

# Leaching behavior of heavy metals from broken ton bags filled with fly ash in acid rain environment



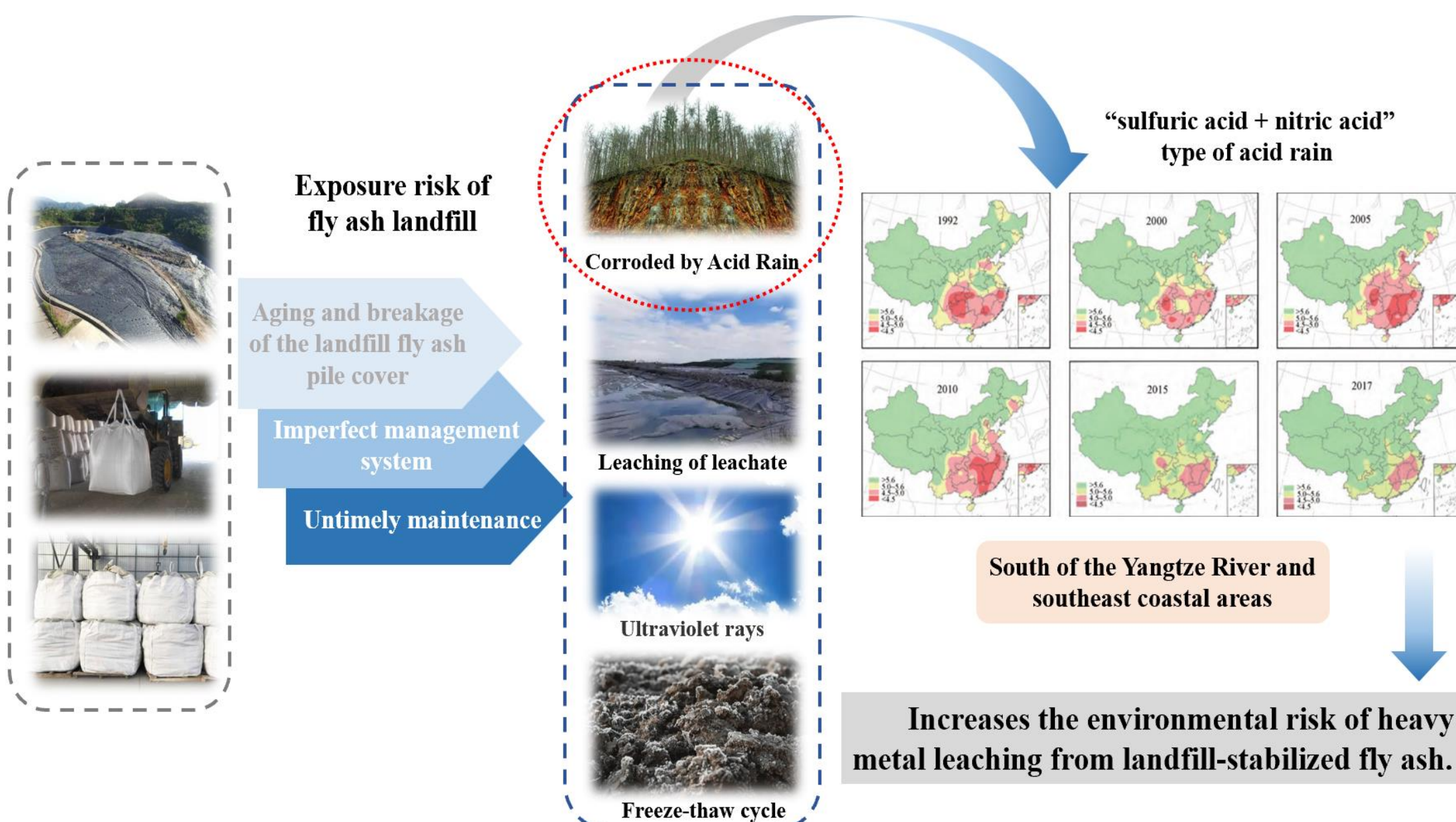
## ACKNOWLEDGMENTS:

The National Natural Science Foundation of China (Grant Nos. 52000111, 51978350).

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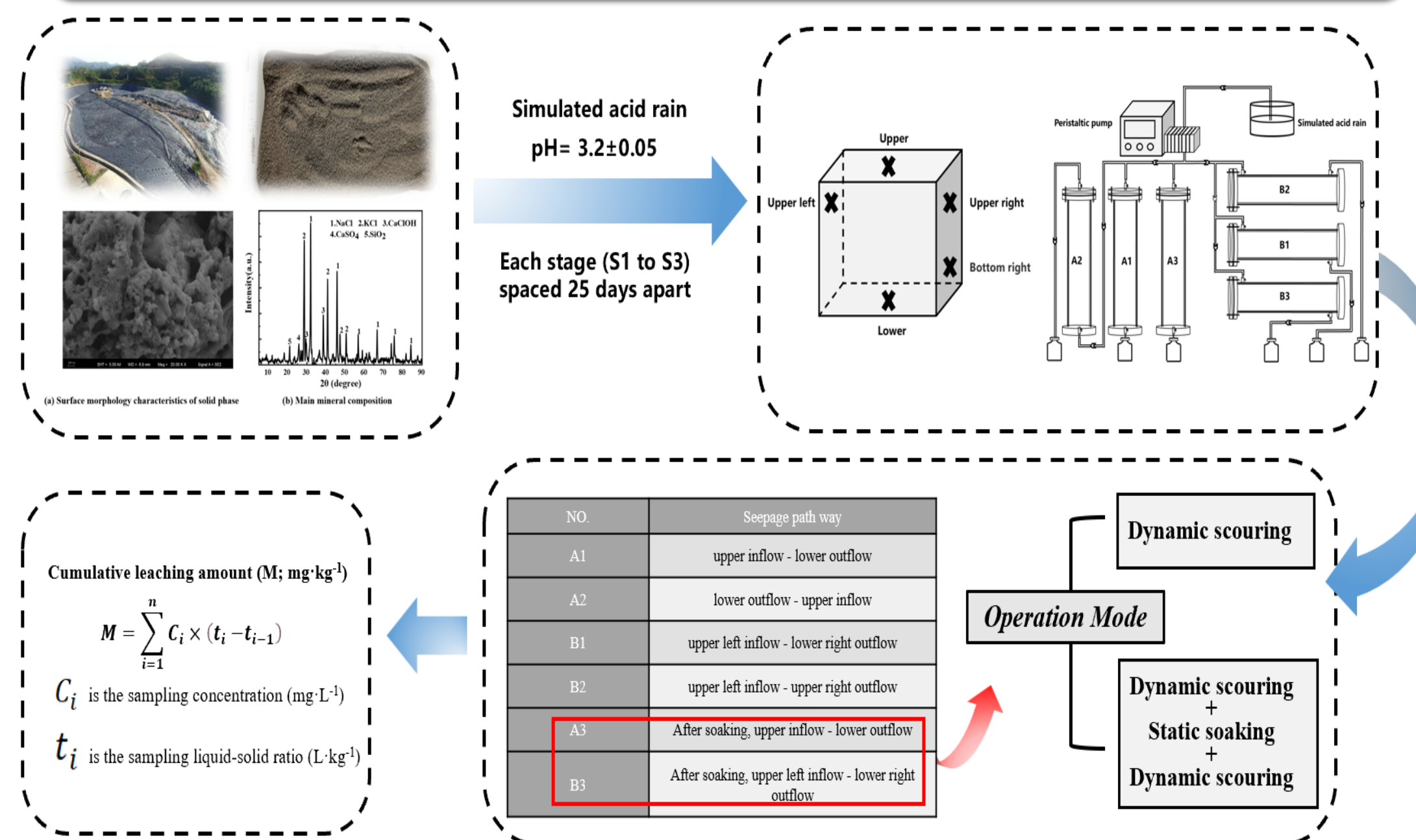
## Introduction



In China, more than 146.076 million tons of raw municipal solid waste (MSW) was incineration in 2020, accounting for 62.3% of the total harmless treatment. According to GB 16889-2008, fly ash can only be landfilled in domestic landfills alone after pretreatment to meet the standards. However, due to the imperfect management system, fly ash ton bags are not strictly sealed in the actual operation of non-standard storage or landfills. Aging and breakage of the landfill fly ash pile cover and untimely maintenance can further increase the risk of exposure of fly ash in broken ton bags to the adverse external environment which increases the environmental risk of heavy metal leaching from landfill-stabilized fly ash. In addition, acid rain is one of the possible risks of environmental exposure for fly ash landfills—acid rainfall, often present south of the Yangtze River and in the southeastern coastal areas. Acid rain with "sulfuric acid + nitric acid" type is the primary type of acid rain evolution in recent years.

This study investigates the effect of acid rain on the leaching behavior of heavy metals in landfill stabilized fly ash under diversified seepage path conditions by simulating acid rain with "sulfuric acid + nitric acid" type extractant. This study provides some theoretical references for the standardization of fly ash ton bag material, the landfill disposal operation process, and improving the management system in China.

## Materials and Methods

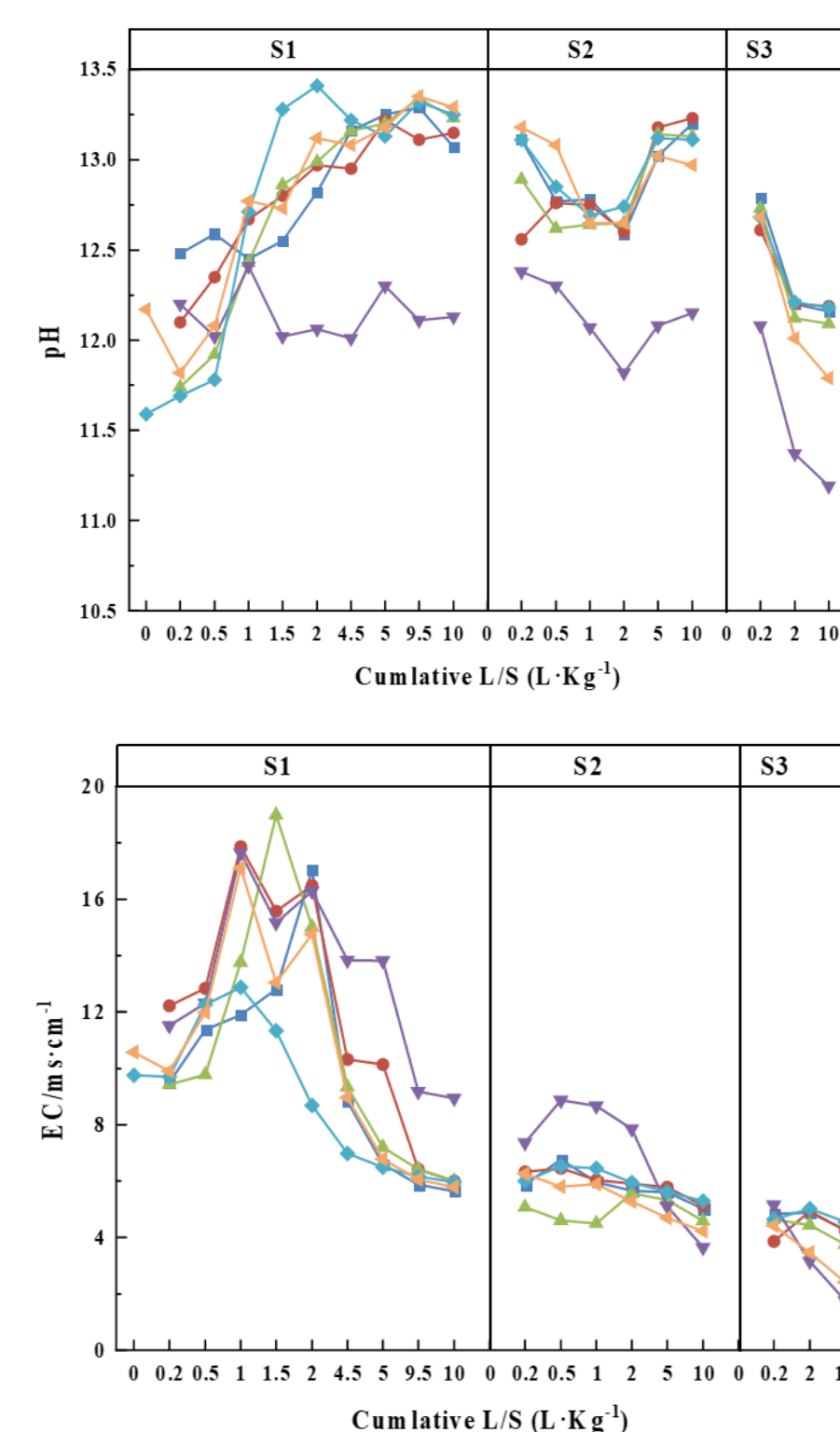


Stabilized fly ash samples were taken from a large domestic waste incineration plant in Qingdao (750 t·d<sup>-1</sup>), and the chelating agent was DTC. The stabilized fly ash samples were crushed and sieved through 10 mesh sieves, mixed by quadratic method then kept in a sealed reserve, pH=12.34.

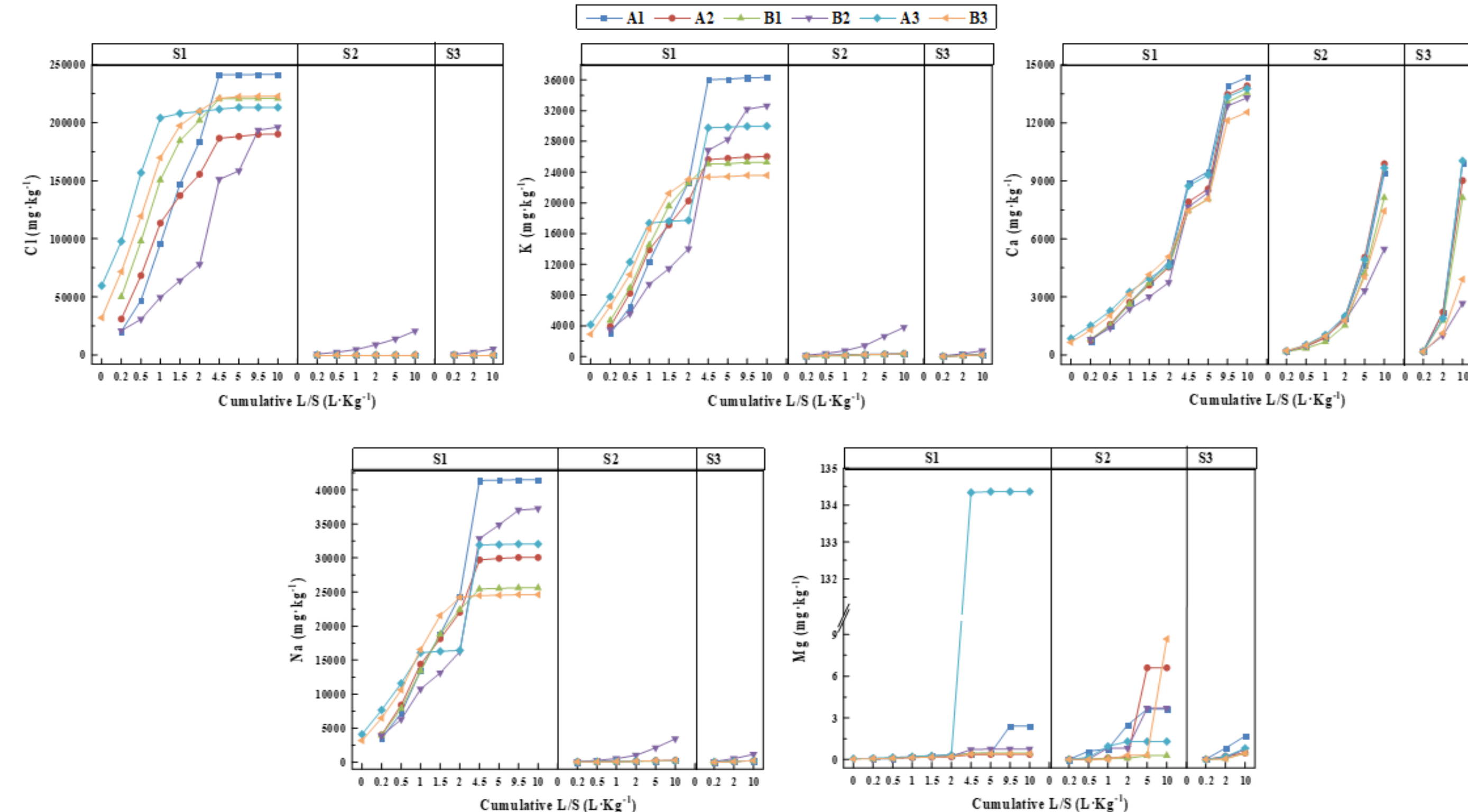
The experiments were conducted in a stage-feed mode, with each stage (S1 to S3) spaced 25 days apart, and each stage time of operation referred to the experimental design of EPA Method 1314, in which the cumulative liquid-to-solid ratio (L/S) reached ten as the end point of the individual stage operation. The leachate sampling sites for the S1, S2, and S3 stages were set at cumulative L/S of 0.2/0.5/1.0/1.5/2.0/4.5/5.0/9.5/10, 0.2/0.5/1.0/2.0/5.0/10 and 0.2/2.0/10, respectively. At the end of each experiment phase, samples of residual landfill fly ash solids in the column were taken.

## Research Results

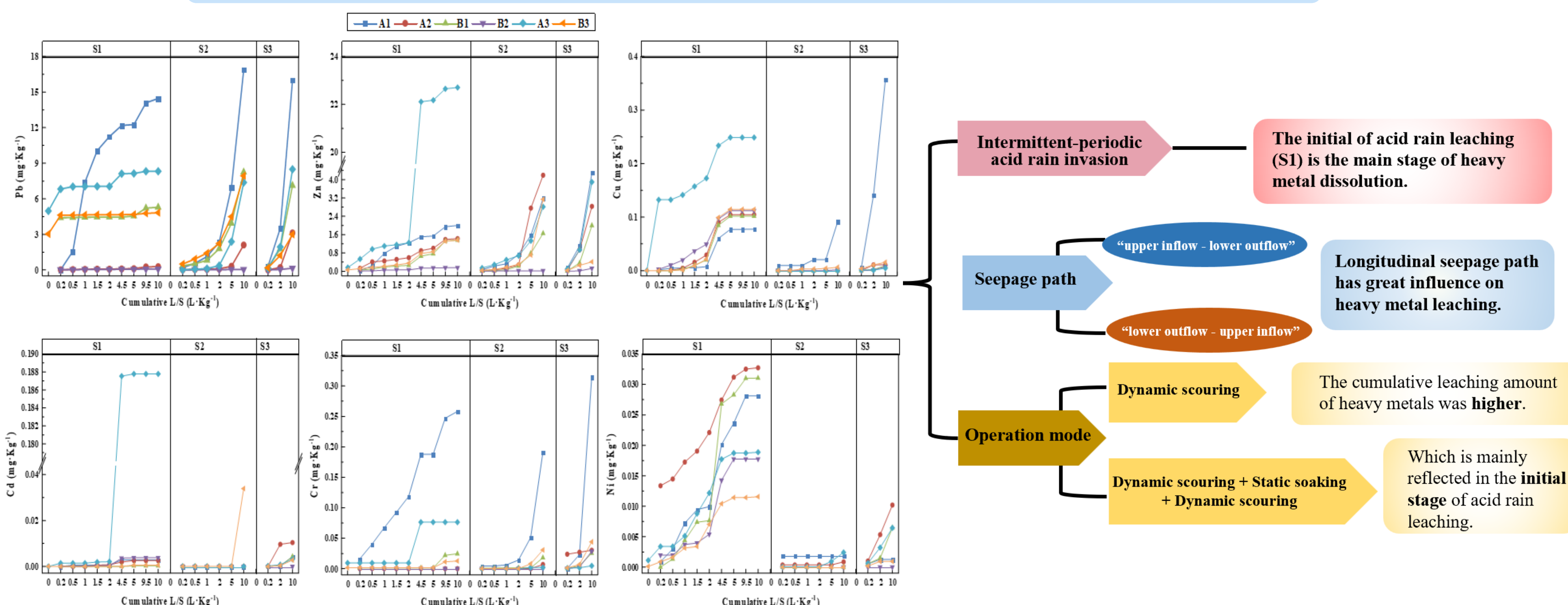
### pH, EC, change



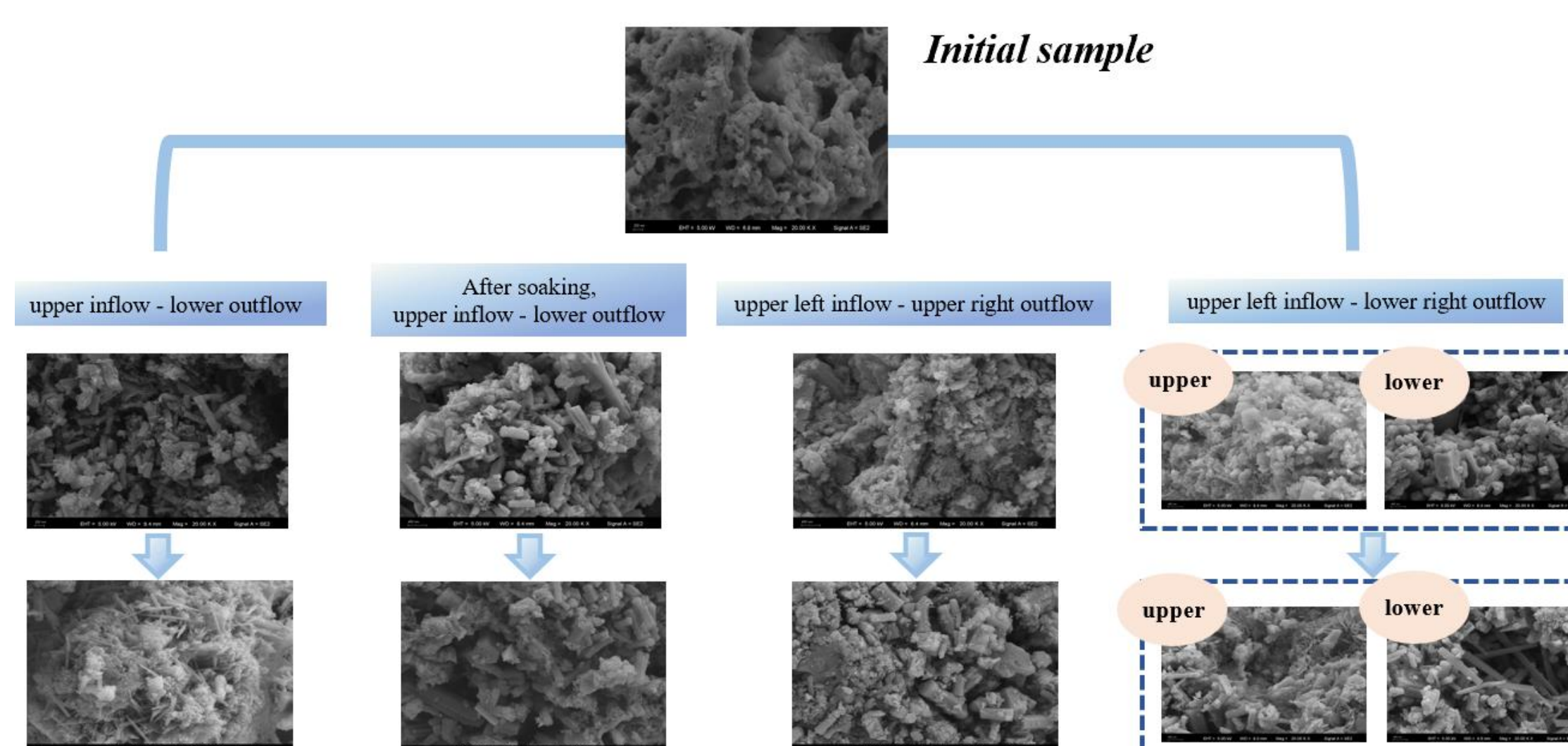
### Changes in leaching behavior of major elements



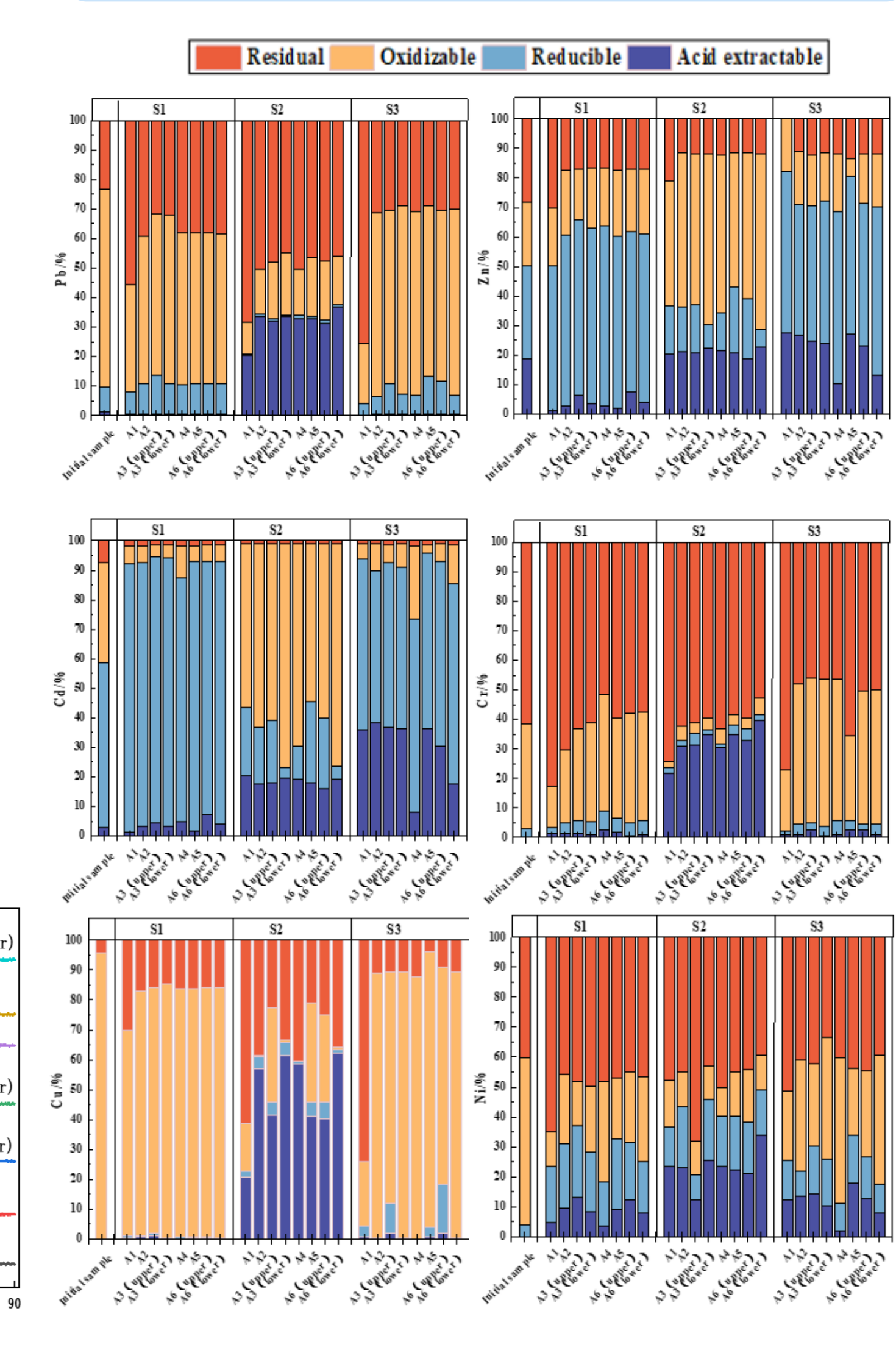
### Changes in leaching behavior of heavy metals



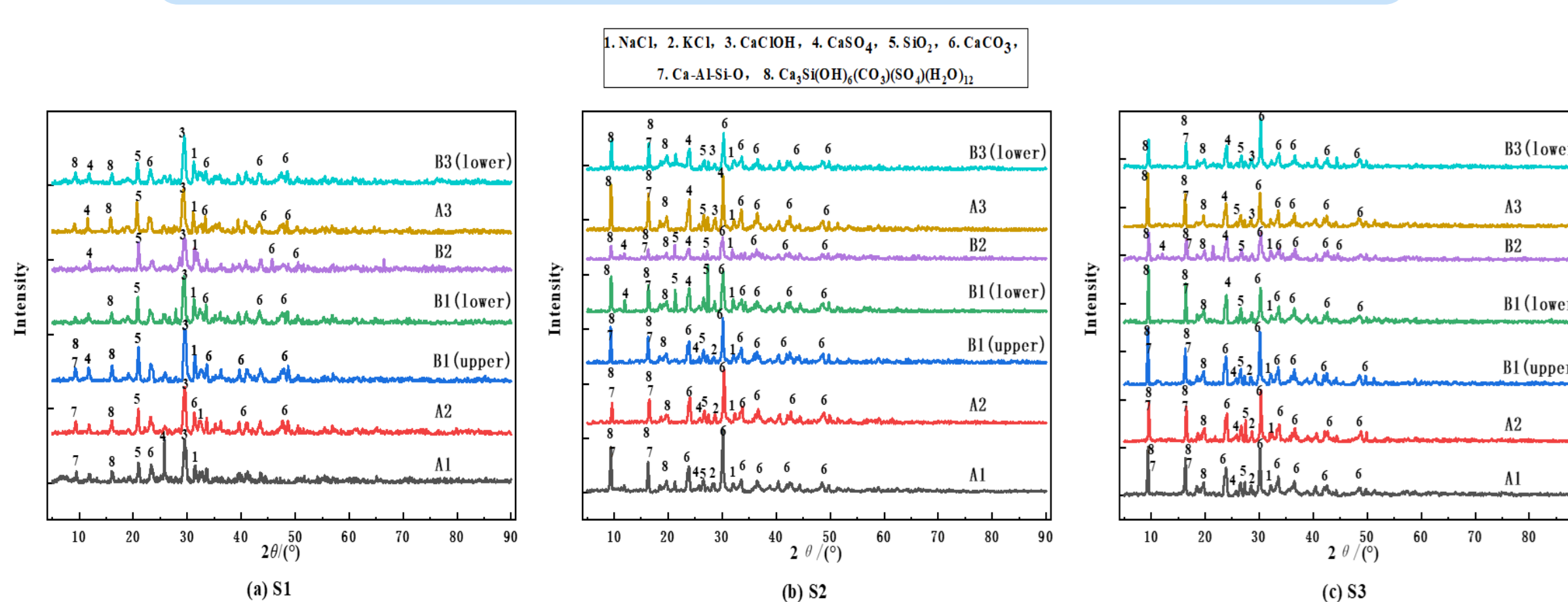
### Changes in surface morphology of micro-areas of solid phase fly ash



### Changes of chemical forms of heavy metals in solid fly ash



### Change of mineral structure of solid fly ash



## Conclusions

S1~S3 phased acid rain intrusion can significantly affect the stability of heavy metals in landfill-stabilized fly ash. The initial acid rain leaching is the main period affecting the leaching of rich gold from landfill-stabilized fly ash. A1 and A3 with "upper inflow - lower outflow", heavy metals in fly ash are more likely to enter the leachate due to the influence of both gravitational potential energy and matrix potential at the early stage of acid rain invasion. Leaching cycles are longer than others because of B1 and B3 lack gravitational potential energy. Thus leaching of heavy metals and significant elements is mainly reflected in the S2 and S3 stages. Compared with the "dynamic scouring + static soaking + dynamic scouring" process, the total accumulated leaching of heavy metals is higher in the single acid rain dynamic scouring mode. The leachate pH was the lowest in B2 with a "upper left inflow - upper right outflow", and the leaching of heavy metals (especially Pb, Zn, and Cr) was the least affected. In the initial acid rain leaching (S1 stage), the soluble salts in the stabilized fly ash were leached out in large quantities. The cluster-like structure on the surface of fly ash is reduced. With the continuous leaching of acid rain (S2 and S3 stages), the rod-like systems on the fly ash surface increase significantly. In general, the changes in surface morphology of landfill-stabilized fly ash are mainly affected by continuous acid rain leaching but relatively less by seepage path changes. Therefore, enhancing the anti-seepage capability of fly ash ton bags and standardizing the landfill operation process plays a vital role in reducing the leaching of heavy metals. Meanwhile, attention should be paid to the long-term stability of heavy metals in landfill-stabilized fly ash.