaeozoic, Mesozoic, and Neogene carbonates of the Silesian-Małopolska and Lublin uplands. In contrast to the geological substrate, surface waters exhibit a relatively narrow range of $^{87}Sr/^{86}Sr$ values, from 0.7083 to 0.7197, as a result of a complex mixing of Sr from various natural sources related to different water-rock interactions in the catchment areas and a strong input of anthropogenic additives. Mineral fertilizers, mine waters, municipal sewage, and industrial effluents constitute the main sources of anthropogenic strontium. For example, only 21% of the dissolved strontium in the riverine waters of the Oder, the 2$^{nd}$ largest river in the country, is of natural origin. The $^{87}Sr/^{86}Sr$ ratios of soils in Poland are systematically lower than those of the underlying bedrock. It is suggested that fertilizers used in agriculture in Poland, which are characterized by an unradiogenic Sr isotope composition, are most likely responsible for the lowering of isotopic signatures of topsoils.

Anthropogenic Sr contamination of the natural environment in the country has important implications for archaeological migration and provenance studies as isoscapes for surface water and plants cannot be directly used to estimate the local $^{87}Sr/^{86}Sr$ baseline for past human and animal populations. Consequently, the strontium isotope composition of bedrock, which may be less affected by anthropogenic contamination, is favoured for the baseline estimation for historical times.

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