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This Week's Citation Classic

Bremner J M. Inorganic forms of nitrogen. *Agronomy* **9**:1179-237, 1965.

This article critically reviewed methods for determination of inorganic forms of nitrogen in soils, discussed the principles, merits, and defects of different methods proposed, and provided detailed descriptions of colorimetric, microdiffusion, and steam distillation methods recommended for determination of ammonium, nitrite, and nitrate. [The *SCI*® indicates that this paper has been cited over 140 times since 1965.]

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"This article was one of six chapters[1-5] on determination of various forms of nitrogen which I was asked to prepare for the American Society of Agronomy monograph on *Methods of Soil Analysis*.[6] It was considerably longer and more difficult to write than the other chapters on nitrogen analyses, and it was completed on schedule only because the editor-in-chief of the monograph, C.A. Black, provided valuable comments and encouragement and shared the tedious and time-consuming task of checking my other manuscripts to insure that use of methods described would not be vitiated by typographical errors.

"Although this article described a variety of methods for determination of inorganic forms of nitrogen, there seems very little doubt that it has been cited largely because it provided detailed descriptions of rapid and simple steam distillation techniques that quickly gained international acceptance for determination of ammonium, nitrite and nitrate in soils, and other complex natural materials. These methods originated from work I did while on the staff of the chemistry department at Rothamsted ExperimentalStation in England to develop techniques that would permit both determination and ^{15}N analysis of inorganic and organic forms of nitrogen in soils. This work was prompted by the obvious deficiencies of the methods available for determination of different forms of nitrogen and by the severe restrictions imposed by these methods on use of ^{15}N-tracer techniques for research on nitrogen transformations in soils. It eventually led to development of methods that permitted both determination and isotope-ratio analysis of total N, exchangeable ammonium N, nonexchangeable ammonium N, nitrite N, nitrate N, hexosamine N, amino acid N, and urea N.

"Although the steam distillation methods of determining inorganic forms of nitrogen originated from my work at Rothamsted Experimental Station, I was unable to complete the numerous tests needed to evaluate them thoroughly before leaving England in 1959 to join the staff at Iowa State University. It was fortunate, therefore, that Dennis Keeney (currently at the University of Wisconsin, Madison) was one of my first graduate students at Iowa State University because he had exceptional enthusiasm and talent for research on analytical problems. With his help, the various interference, specificity, and recovery tests needed to complete development and evaluation of the methods for determination of ammonium, nitrite, and nitrate were performed and papers describing these methods were published.[7,8] It is fitting that Keeney has been invited to coauthor the chapter on determination of inorganic forms of nitrogen for a revision of the *Methods of Soil Analysis* monograph because, although several new methods of determining inorganic forms of nitrogen in soils have been proposed since 1965, the steam distillation methods he helped to develop are still the methods of choice for most research on nitrogen transformation in soils."

1. **Bremner J M.** Total nitrogen. *Agronomy* **9**:1149-78, 1965.
2. ..... Organic forms of nitrogen. *Agronomy* **9**:1238-55, 1965.
3. ..... Isotope-ratio analysis of nitrogen in nitrogen-15 tracer investigations. *Agronomy* **9**:1256-86, 1965.
4. **Cheng H H & Bremner J M.** Gaseous forms of nitrogen. *Agronomy* . **9**:1287-323, 1965.
5. **Bremner J M**. Nitrogen availability indexes. *Agronomy* **9:**1324-45, 1965.
6. **Black C A, ed.** *Methods of soil analysis.* Madison, WI: American Society of Agronomy, 1965. 2 vols.
7. **Bremner J M & Keeney D R.** Steam distillation methods for determination of ammonium, nitrate, and nitrite. *Anal. Chim. Acta* **32**:485-95, 1965,
8. ..... Determination and isotope-ratio analysis of different forms of nitrogen in soils. 3. Exchangeable ammonium, nitrate, and nitrite by extraction-distillation methods *Soil Sci. Soc. Amer. Proc.* **30**:577-82, 1966.