

# This Week's Citation Classic™

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Schwertmann U. Differenzierung der Eisenoxide des Bodens durch Extraktion mit Ammoniumoxalat-Lösung. (The differentiation of iron oxides in soils by extraction with ammonium oxalate solution.) *Z. Pflanz. Bodenk.* 105:194-202, 1964.  
[Tech. Hochschule, Hannover, Federal Republic of Germany]

This paper describes a simple method for separating an active poorly ordered fraction of Fe-oxides in soils and related materials from a less active and more crystalline one by a simple extraction with acid oxalate solution in the dark. The extracted fraction consists mainly of the mineral ferrihydrite. [The *SCI*® indicates that this paper has been cited in over 160 publications, making it the most-cited paper ever published in this journal.]

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"In 1922, O. Tamm<sup>1</sup> from Stockholm first used an oxalate solution to extract from soils what he then called 'the inorganic gel complex,' an undefined mixed weathering product of oxides of Al, Fe, and Si. Hence, when I started to work on Fe-oxides in soils during my PhD studies in 1957, it was only logical to include oxalate as well. It turned out to be the most suitable extractant because it roughly separated a crystalline proportion (nonextractable) from a 'noncrystalline' one, provided sunlight was excluded during extraction. At this time, I asked Tamm whether he had not noticed this influence of light. His answer was that he had always extracted the sample in the basement and during the winter (in Sweden)."

"The revised method was first described in 1959<sup>2</sup> but this paper was not cited as frequently as the one of 1964, probably be-

cause it did not deal solely with the method itself. A few years later the same method was again published in Canada by McKeague and Day,<sup>3</sup> and possibly because this paper was written in English, it was frequently cited, and was a *Citation Classic* in 1980.<sup>4</sup> "In 1967,<sup>5</sup> we showed how the method could be applied to problems of soil genesis, still not knowing at that time whether or not the extractable part of Fe was mineralogically a separate phase. This was only possible after the poorly ordered Fe-oxide mineral ferrihydrite was discovered and named in 1972 by Chukhrov<sup>6</sup> in the USSR. This enabled us recently to demonstrate that the oxalate extractable part of the Fe-oxides in many soil samples, as well as in synthetic preparations, was more or less identical to ferrihydrite.<sup>7</sup>"

"Reasons why the paper is frequently cited may be the following: first, it describes a very simple and rapid method which can be used even in a less well-equipped laboratory, and is capable of handling a large number of samples in a short time. Secondly, since reactions between constituents in soil solutions (phosphate, heavy metals, etc.) and Fe-oxides are common and likely to occur predominantly on the large surface area of the poorly ordered fraction of Fe-oxides, significant quantitative relationships were often observed between the extent of these reactions and the amount of oxalate-extractable Fe. This helps explain the behavior of such solutes in the environment. Finally, the ratio of oxalate-Fe to total oxidic-Fe reflects the state of Fe-oxide formation in soils as an important process in pedogenesis. It was extensively used to characterize this process and even the relative age of a soil."

"The work on Fe-oxides has continued and I have had the great pleasure of making many contacts throughout the world as a result of these studies."

1. Tamm O. Eine Methode zur Bestimmung der anorganischen Komponenten des Gelkomplexes im Boden. *Medd. Statens Skogsförökansstalt* 19:385-404, 1922.
2. Schwertmann U. Die fraktionierte Extraktion der freien Eisenoxide in Böden, ihre mineralogischen Formen und ihre Entstehungsweisen. *Z. Pflanz. Dung Bodenk.* 84:194-204, 1959. (Cited 30 times.)
3. McKeague J A & Day J H. Dithionite- and oxalate-extractable Fe and Al as aids in differentiating various classes of soils. *Can. J. Soil Sci.* 46:13-22, 1966. (Cited 225 times.)
4. McKeague J A. *Citation Classic*. Commentary on *Can. J. Soil Sci.* 46:13-22, 1966. *Current Contents/Agriculture, Biology & Environmental Sciences* 11(16):14, 21 April 1980.
5. Blume H P & Schwertmann U. Genetic evaluation of the profile distribution of aluminum, iron and manganese oxides. *Soil Sci. Soc. Amer. Proc.* 33:438-44, 1969. (Cited 70 times.)
6. Chukhrov F V, Zvijagin B B, Gorkhov A I, Ermolova L P & Balashova V V. Ferrihydrite. *Izv. Akad. Nauk. SSSR Ser. Geol.* 4:23-33, 1973. (Cited 10 times.)
7. Schwertmann U, Schulze D G & Murad E. Identification of ferrihydrite in soils by dissolution kinetics, differential X-ray diffraction and Mössbauer spectroscopy. *Soil Sci. Soc. Amer. J.* 46:869-75, 1982.