Systematic study of the validity and robustness of the quenching index of commercial LS counters

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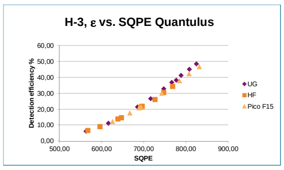
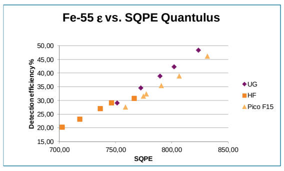
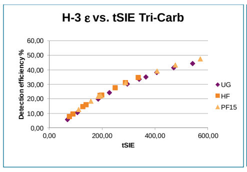
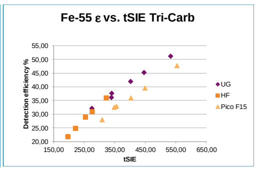
The detection efficiency of a LS source is a function of the quenching level. Several methods can be applied to determine the value of a quenching index which is used to determine the relation between this quenching index and the detection efficiency of a given radionuclide. In commercial counters, the quenching index is generally derived from the analysis of the Compton spectrum created by an external gamma-ray source. In a 3-PMT counter, the quenching can also be deduced from the value of the triple to double coincidence ratio (TDCR). The goal of this study is to test the performances and robustness of these quenching indexes. In this study we considered low-energy radionuclides (^{3}H, ^{55}Fe and ^{63}Ni), three commercial LS cocktails (Ultima Gold, Hionic Fluor and PicoFluor 15 from Perkin Elmer) and two counters (Quantulus, TriCarb 3170 TR). Sets of sources were all individually standardized using the TDCR method and then quenched with various amount of nitromethane or color quencher. The sources were measured using the 2 commercial LS counters and also with locally-made TDCR counter, to study the properties of the TDCR value as a quenching index.

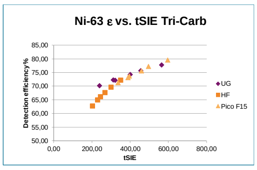
The Tables and graphs report the influence of the scintillator and the influence of the nature of quenching (i.e. chemical or color) on the value of the quenching index. A robust quenching index must not depend on the scintillator, on the radionuclide or on the nature of the quenching.

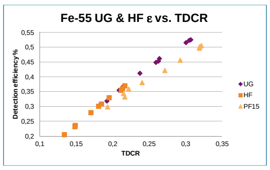


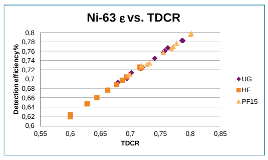






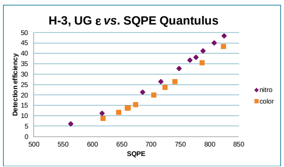


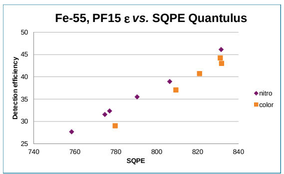


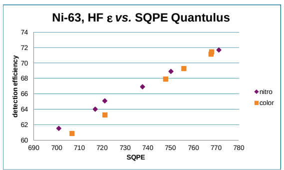


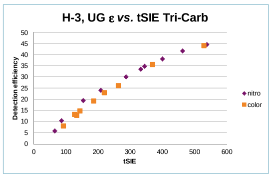
	Quantulus	Tri-Carb	TDCR
^{3}H	small	small	no
^{55}Fe	yes	yes	yes
^{63}Ni	small	yes	no
Influence of the scintillator (Ultima Gold, Hionic Fluor, Picofluor 15)			

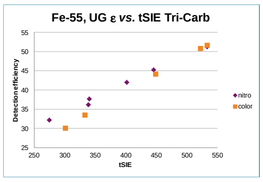
Influence of the nature of quenching			
^{3}H	yes	small	no
^{55}Fe	yes	yes	no
^{63}Ni	yes	yes	no
	Quantulus	Tri-Carb	TDCR

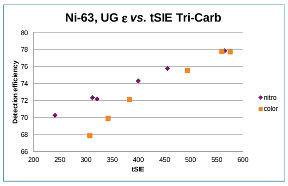


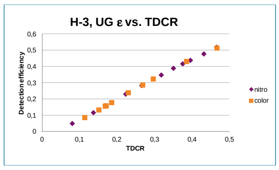


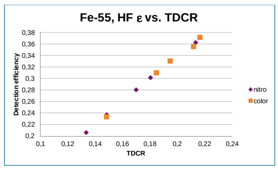


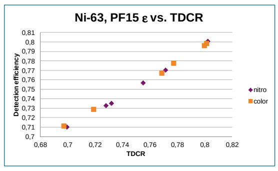












Legend

- tSIE: transformed spectral index of the external standard (Packard, Perkin Elmer) ^{133}Ba external source
- SQPE: external spectral quench parameter (Wallac, Perkin Elmer) ^{152}Eu external source
- UG: Ultima Gold, HF: Hionic Fluor, PF15: Picofluor 15, LS cocktails (Perkin Elmer)
- ε: detection efficiency (ratio of the counting rate and activity of the source)

Discussion

The quenching index seems to depend on the nature of the scintillator but results vary with the radionuclide. It is worth noticing that the smaller effect is observed for tritium and the larger for ^{55}Fe. It can be observed that generally, the color and chemical quench curves are not identical. The dependence on the scintillator and on the nature of quenching is not observed for the TDCR as a quenching index, except in the case of ^{55}Fe, where this dependence is due to the composition of the scintillator, especially the phosphorus content. This cause a difference in the probability of absorption of KX rays in the scintillator and thus in the detection efficiency. This later point is taken into account in the TDCR model calculation.

Conclusions

The TDCR value appears to be the more robust quenching index in LSC. External sources quenching indexes like tSIE or SQPE appears to be more or less dependent on the nature of the scintillator, on the radionuclide to measure and on the nature of the quenching. The consequence is the well known fact that, when using these indexes, a quenching curve is only valid for the radionuclide to measure, the scintillator to be used and for the quenching phenomenon occurring in the source to measure. For metrological applications, like the CIEMAT/NIST method, this study also confirm the fact that the chemical composition of the source to measure and of the tracer source must be strictly matched, in order to be able to consider that the quenching index of the tracer source and the source to measure have the same meaning.

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