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Comparison of Quantitative Neutron Capture Radiography, Inductively Coupled Plasma Mass Spectrometry, and
Prompt Gamma Activation Analysis for Boron Determination in Biological Samples

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Introduction:
Boron determination is most commonly carried out in water and geological samples. Its determination in blood and tissue samples is a crucial task especially for treatment planning, preclinical research, and clinical application of BNCT. However, comparison of clinical findings remains difficult due to a variety of analytical methods, protocols and standard reference materials in use [1]. This abstract addresses the comparability of Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Quantitative Neutron Capture Radiography (QNCR), and Prompt Gamma Activation Analysis (PGAA) for the determination of boron in biological samples, using blood and tissue samples from a clinical study for the comparison. The methodical comparison of ICP-MS, ICP-OES, PGAA, and QNCR is of general interest, because these are the most frequently used methods for quantitative analysis in clinically relevant studies

Materials and Methods:
Blood and tissue samples were obtained from a clinical study to investigate the uptake behaviour of p-boronophenylalanine-fructose (BPA-f) in cancerous and tumour free liver tissue. Since the boron distribution within a sample taken from tumour free liver tissue was very homogeneous, it serves as an ideal sample matrix to compare methods for integral and locally selective boron analyses. To be able to compare data from ICP-MS or PGAA directly to those obtained by QNCR, a set of reference blood samples was included in the comparison, which before had been used for the production of reference standards for analysis by QNCR [2]. Irradiations for QNCR and PGAA took place at the research reactors of the University of Mainz, the HFR Petten, the Netherlands, and the FRM II of the Technical University of Munich, Germany.
The larger part of the tissue biopsies could be analysed by all three methods, thus creating a situation similar to a Round-Robin trial. The blood samples were first analysed by PGAA and then by ICP-MS, since the latter required wet-ashing for sample preparation. The measurements by QNCR and PGAA, as well as the related clinical study are described in detail elsewhere [2, 3].
Results and discussion:
Consistency and conformity of ICP-MS and PGAA measurements for blood samples in a range of 0 –30 ppm 10B was very good. From previous works, it is known that both methods relying on the inductively coupled plasma showed little difference in performance when measuring samples equally prepared following the same protocol [4, 5]. Also, comparison of ICP-OES to PGAA had revealed good agreement [6].
However, for none of the three methods accordance with QNCR has been found so far. In previous works, Probst et al. concluded that differences to QNCR may be due to the fact that ICP-MS and ICP OES could not

account for the very heterogeneous boron concentration that can occur in tissue samples. In this respect, tumour free liver tissue appears as a very suitable "model system"to overcome this problem, which could be demonstrated by very consistent measurements comparing the three methods included in the comparison.

Conclusion:
The data of all methods and their comparison revealed that it is possible to obtain matching results from all three methods for a specific type of organic sample (tumour free liver tissue). also demonstrating the possibility to obtain consistent results from analytical techniques for integral boron determination in comparison to a locally selective method.
Reference materials in use for analytical, and especially radioanalytical, boron determination by groups worldwide vary in their characteristics depending on each method. For standardisation of analytical protocols, BPA-f in whole blood is suitable for comparison of ICP-MS, ICP-OES, PGAA and, indirectly, for QNCR and could therefore serve in a larger Round-Robin trial as reference material.

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