Supplement 1: The description of sampling.

The soil samples selected for this experiment are from farmlands in three different cities in China, named SX, TH, and NX. Their geographical locations are 33°16′-33°46′ N, 117°40′-118°10′ E; 33°04′-33°35′ N, 115°25′-115°55′ E; and 35°14′-39°23′ N, 104°17′-107°39′ E. Soil samples are collected from the surface layer, 1-2 cm from the surface, to represent the typical properties of the soil in that area.

Soil samples from various locations were collected to represent the soil characteristics of different geographical environments. The SX region's soils are yellow-brown, rich in organic matter and fertility, with pH values ranging from neutral to slightly alkaline. In contrast, the TH region features sandy loam soils, which are well-drained but have poor water retention, making them suitable for certain tuberous plants. The NX region is characterized by aeolian sandy soils and desert soils, which contain less organic matter, exhibit high alkalinity, and are prone to salinization.

Samples were collected from the top 1-2 cm layer of farmland using sterile shovels and containers to prevent contamination. These samples were immediately sealed and stored for transport to the laboratory for further analysis. In the laboratory, soil samples from the SX region were first placed in an oven preheated to 105°C for 15 minutes to remove moisture, providing a dry base for subsequent experimental procedures. After drying, the soil was transferred to a square container measuring 6 cm by 4 cm, where it was evenly filled and compacted to ensure a controlled volume of 144 cubic centimeters, with a total mass of approximately 187.2 grams.

The focus on sampling the upper soil layers is particularly relevant for detecting recent contamination, as this zone is where most plant roots are located, thus posing immediate risks to crops. However, it is acknowledged that deeper soil samples could provide insights into longer-term contamination trends. Future studies will take this into account to offer a more comprehensive assessment of soil health.

Supplement 2: Handling of samples.

To obtain high-quality experimental data with a favorable signal-to-noise ratio, thorough analysis is essential. Therefore, soil samples should be dried and pressed into pellets to enhance the signal-to-noise ratio. The increased density and hardness, along with a flat surface, contribute to more stable spectral signals.

The sample preparation process begins by filling the die with the powder (soil) material to be pressed. The die assembly consists of an upper punch, a die set, a die bottom, and a lower punch, as illustrated in Fig. S1(c). The assembly process starts by positioning the die bottom at the lowest level, followed by the insertion of the die set. The lower punch is then placed into the cylindrical recess of the die set, after which the powder material is added. A second lower punch is placed on top of the powder, and finally, the upper punch is inserted into the recess to complete the die assembly. The cross-sectional view of the assembled die is shown in Fig. S1(a).

For the tablet press process, depicted in Fig. S1(b), the die is placed at the center of the press. The screw at the top of the press is tightened to secure the die in position, ensuring it remains immobile and tightly compressed. The air valve is then tightened, and pressure is manually applied continuously. The actual pressure exerted, measured in tons of force (tonf), can be monitored on the pressure gauge located on the right side. Typically, maintaining a pressure of 10 tonf for 1-2 minutes is sufficient. Afterward, the air valve is released to depressurize, and the die is removed from the press.

The final step is extracting the pressed sample from the die, a process known as demolding. This is achieved by replacing the die bottom with a demolding pad, inverting the die on the press, and rotating the screw to eject the sample from the die set. This completes the pressing operation. The final compression diagram is presented in Fig. S2.

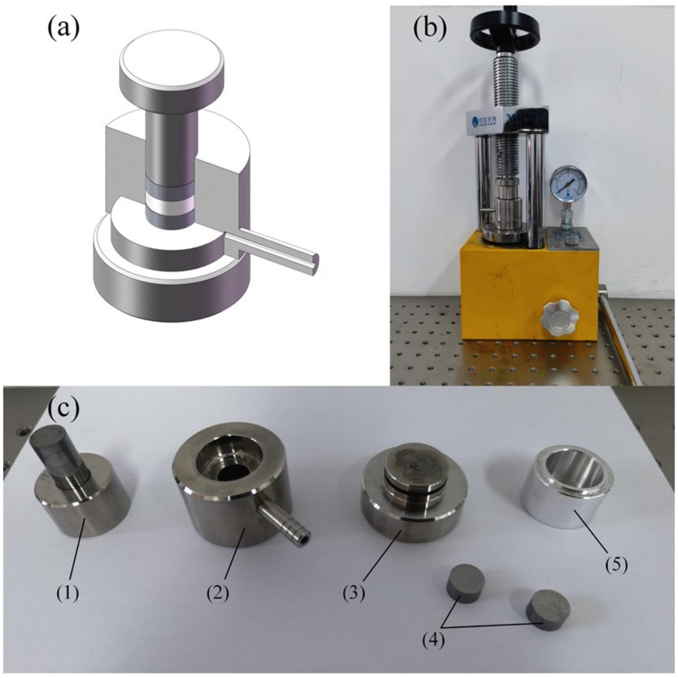

Fig. S1 Diagram of the pressing process: (a) assembled die containing items to be pressed, (b) tablet press, (c) The various parts of the die. (1) upper punch, (2) die set, (3) die bottom, (4) lower punch, (5) demolding pad.

Fig. S2 Soil after pressed.

Supplement 3: The growing environment of garlic.

The selected garlic used in this study was white garlic, produced in Heze city, Shandong Province. The soil sample used, designated as SX, was collected from farmland in Sixian County, Anhui Province.

When cultivating garlic under laboratory conditions, disease-free garlic cloves were chosen for planting. Preprocessing included disinfecting the cloves with a 0.5% potassium permanganate solution for 24 hours. After planting, the temperature was maintained between 13°C and 24°C, with a particular focus on keeping it within 18°C to 20°C during the initial germination phase. Soil moisture was kept at 60% to 70%, achieved through a drip irrigation system, providing water for 15 minutes twice daily, in the morning and evening. Lighting was provided for 14 hours daily using LED lights at an intensity of 2000-3000 lux. The experimentally prepared soil had a pH maintained between 6.5 and 7.0. A balanced NPK fertilizer with a 10-10-10 ratio was applied, supplemented with liquid compound fertilizer monthly during the growth period. Regular inspections were conducted to prevent pests and diseases, and the garlic was harvested when one-third of the leaves had turned yellow.

When the garlic seedlings reached approximately 15 cm in height, the preparation of experimental samples was completed. At this stage, soil samples with varying pollution levels were prepared, and the garlic plants were carefully removed from the soil and washed with water. The garlic was then separated into roots and stems, and the soil samples were placed in a drying oven for moisture reduction. This step was taken to minimize water content in both plant tissue and soil, thereby reducing background noise and enhancing the signal-to-noise ratio, ultimately improving the accuracy of trace element detection. The stem, being the organ responsible for nutrient and heavy metal transport, plays a crucial role in the accumulation of heavy metals in the above-ground parts of the plants. Therefore, elemental detection in the stem was a necessary part of the experiment.