EDITORIAL

for: *Journal of Flow Injection Analysis*

ELECTROOSMOTIC FLOW: A rather recently introduced form of continuous-flow processing.

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A family, like it or not, is an entity to which everybody belongs. This is true for individuals as well as for analytical methodologies. To what family of analytical methodologies does flow injection analysis belong? Is there any newly recognized member in this family? Is there a characteristic that can be used to differentiate members within the family? This short note attempts to address these questions.

What is generally recognized as flow injection analysis is, in actuality, one of several forms of continuous-flow processing of great utility in the analytical laboratory [1]. Flow-aided continuous processing of samples and reagents entered the analytical laboratory via the air-segmented version introduced by Skeggs [2]. Modern chromatography, in its gas-liquid form, is another flow-aided continuous processing of samples; it consolidated its place in the analytical laboratory in parallel with air-segmented continuous-flow. Chromatography today, even in its liquid-liquid version, is still not recognized or only reluctantly accepted as belonging to the same type of methodologies to which segmented and unsegmented sample/reagent(s) processing belong. Capillary zone electrophoresis, a recent offspring of electrophoresis [3], is analogous to elution chromatography and also to what we recognize as continuous-flow analysis in that a narrow sample plug is introduced into a narrow tube and a continuous flow transports the sample from injection to detection. Consequently, capillary electrophoresis joins chromatography and continuous-flow systems as a recently added form of flow-aided sample manipulation to achieve specific analytical tasks.

Electroosmosis is defined as the flow of solvent in a capillary when a tangential field is applied [4]. The electroosmotic flow dictates the residence time that a solute or zone spends in the capillary; similarly, the physically imposed flow rate affects the residence time of sample components in chromatography and in continuous-flow analyses. The flow profile observed because of electroosmotic flow in narrow tubes is, however, believed to be drastically different from the type observed in conventional flow injection analysis

(Figure 1). The basic processes observed in all these flow-aided methodologies, however, take place as the plug moves down a narrow tube, and as such, provide the scientific basis for their differentiation within the context of their common characteristic: sample or sample/reagent(s) processing. The hydrodynamic characteristics that predominate in segmented and unsegmented continuous-flow point to convection as the dominant form of mass transfer in and out of the sample plug. With the flat velocity profile dominant in electroosmotic flow, longitudinal diffusion is the main source of solute dispersion in and out of the sample plug.

In summary, I hope that this short editorial has served to point out that: (1) flow injection analysis is a sample/reagent(s) processing methodology, (2) some other analytical procedures are also flow-aided and share the common characteristics of sample or sample/reagent(s) processing (e.g. segmented continuous-flow analysis, chromatography in general, and capillary electrophoresis), and (3) differences in modes of mass transfer and physical and chemical interactions are the fundamental distinctive aspects that distinguish among these flow-aided methodologies. These differential characteristics are summarized in Table 1.

REFERENCES

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TABLE 1. Most relevant members of the family of analytical methodologies used for sample or sample/reagent(s) processing.

Continuous-flow approach	Common Name	Basic processes that may take place during transport of the sample plug from injection to detection
Air-segmented	Continuous-flow analysis or segmented continuous-flow analysis	Radial mass transfer, mainly due to molecular diffusion, predominates in straight portions of the tubing manifold. Axial dispersion along the flowing streams alters the time distribution of the monitored species. The rate-limiting process is the radial mixing across fluid streamlines. Chemical kinetics may play a role.
Unsegmented	Flow injection analysis	Normally operates under laminar flow conditions. Convective mixing prevails with short residence times. Diffusional transport plays an increasing role as the residence time increases. Chemical kinetics may play a significant role.
Mass transfer between phases	Chromatography	Eddy diffusion, longitudinal molecular diffusion, and resistance to mass transfer may play predominant roles. Chemical kinetics only occasionally may play a role.
Electroosmosis	Capillary zone electrophoresis	Plug flow is believed to predominate. Thus, longitudinal diffusion controls mixing patterns. Chemical kinetics only occasionally may play a role.

Note: air-segmented and unsegmented continuous-flow sample/reagent(s) processes are generally considered "determination" approaches although both have been expanded to incorporate ancillary operations such as preconcentration and separation. Chromatography and electrophoresis are, on the other hand, considered "separation" approaches although both can be and are used for determination as well.

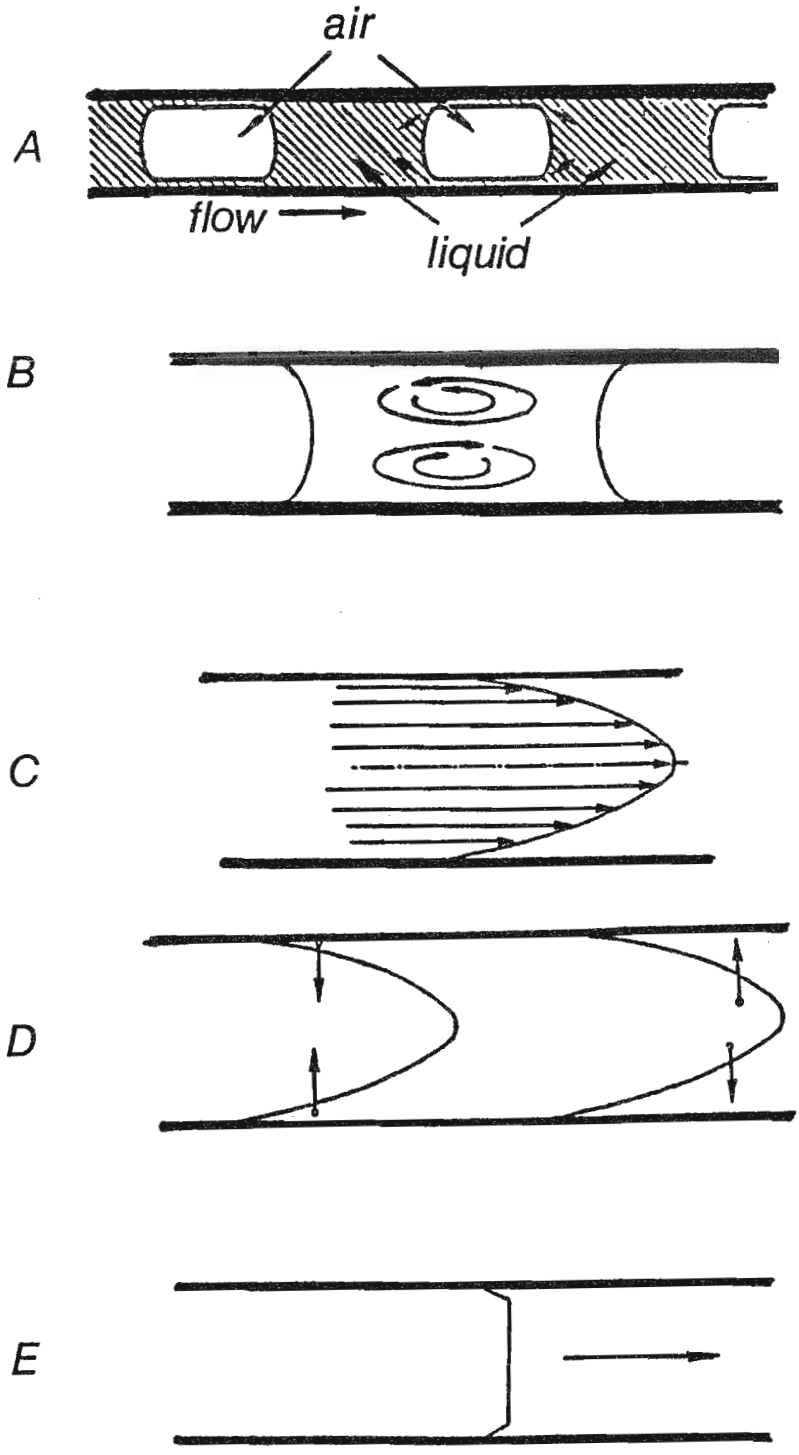

FIGURE 1. (A): sequence pattern of air and liquid plugs in air-segmented continuous-flow sample/reagent(s) processing. (B): mixing pattern in a liquid plug in air-segmented continuous-flow sample/reagent(s) processing. (C): parabolic flow profile and flow vectors in laminar flow. (D): initial mass transfer that develops once the parabolic flow profile is established in unsegmented continuous-flow sample/reagent processing. (E): flow profile observed during electroosmotic flow in narrow tubes.