Journal of Pharmaceutical & Biomedical Analysis
Vol. 6, No. 1, pp. 29–33, 1988
Printed in Great Britain

0731–7085/88 $3.00 + 0.00

Aluminium in peritoneal dialysis fluids as determined by stabilised temperature platform furnace atomic absorption spectrometry

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Abstract: A procedure is described for the determination of aluminium in peritoneal dialysis fluids. It is based on Zeeman corrected graphite furnace atomic absorption spectrometry employing stabilised temperature platform furnace (STPF) conditions. The samples are analysed after dilution 1 + 1 without pretreatment. The limit of detection of the procedure is 1.5 $\mu g\ l^{-1}$, and the accuracy and precision were found acceptable. A screening survey showed that aluminium contamination of peritoneal dialysis fluids is not a general problem, but that exceptions to this do occur.

Keywords: *Aluminium determination; Zeeman graphite furnace; atomic absorption spectrometry; peritoneal dialysis fluids.*

Introduction

The toxic effects of aluminium on the human body have recently gained considerable interest. In 1976, aluminium was implicated as the cause of the clinical conditions dialysis encephalopathy and dialysis osteomalacia observed in patients undergoing long-term haemodialysis [1]. In these patients aluminium accumulates in the body and causes the above disorders in the brain and the skeleton. The aluminium originates from two main sources — the aluminium-containing phosphate binders given orally to dialysis patients in order to maintain their plasma phosphate levels within acceptable limits [2], and the dialysis fluids used in the dialysis process [3]. Since peritoneal dialysis has recently become more common than haemodialysis, a reliable analytical procedure for the determination of aluminium in peritoneal dialysis fluids is important. Even very small concentrations of aluminium, 10–15 $\mu g\ l^{-1}$, may result in a net transfer across the peritoneal membrane since most of the aluminium in plasma is bound to proteins and therefore not dialysable [4, 5].

Here we report an analytical procedure for the quantitative determination of aluminium in peritoneal dialysis fluids employing state-of-the-art graphite furnace atomic absorption spectrometry (GFAAS) — the so-called "Stabilised Temperature Platform Furnace" (STPF) technique [6]. Previous reports using the same technique have not utilised all of the parameters in the STPF concept [7], and/or have used instruments not ideally suited for GFAAS, since the time constants for the spectrometer electronics were of the order of several hundred ms [8, 9]. When spectral interferences,

or background absorbances are present in the matrices [7, 9], such long time constants may give inaccurate results.

Experimental

Instrumentation

A Perkin–Elmer Zeeman 5000 atomic absorption spectrometer equipped with a Perkin–Elmer AS-40 autosampler was used. The atomisation signals were displayed on a Perkin–Elmer R100-A recorder and their integrated absorbances (A*s) printed out on a Perkin–Elmer PRS-10 printer. Pyrolytically coated graphite tubes with inserted platforms of solid pyrolytic graphite were used throughout. The instrumental conditions are given in Table 1.

Table 1
Instrumental conditions for the determination of aluminium in peritoneal dialysis fluids

Wavelength	396.2 nm
Spectral band pass	0.7 nm
Lamp current	20 mA
Sample volume	20 µl

Graphite furnace programme:

Step	Temp. (°C)	Ramp(s)	Hold(s)
Dry I	120	30	20
Dry II	200	20	10
Char	1400	40	30
Atomise	2500	0*	7
Clean	2700	1	2
Cool	20	3	5

*Maximum power heating.

The internal argon gas flow was stopped and the Zeeman background correction was on during atomisation. As temperatures may vary slightly between instruments for a given setting, they should be regarded as approximate values only.

Reagents

The nitric acid was purified by sub-boiling distillation in an all-quartz apparatus (Hans Kürner, Rosenheim, FRG). The Triton X-100 was of scintillation grade, purchased from E. Merck (Darmstadt, FRG). A certified (1 g l^{-1}) aluminium reference solution (Titrisol; E. Merck) was used, diluted with a solution containing nitric acid and Triton X-100 (see below) to yield working standards. Milli-Q water, which is a type I ultrapure water prepared using a Milli-Q deionisation unit (Millipore, Bedford, MA, USA), was used.

Contamination control

Contamination is a serious problem when dealing with samples containing low concentrations of aluminium because of the ubiquitous nature of the element. Therefore, all utensils e.g. sample cups, pipette tips, sample containers etc., were carefully decontaminated by nitric acid wash as previously described [10].

Sample pre-treatment

The peritoneal dialysis fluids were analysed directly after dilution 1 + 1 with a 0.1% solution of Triton X-100 in 10^{-3}M nitric acid. Three separate preparations were made of each sample containing zero, one and two standard additions respectively. The unknown aluminium content was calculated by linear regression.

Discussion and Results

General

It has been proposed that the aluminium in dialysis fluids is more dangerous to patients treated by peritoneal dialysis than to those on haemodialysis [11]. The rationale for this is that the dialysability of aluminium is enhanced by a lowering of pH and fluids used in peritoneal dialysis are more acidic than those used for haemodialysis. This line of thought is substantiated by the significantly higher serum aluminium concentration found in patients on peritoneal dialysis compared with patients treated by haemodialysis and also by the finding that the mean aluminium concentrations found in inflow dialysate is higher than in outflow dialysate [11]. Unfortunately, the conclusions, based on serum aluminium concentrations are obscured by the fact that the consumption of aluminium-containing phosphate binders in the patient groups was not reported.

There are, however, clear indications for aluminium transfer from the dialysis fluid to the body across the peritoneal membrane and the aluminium concentration in the dialysate should be minimal in order to prevent an increase in the body burden of the element. The Commission of the European Community has proposed that the aluminium concentration of peritoneal dialysis fluids should be less than 15 $\mu g\ l^{-1}$, to be lowered later to 10 $\mu g\ l^{-1}$ [12, 13]. Unfortunately, the proposal has not been implemented until now, partly because of inadequate analytical performance in Member State laboratories. The method described here may be helpful in improving this analytical situation.

In order to quantify aluminium at the low levels required, it is necessary to employ the sensitivity of GFAAS. The signals produced by the graphite furnace are fast and transient and require spectrometers with fast electronics. Slow electronics may severely distort the signals and interferences in signal handling may produce poor accuracy [14, 15]. The Perkin–Elmer Zeeman 5000 has therefore been used. It has an adequate time constant of 20 ms and the Zeeman effect background correction is capable of correcting for structured and rapidly changing backgrounds; these features are prerequisites for reliable absorbance readings. With the present furnace programme, Table 1, the background absorbances are small. They never exceed 0.1 A*s, and are easily corrected for by the Zeeman system. STPF conditions are adhered to, cf. Table 1, but external matrix modification is unnecessary, as the sample itself contains the required ingredients [16], i.e. magnesium ions from the dialysis fluid and nitrate from the diluent solution. The reasons for the choice of analytical wavelength [10, 17] and method of calibration have been discussed previously [10].

Analytical performance

Three things are important in assessing the performance. Firstly, the limit of detection, defined as the blank value plus three times the standard deviation of the blank value [18]. We find a limit of detection of 1.5 $\mu g\ l^{-1}$ with the conditions given in Table 1. This result was calculated from 20 determinations on pure diluent solution.

Secondly, the precision. For aluminium concentrations above 5–10 μg l^{-1}, relative standard deviations better than 10% were routinely achieved. (See also Table 2 to be discussed below.) Finally, the accuracy. Unfortunately, no suitable reference material was available, however, quantitation is obtained here through standard additions and this is generally believed to produce acceptable accuracy in the same manner as are recovery experiments. It is fully recognised that this method of calibration is not without severe drawbacks and that a number of conditions must be obeyed to achieve meaningful and accurate results [19]. In the procedure given here we believe that these conditions are met.

Alternatively, and perhaps of more general use, quantitation may be effected by comparison with an aqueous standard curve in accordance with the STPF concept [6]. For a large sample series this will decrease the analysis time per sample, but the standard curve should be checked frequently.

Accuracy was evaluated in the "Guildford Trace Element Quality Assessment Scheme" [20]. During the period concerned, only two peritoneal dialysis fluid samples were included in the scheme — Sample 2017, December 1985 and sample 3003, May 1986. The consensus mean values and their standard deviations for the aluminium content based upon the results submitted from the participants in the scheme were: Sample 2017: 176.6 ± 58.0. μg l^{-1}; N = 21, and sample 3003: 121.3 ± 90.1 μg l^{-1}; N = 28. The results obtained by us using the present procedure were 183 μg l^{-1} and 115 μg l^{-1}, respectively. Unfortunately, such high concentrations are seldom encountered in real samples, and the value of the Guildford results in assessing accuracy at low levels is limited.

In conclusion, detection limit and precision for the described procedure are satisfactory and to the best of our knowledge, the procedure is also accurate.

Screening test

The results obtained by analysing various peritoneal dialysis fluids commonly used in Denmark are given in Table 2. Brands I and II are factory made preparations; Brand III represents a series of products made in the pharmacy unit of a hospital in Copenhagen and used in a number of hospitals in the greater Copenhagen area. The Brands I and II

Table 2
Aluminium contents in peritoneal dialysis fluids

Brand	Potassium	Glucose content (g l^{-1})	Aluminium content (μg l^{-1})
Ia	No	13.6	<1.5
Ib	No	22.7	<1.5
Ic	No	38.6	<1.5
IIa	Yes	15.0	3.3 ± 0.3
IIb	No	15.0	3.5 ± 0.5
IIc	Yes	40.0	4.4 ± 0.3
IIIa	Yes	15.0	<1.5
IIIb*	Yes	15.0	45.6 ± 0.8
IIIc	No	40.0	1.5 ± 1.0
IIId	Yes	40.0	<1.5

* Stored in glass.

preparations have pH-values of approximately 5, whereas the Brand III preparations are somewhat less acidic, i.e. pH approximately 6. As the glucose and potassium content varies most in the preparations these are also included in Table 2. The table indicates that all of the preparations, except one, contain less aluminium than the most severe limit of 10 $\mu g\ l^{-1}$ proposed by the Commission of the European Communities. The exception is a preparation being stored in 1 l glass bottles; all other samples were in plastic bags, i.e. Brand I in polyvinylchloride, Brand II in polypropylene and Brand III in high density polyethylene bags. As aluminium is a constituent of glass, the elevated amount found in this sample presumably originates from the bottle; storage of dialysis fluids in glass containers should be avoided.

Conclusion

A method is presented for the determination of aluminium in peritoneal dialysis fluids, based on GFAAS employing STPF conditions. It is sensitive, precise, accurate and sufficiently fast to be useful routinely. A screening survey of the most common preparations of peritoneal dialysis fluids used in Danish hospitals revealed that aluminium contamination of these is generally not a problem, but exceptions do occur. Regular monitoring of the aluminium concentration in these fluids should be instituted.

Acknowledgements: The technical assistance of Susanne Reimert and the help of Eva Johnsen, Jørgen Lang Pedersen and Steffen Bager in providing the samples, are gratefully acknoweledged.

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[*Received for review 10 November 1986; revised manuscript received 27 March 1987*]