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Assessment of Quench Indicating Parameters (QIP) of an Alternative Scintillation Cocktail Mixture by Low Level Liquid Scintillation Counting

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Abstract: The evolution of the accurate, precise measurements and applied research in the nuclear field is entailed to the development of the new types of liquid scintillation cocktail, which have determined different technological applications in several areas. Aiming to reach this goal, the low-cost, suitable chemical composition, significant scintillation efficiency and high alpha-beta discrimination process have been considered by preparing of a modified scintillator cocktail mixture. Suitable chemical composition was developed based not only on the high scintillation response of the primary salt but also on the achievement of complete solubilization of the aqueous solutions containing different radionuclides in the organic phase. Quenching Indicator Parameters (QIP) including SIS and tSIE were measured and considered as a direct evaluation terms for the scintillator capability. All measurements were carried out using both CPM mode and a-ß counting mode to check the pulse discrimination capability of the new mixture. The obtained results show that the present cocktail can be advantageously applied for low level counting of both a and ß emitting radionuclides with high sample homo geneity.

Key words: Liquid scintillation counting . scintillation efficiency . alpha/beta discrimination . Quench Indicating Parameters (QIP)

INTRODUCTION

Detecting and quantitating alpha and beta emitting radionuclides are routine tasks in nuclear activities and environmental monitoring. For this purpose, Liquid Scintillation Counting (LSC) is an excellent technique because alphas and betas are counted with nearly 100% and >90% counting efficiency respectively with low background, even with severe quenching [1].

Basically, the liquid scintillation process is the conversion of the energy of a radioactive decay event into photons of light. Photomultiplier Tubes (PMT's) are used to detect and convert the photons into electrical pulses. Both the sample and the scintillator are dissolved in an aromatic solvent, which allows energy to be transferred. Any factor reduces the efficiency of the energy transfer or causes the absorption of photons, results in quenching in the sample. There are two main types of quench: chemical quench occurs during the transfer of energy from the solvent to the scintillator [2, 3] and color quench causes attenuation to the photons of light by absorbing and scattering them in the solution, resulting in reduced light output available for measurement by the PMT's [4].

The number of photons released by the scintillator is directly proportional to the energy of the beta particles; this property of the scintillator can be used, not only for counting, but also for identifying beta-emitting radionuclides of different energies [5]. In liquid scintillation counting the proper sample should always exhibit 4π-counting geometry; that is, it should be clear, colorless and homogeneous. If the sample is not homogeneous, an accurate determination of sample efficiency cannot be made, resulting in an erroneous DPM estimate [6-8].

Insoluble samples which phase or precipitate out of solution, or samples which bind to the vial wall can result in counting efficiency which fall somewhere between 2π- and 4π- counting geometry. The situation is especially critical for weak beta particles in that, along with poor counting geometry, they may be lost by self-absorption. A heterogeneous sample can be responsible for huge errors in the estimation of radioactivity content [9, 10].

When Disintegration Per Minute (DPM) are being calculated, the sample must be checked not only for complete homogeneity but also for quench. If a sample is not corrected for quench, erroneous DPM results may be reported. Generally, the more the sample is quenched, the lower it's counting efficiency [11, 12].

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From this point, several researchers were published articles concerning the effect of quenching on both beta and alpha emitting radionuclides in different scintillation cocktails [9, 13], proposed data treatment procedure which allowed a drastic reduction of the chemical separation steps involved in the quantification of ^{55}Fe, ^{63}Ni, ^{99}Tc, ^{137}Cs and $^{90}Sr/^{90}Y$ in radioactive waste by liquid scintillation. Also, the influences of quenching and level of activity was evaluated and the activity of unknown samples determined.

Altzitzoglou [6] demonstrated a new method for simultaneous analysis of ^{32}P, ^{33}P and ^{35}S present in the same sample by 4π-ß liquid scintillation spectrometry. This method was used to investigate the behavior of the samples in two different scintillators, Ultima-Gold and Insta-Gel Plus, for a period of 120 days giving a decrease in the quenching parameter (tSIE) during approximately 15 days. This study revealed that Ultima-Gold is stable during the counting period while, the stability in Insta-Gel Plus is not adequate. Also, the consistency of the counting efficiency was determined by measuring some of the samples at different degrees of quenching using CCl_4. Samples with quenching from 515 to 200 in tSIE units, or equivalently with ^{3}H efficiency from 48% to 21%, provides the same result within the measurement uncertainty.

The present work aims in principle to prepare a new scintillation cocktail mixtures containing different solublizing agents and comparing them with well known scintillator cocktail Ultima Gold AB. This can be achieved by measuring the counting efficiency versus SIS and tSIE quenching parameters at different degrees of quenching by adding certain chemical agents.

EXPERIMENTAL

Reagents and solutions: All chemicals and solvents were analytical grade. Benzene, Toluene and Xylene were purchased from BDH (England). 1-phenyl, 4-phenyloxazole (PPO) and 1,4-di-2-(4-methyl, 5-phenyl oxazoyl) benzene (POPOP) were obtained from Merck (Germany). Iso-propanol and n-butanol were purchased from ADWIC (Egypt). Other chemicals were obtained from different suppliers including, naphthalene from WINLAB (England) and anthracene from Brixworth Northants (UK). Ultima Gold AB scintillation cocktail and 22 ml glass vials were supplied by Packard (USA).

Radioisotopes: Four different stock standard solutions from ^{133}Ba, ^{226}Ra, ^{243}Am and ^{90}Sr radionuclides were used for conducting the present study. These were obtained from International Atomic Energy Authority, IAEA.

Apparatus: A Tri-Carb 2770 TR-LSC Analyzer with Pulse Shape Analysis (PSA) and Multichannel Analyzer (MCA) supplied from Canberra-Packard, USA was used in this study.

RESULTS AND DISCUSSION

Optimizing of the cocktail composition: A wide range of scintillator solutions is available in modern radiochemical laboratories. The choice of suitable cocktail composition for a particular application should characterize by having low background and high sample loading capacity. One of the problems in liquid scintillation counting is that all the scintillation events can not be detected, so that the counting efficiency is normally <100% and the actual efficiency must be determined before the activity of the radioactive material can be calculated. Achieving these objectives should be accompanied by considering the cost of the new composition cocktail. In this respect, anthracene and naphthalene are carefully tested as a primary scintillator with or without a mixture of PPO and POPOP dissolved in a suitable various solvent in the presence of different solubilizing agent such as n-butanol and isopropanol.

Effect of solvent: In any scintillation cocktail not only solvent's functions are to keep the scintillators or solutes in solutions but also to absorb the decay energy of the radioisotopes for subsequent transfer to the solutes.

The data obtained in this study (not presented) to choose the most efficient solvent from benzene, toluene and xylene based on the count rate of ^{133}Ba as radioactive materiel, illustrates that the maximum count rates were greatly enhanced using toluene rather than using xylene, while benzene is less efficient in comparable with others.

Effect of primary and secondary solutes without solubilizing agent: ^{133}Ba is used as radioactive source to investigate the roles of primary and secondary solutes in scintillation cocktail mixture. The primary solute as naphthalene and anthracene act as a trap for the radioactive decay energy initially converted into electronic excitation energy by the solvent molecules. The secondary solute like POPOP is used to trap the excitation energy from the primary solute and emits photons of longer wavelength. The obtained results (not presented) revealed that the count rate (CPM) found to

Table 1: Effect of solublizing agent addition (Isopropanol and m-butanol)

	CPM			CPM	
Org/Isopropanol ratio	Beta	Alpha	Org./n-Butanol ratio	Beta	Alpha
-	-	-	Blank	11.6±0.88	0.7±0.22
Blank	8.5±0.75	0.2±0.11	20/0	177±3.44	67±2.11
20/0.0	177±3.44	67±2.11	15/5.0	200±3.65	67±2.12
15/5.0	223±3.86	70±2.16	14/6.0	213±3.77	68±2.13
14/6.0	426±5.33	212±3.75	13/7.0	240±4.0	73±2.21
13/7.0	657±6.62	350±4.83	12/8.0	280±4.32	95±2.52
12/8.0	637±6.52	300±4.47	10/10	485±5.69	145±3.11
10/10	602±6.34	219±3.82	5/15	306±4.51	30±1.41

(11.3×10^{-3} M PPO + 6.8×10^{-4} POPOP in toluene)

increase by increasing the anthracene concentration in toluene solvent until specific concentration equal 11.2×10^{-3} M, after this point, the CPM start to decrease, which may be attributed to the phenomenon of photon absorption by the anthracene itself. On the other hand, the count rate increases gradually by increasing naphthalene scintillator until its maximum solubility giving optimum concentration of 2.34 M.

The effect of using POPOP as a secondary scintillator at the optimum conditions of both anthracene and naphthalene shows that POPOP concentration of 6.8×10^{-4} M is chosen as the best, causing enhancement in the count rate from 58.7 to 76.5 CPM in anthracene system.

Effect of solubilizing agents: Starting from the fact that, the degree of miscibility is very important in measuring radioactive samples efficiently, especially for low energy emitters. The present point aims to prepare a homogeneous solution containing a significant volume of aqueous sample and organic scintillation cocktail (mixture of PPO and POPOP in toluene solvent) by using commercially available and cheap industrial solubilisers such as isopropanol and n-butanol.

The data in Table 1 shows the effect of solubilizing agent such as isopropanol and n-butanol agents with different ratios on the count rate of ^{133}Ba in both beta and alpha region using PPO-POPOP/toluene system.

First, stock of 20 ml organic scintillation without solubilizing agent was counted. The count rate was 177 and 67 CPM in beta and alpha region, respectively giving two immiscible layers. In these respects, serial addition of isopropanol to the organic mixture was investigated to prevent the phases separation. By increasing isopropanol ratio to the organic solution, the count rate found to increase gradually until optimum value at 13/7 organic/isopropanol (v/v) ratio giving count rate 657 CPM in beta region and 350 CPM in alpha region. This is considered as a typical required condition for homogeneous scintillator with maximum counting efficiency. After this ratio, the count rate starts to decrease by increasing isopropanol volume.

By using n-butanol as a solubilizing agent instead of isopropanol under the same condition, the data showed that the counting rates without n-butanol are 177 and 67 CPM in beta and alpha region, respectively. At this condition, two immiscible layers were observed. Therefore, serial addition of n-butanol to toluene was investigated to prevent the phase separation and improve the counting rate.

Monitoring the CPM, it was found that the maximum count rate was obtained at organic/n-butanol ratio of 10/10 (v/v) giving homogeneous solution of 485 and 145 CPM in beta and alpha regions respectively. Although there is one layer observed at 5/15 organic/n-butanol ratio, the counting rate was decreased to 306 and 30 CPM for beta and alpha, respectively. This might be attributed to the less capability of the small volume of toluene to transfer the emitted photons from the primary and secondary scintillators to the detector.

From Table 1, it is concluded that both the count rate and counting efficiency in POP-POPOP in toluene/isopropanol at 13/7 ratio are significantly greater than that in POP-POPOP in toluene/n-butanol at 10/10 mixture.

By adding naphthalene as a primary solute to the optimum organic and isopropanol mixture at 13/7 ratio, the count rate is significantly enhanced from 657 to 870 CPM in beta region and from 350 to 445 CPM in alpha region at 1.25 M naphthalene concentration, while the naphthalene solute found to be less soluble in 10/10 organic/isopropanol mixture. Also, this mixture found to be less efficient than other system containing n-butanol as a

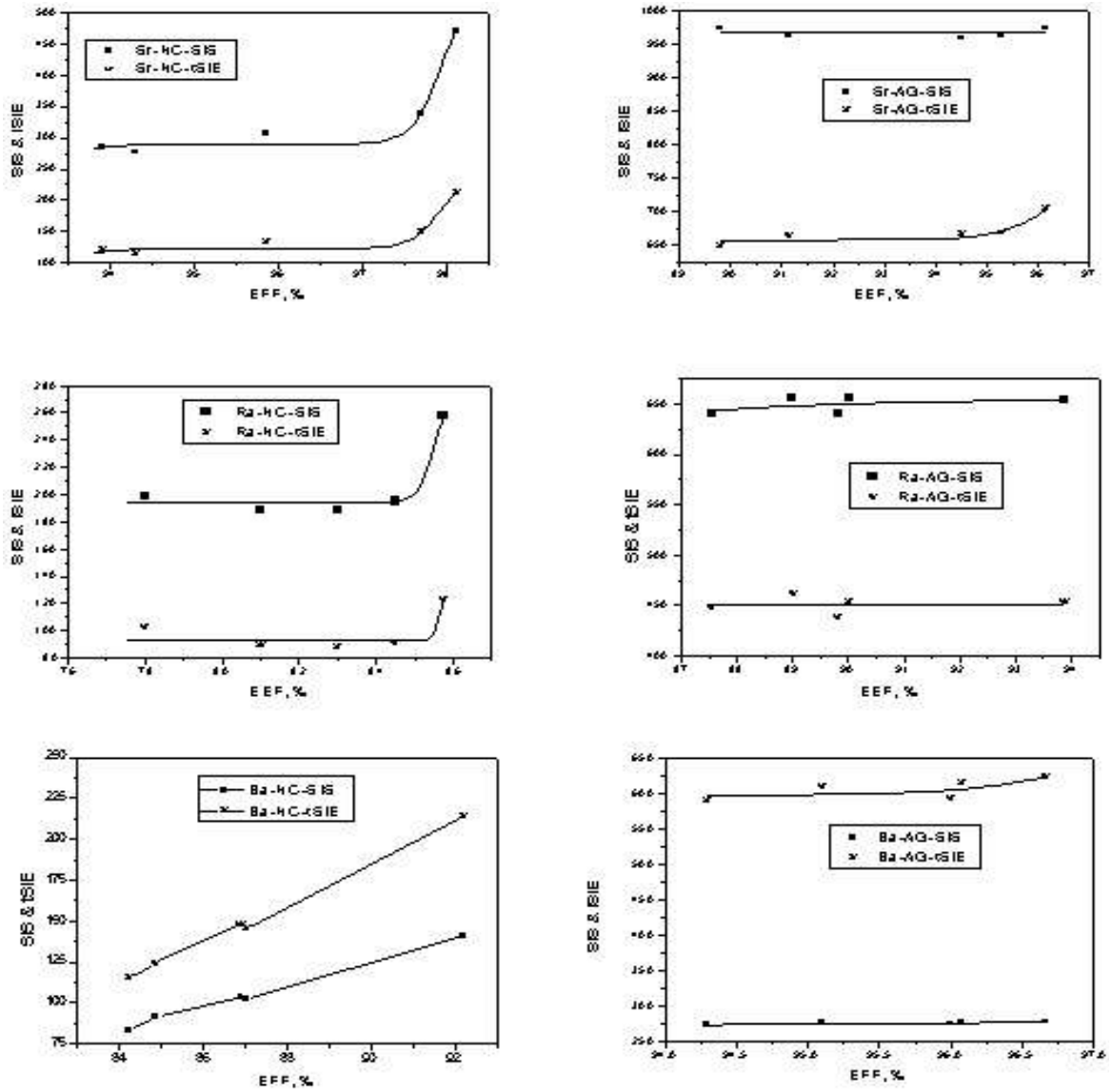

Fig. 1: Effect of Quench Indicating Parameters (QIP) on the counting efficiency

solubilizing agent, where count rate enhanced from 485 to 727 CPM and from 145 to 291 CPM in beta and alpha region, respectively at 1.10 M naphthalene concentration. It could be stated that the optimum cocktail composition was obtained by using PPO-POPOP/toluene in presence of isopropanol as solubilizing agent within ratio 13/7 (v/v) at 1.25 M of naphthalene.

By adding anthracene as a primary solute to the optimum conditions of both organic/isopropanol mixture at 13/7 ratio and organic/n-butanol mixture at 10/10, the count rate found to decrease gradually with increasing the concentration of anthracene in beta and alpha regions, which significantly suppresses the count rates and decreases the corresponding counting efficiency.

Comparing the obtained result using the prepared organic cocktail with Ultima Gold (AB) scintillation cocktail supplied from Canberra-Packard, the count rates are 620 and 695 CPM in beta and alpha regions by using Ultima Gold cocktail while the corresponding values are 870 and 442 CPM in beta and alpha regions by using locally prepared cocktail, respectively. These results revealed that the count rate of ^{133}Ba in beta region using the prepared mixture is higher than that used at the same volume of Ultima Gold cocktail which inconsistent in alpha region. In this respect, optimization of the counting region as well as the alpha/beta discrimination line is essentially tested.

Determining the Quench Indicating Parameters (QIP): Quench Indicating Parameters (QIP) are used to

assign a numeric value to the amount of quench in a sample. The two QIPs used by the instrument are the Spctral Index of the Sample (SIS) and the Transformed Spectral Index of the External Standard (tSIE).

SIS uses the interaction between the radioactivity of the sample and the scintillator in the sample vial to determine the quench level. The SIS parameter is calculated from the mean pulse height (in keV) of the sample spectrum. For most nuclides, SIS will approximate the unquenched endpoint of the nuclide spectrum. Since, the SIS parameter is based on actual sample counts, very low count rate samples may require longer counting times to determine SIS values. In this case (at very low counting rate), quench is best determined by tSIE, which is independent of sample count rate.

Plotting of counting efficiency against the quenching indicating parameters SIS and tSIE for three different radionuclides ^{90}Sr, ^{226}Ra and ^{133}Ba using prepared cocktail mixture at optimum conditions (NC) and AG reference cocktail was demonstrated as shown in Fig. 1.

For ^{90}Sr as pure beta emitting radionuclide in NC cocktail, there is no significant change of both SIS (290) and tSIE (125) within the efficiency range from 94 to 97.5%. After 97.5% counting efficiency, there is abrupt change and increasing of both SIS and tSIE with values 475 and 256, respectively. At these points a typical zero volume of acetone as quenching agent was applied. In case of AG cocktail with ^{90}Sr, there is insignificant change (steady state) of both SIS (975) and tSIE (630) with increasing the efficiency from 90 to 96%. This indicates that the addition of acetone as quenching agent has insignificant change of QIP within the counting efficiency up to 97.5% during ^{90}Sr measurement. This behavior can be confirmed from insignificant change in the spectral height (keV) of ^{90}Sr using the two cocktails as shown in Fig. 2.

For alpha emitting radionuclide ^{226}Ra, there is no significant change for both SIS (200) and tSIE (95) using NC cocktail within the efficiency range from 78 upto 85%. Over 85% counting efficiency, the values of both SIS and tSIE increased to 260 and 120, respectively without quenching agent. In case of AG cocktail with ^{226}Ra, there is insignificant change in the efficiency for the two parameters within the range 87.5 to 94%. The SIS (650) and tSIE (450) values using AG are notably higher than corresponding values using NC, this can be indicated from a large shift in spectral pulse height for ^{226}Ra.

To investigate the effect of gamma ray on NC and AG cocktails, ^{133}Ba as gamma emitting radionuclide was used. The obtained results give linear increasing for both SIS and tSIE with increasing the counting efficiency as a result in decreasing the amount of acetone. This unconventional behavior is mainly attributed to the non-definite electron emission from ^{133}Ba which may be counted as non-typical alpha and beta particles. In case of AG cocktail, there is insignificant change for both SIS (625) and tSIE (275) with increasing the efficiency from 94.2 to 96.5%.

Generally, it was observed that using acetone as a quenching agent has significant effect on the QIPs using NC cocktail rather than using AG as reference cocktail, however, accurate CPM values can be determined for samples with both of SIS and tSIE parameters, regardless of the quench level. This is clearly tested by the correlation between the counting rate and the corresponding quenching level.

Counting rate and quenching: There are a number of ways for estimating the counting efficiency in liquid scintillation counting. As there is a sense in which all lowering of counting efficiency below 100% is a result of quenching, the procedure of estimating the efficiency of counting is frequently referred to the estimation of the quench correction.

The standards of ^{133}Ba, ^{226}Ra and ^{90}S in addition to the blank sample are used to measure the counting efficiency of LSC by dividing the net count rate in CPM by DPM of used standards. Counting efficiency generally depends on the counted radioisotopes, sample compositions and scintillation counters. In general, poor counting efficiency can be caused by an extremely low energy to light conversion rate (scintillation efficiency). It has been calculated that only 4% of the energy from ß emission event is converted to light by even the most efficient scintillation cocktails. Fortunately, this number does not vary greatly across a wide range of ß-energies, which avoids an additional level of complexity in signal interpretation. Also, the loss of CPM due to absorption of ß-energy or photons by sample components is due to quenching. This may leads to an underestimate of the total counts

As shown in Table 2, a set of quenched standards is created by adding acetone as a quenching agent. The CPM of each standard was calculated using two modes of measurements using CPM and alpha-beta modes. Quenching reduces the intensity of each light pulse, so that the counts appeared at lower energy. This shifted the counts from high to low energy channels and decrease the channels ratio (Fig. 2).

Using total CPM mode, insignificant differences in the count rates of ^{133}Ba, ^{90}Sr and ^{226}Ra using each of AG and NC cocktails were obtained with gradual

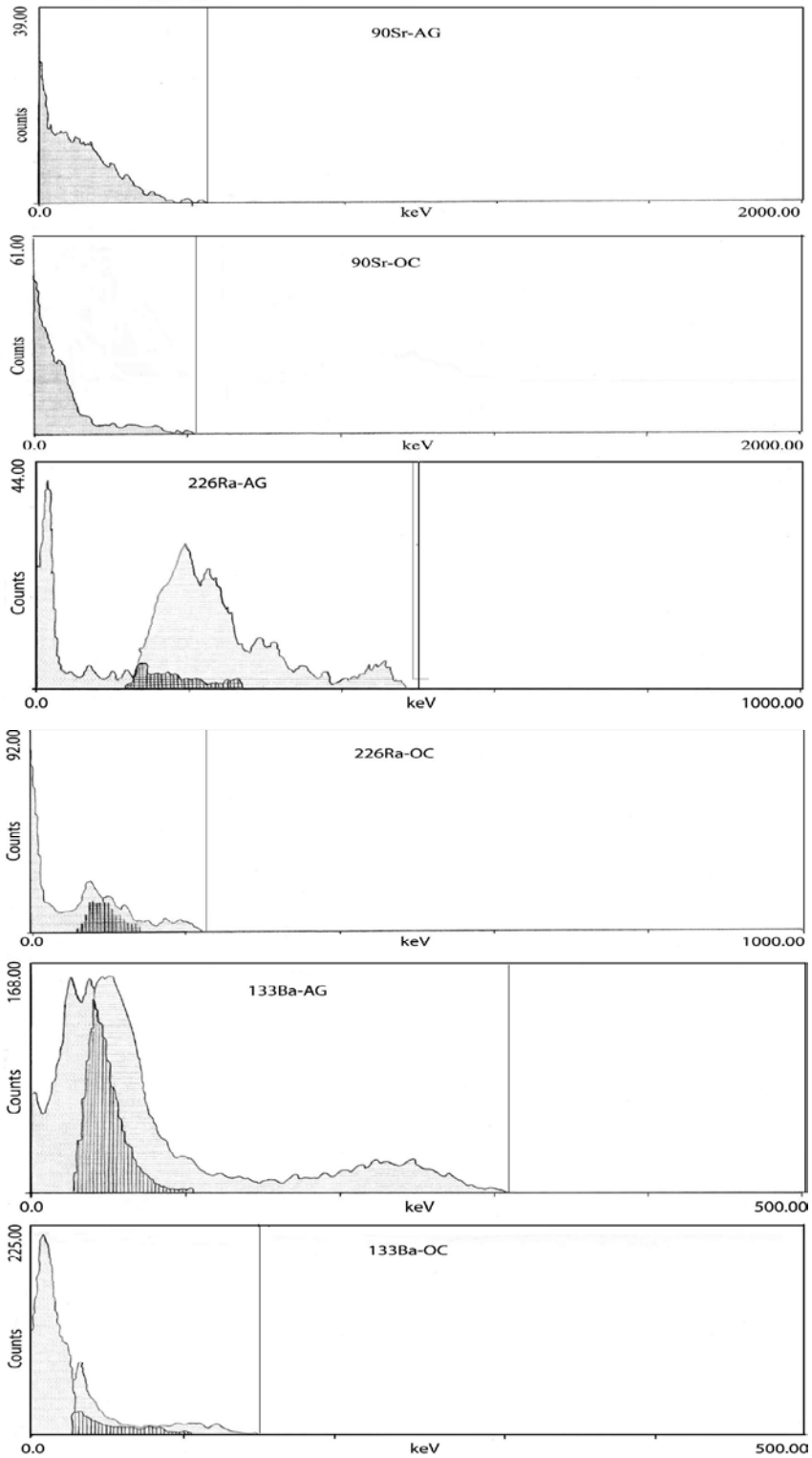

Fig. 2: The respective counting region of ^{90}Sr, ^{226}Ra and ^{133}Ba as an indictor for quenching effect

Table 2: Effect of acetone concentration as a quenching agent on counting rate

Quenching agent (µl)	CPM-Mode		a-ß Mode			
			AG		NC	
	AG	NC	Beta	Alpha	Beta	Alpha
Ba-133						
0.0	1130±8.68	1111±8.61	523±5.91	731±6.98	790±7.25	423±5.31
20	1123±8.56	1021±8.25	524±5.90	709±6.87	824±7.41	311±4.55
30	1122±8.61	977±8.07	533±5.96	715±6.91	803±7.32	311±4.54
40	1112±8.31	985±8.10	507±5.81	695±6.81	812±7.36	275±4.28
50	1102±8.34	981±8.09	517±5.87	709±6.88	833±7.45	266±4.21
Sr-90						
0.0	284±4.35	261±4.17	286±4.37	2.3±0.39	263±4.18	2.6±0.42
20	270±4.24	260±4.16	273±4.27	2.5±0.41	258±4.15	3.9±0.51
30	282±4.33	255±4.22	284±4.35	2.7±0.42	265±4.20	2.8±0.43
40	279±4.31	250±4.08	282±4.36	2.8±0.43	261±4.17	2.7±0.42
50	265±4.20	251±4.10	267±4.21	2.1±0.37	266±4.21	2.0±0.36
Ra-226						
0.0	375±5.0	313±4.92	130±2.94	247±4.06	204±3.68	110±2.71
20	391±5.11	284±4.99	140±3.06	266±4.21	205±3.70	118±2.80
30	365±4.93	308±4.58	137±3.02	224±3.86	196±3.61	113±2.74
40	374±4.99	303±4.50	143±3.09	232±3.93.	207±3.71	104±2.63
50	371±4.97	296±4.54	141±3.07	254±4.11	185±3.51	126±2.90

increasing in the amount of acetone. Using alpha-beta counting mode, for ^{133}Ba using NC, there is insignificant change in beta window while in alpha region there is gradual decreasing in counting rates from 423 CPM at 0.0 µl to 266 CPM at 50 µl of acetone. Inconsistently, insignificant differences in the count rates of ^{90}Sr and ^{226}Ra were observed by gradual increasing in the volume of acetone as quenching agent.

Practically, using alpha-beta counting mode gives significant differences in the count rates for ^{133}Ba and ^{226}Ra using both AG and NC cocktails, while minor differences in the count rates of ^{90}Sr were observed. In these respects, the quench correction curves must clearly created for each isotope.

Alpha/beta discrimination: The alpha and beta emitting radionuclides produce different shapes at the photomultiplier tube PMT anode and may be separated [14, 15]. Most of the environmentally significant alpha emitting radionuclides emit particles in the 4-6 MeV energy region while the beta rays of interest typically have E_{max} values below 2.5 MeV. Separation of alpha from beta events is thus necessary because the energy to light conversion yield from alpha particles is a factor of ten lower than that from beta particles, thus lowering the spectral reading into the beta region. The optimum pulse decay discriminator minimizes the possibility of alpha events being counted as beta events and vice versa.

From this point, two standard sources including ^{243}Am as alpha emitter and ^{90}Sr as pure beta emitter were measured separately and after being mixed together to specify the optimum discrimination value for new cocktail mixture (NC) by indicating the minimum % Spill value, at which, the percent of alphas that counted as beta and betas that counted as alpha arrive to the minimum value. As shown in Fig. 3, the discrimination lines found to be 100 for cocktail mixture (NC), while it is 129 for Ultima Gold cocktail, respectively.

The results in Table 3 were obtained using open scale counting region ranged from 0-2000 keV for beta and alpha regions. Two different counting regions (beta–1 and beta–2) were sub-classified in order to express the pure beta region in beta-1 and the overlapped beta counting in mixed region (beta-2). i.e. beta-2 is a beta particles that counted as alpha region.

The data revealed that, the result of count rate in beta –1 region for pure beta radionclide (for ^{90}Sr) using NC at discrimination line (100) is closed enough to that obtained using AG at discrimination line (129). The same case occurred in beta-2 region, which is corresponding, to relative daughter of ^{90}Sr (^{90}Y).

Table 3: Comparison between the count rates of various radionuclides using AG and NC at different alpha-beta discrimination lines

	Count rate (CPM)					
	AG (129)			NC (100)		
Radionuclides	Beta-1	Beta-2	Alpha	Beta-1	Beta-2	Alpha
^{90}Sr	32.4±1.47	33.0±1.48	--	31.0±1.44	30.4±1.42	--
^{243}Am	14.5±0.98	--	24.0±1.26	10.9±0.85	--	27.0±1.34
^{226}Ra	130.0±2.94	--	241.0±4.01	135.0±3.0	--	210±3.74
$^{90}Sr/^{243}Am$	44.0±1.71	--	46.0±1.75	38.0±1.59	--	45±1.73

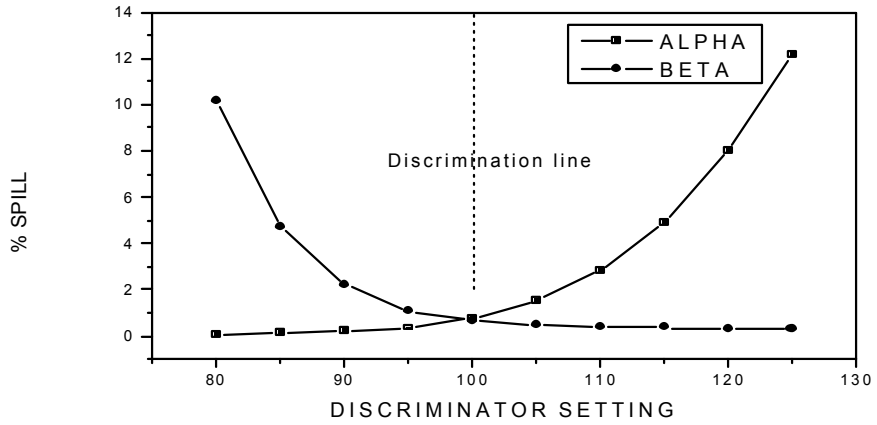

Fig. 3: Setting the discrimination line for alpha and beta particles using NC cocktail

For ^{243}Am, the count rates using NC (100) are close enough to the count rates using AG (129) in alpha window. In case of ^{226}Ra, there is slight change in the count rate in alpha region using AG and NC while in beta region insignificant change in the count rate was observed.

By counting the same activity of a mixture of ^{90}Sr and ^{243}Am, there is a slight change in the count rate in alpha region using AG and NC. The same previous trend was obtained in beta region. From Table 3, it is concluded that NC at discrimination (100) can be used successfully and very suitable for measuring both alpha and beta emitting radionuclides comparable with AG (129) that used as reference cocktail.

Calculation of the overlapping between beta-2 and alpha regions using AG and NC: Measurement of mixture of both alpha and beta radionuclides using open scale window for beta–1, beta-2 and alpha ranged from 0-2000 keV, showed some overlapping between beta-2 and alpha regions. This overlap is mathematically calculated using the results obtained from AG (129) and NC (100) as presented in Table 3.

For AG (129) using mixture of $^{90}Sr/^{243}Am$, the contribution of ^{90}Y (beta-2 window) in alpha window can be calculated using the following equation:

$$C_{1AG(129)} = C_{a\,(mix)} - C_{a\,(pure)}$$

Where $C_{1AG(129)}$: Count rate cpm due to the contribution of ^{90}Y (beta-2 window) in alpha region.

$C_{a\,(mix)}$: Count rate, cpm (in alpha region) in case of mixture of $^{90}Sr/^{243}Am$

$C_{a\,(pure)}$: Count rate, cpm (in alpha region) in case of pure ^{243}Am.

Referring to Table 3

$$C_{1AG(129} = 46 - 24 = 22 \text{ cpm.}$$

The correction factor

$$F_{1AG(129)} = C_{a\,(pure)}/C_{a\,(mix)} = 24/46 = 0.52$$

This factor (0.52) is used to correct the count rate in mixture of $^{90}Sr/^{243}Am$ to get the actual result of calculation of pure ^{243}Am.

Similarly, for NC (100) using mixture of $^{90}Sr/^{243}Am$, the contribution of ^{90}Y (beta-2 window) in alpha window can be calculated using the following equation:

$$C_{1\,NC\,(100)} = C_{a\,(mix)} - C_{a\,(pure)}$$

Where $C_{1NC\ (100)}$: Count rate cpm due to the contribution of ^{90}Y (beta-2 window) in alpha region.

$C_{a\ (mix)}$: Count rate, cpm (in alpha region) in case of mixture of $^{90}Sr/^{243}Am$

$C_{a\ (pure)}$: Count rate, cpm (in alpha region) in case of pure ^{243}Am.

Referring to Table 3 $C_{1AG(129} = 45 - 27 = 18$ cpm.

The correction factor $F_{1NC\ (100)} = C_{a\ (pure)}/C_{a\ (mix)} = 27/45 = 0.60$

This factor (0.60) is used to correct the count rate in mixture of $^{90}Sr/^{243}Am$to get the true result of calculation of pure ^{243}Am using NC (100).

CONCLUSION

The present work was mainly focused on preparation of local scintillation cocktail with low cost chemicals. The new prepared scintillation cocktail provides a significant improvement in the count rate and hence the counting efficiency for both alpha and beta emitters with complete homogeneity and clearance. So, it can be used as an alternative mixture to Ultima Gold (AG) scintillation cocktail that was be used as a reference in different applications. The low Quenching Indicating Parameters (QIP) of NC comparing with that of AG leads to shift the maximum counting region to lower keV however, accurate CPM values can be determined by applying the new quenching curve as well as pulse discrimination line for the new cocktail. Furthermore, in mixed alpha/beta radionuclides, mathematically correction was created and applied to determine the overlap of beta particles in the alpha region and to get accurate DPM values.

REFERENCES

1. Application Note The Effect of Quench on Quantitative Alpha Radionuclides by Liquid Scintillation Counting. Packard Instrument Company, 800 Parkway Meriden, CT06450.
2. Gibson, J.A.B., 1980. Modern Technique for Measuring the Quench Correction in a Liquid Scintillation Counter, Liquid Scintillation Counting. Recent Application and Development. In: Peng, C.T., D.L. Horrocks and E.L. Alpen (Eds.). Academic, New York, pp: 153-172.
3. Birks, J.B., 1971. Liquid Scintillation Solvents. Organic Scintillators and Liquid Scintillation Counting. Recent Application and Development. In Peng, C.T., D.L. Horrocks and E.L. Alpen (Eds.). Academic, New York, pp: 3-23.
4. Grau Carles P. and A. Grau Malonda, 2001. Free Parameter, Figure of Merit and Ionization Quench in Liquid Scintillation Counting. Applied Radiation and Isotopes, 54: 447-454.
5. Horrocks, D.L., 1974. Applications of Liquid Scintillation Counting, Academic, New York.
6. Altzitzoglou, T., 2004. Analysis of Triple-Label Samples by Liquid Scintillation Spectrometry. Applied Radiation and Isotopes, 60: 487-491.
7. Buck, C., F.X. Hartmann, T. Lasserre, D. Motta, S. Schonert and U. Schwan, 2004. Luminescent Properties of a New In-Based Organic Liquid Scintillation System. J. Luminescence, 106: 57-67.
8. Verrezen, F. and C. Hurtgen, 2000. A Multiple Window Deconvolution Technique for Measuring Low-Energy Beta Impurities Using Liquid Scintillation Spectrometry. Applied Radiation and Isotopes, 53: 289-296.
9. Mellado, J., A. Tarancon, J.F. Garcia, G. Rauret and P. Warwick, 2005. Combination of Chemical Separation and Data Treatment for ^{55}Fe, ^{63}Ni, ^{99}Tc, ^{137}Cs and $^{90}Sr/^{90}Y$ Activity Determination in Radioactive Waste by Liquid Scintillation. Applied Radiation and Isotopes, 63: 207-215.
10. Thakkar, A., M. Fern, T. Kupka and J. Harvey, 1997. A New Approach to Gross Alpha Measurements in Aqueous Samples Using Extraction Chromatography and Liquid Scintillation Counting. Application Note, Packard Instrument Company 800 Parkway Meriden, C T06450.
11. Kashirin, I.A., A.I. Ermakov, S.V. Malinovskiy, S.V. Belanov, A. Sapozhnikov Yu, K.M. Efimov, V.A. Tikhomirov and A.I. Sobolev, 2000. Liquid Scintillation Determination of Low Level Components in Complex Mixtures of Radionuclides. Applied Radiation and Isotopes, 53: 303-308.
12. Akopyan, G.G. and V.B. Gavalyan, 2005. New Boron-Containing Polystyrene Scintillators Based on 3-Hydroxiflavone. Instruments and Experimental Techniques, 48: 194-197.
13. Djurcic, Z., D. Glasgow, L.W. Hu, R.D. Mckeown, A. Piepke, R. Swinney and B. Tipton, 2003. Novel Technique for Ultra-Sensitive Determination of Trace Elements in Organic Scintillators. Nuclear Instruments and Methods in Physics Research A, 507: 680-690.
14. Thorngate, J.H., W.J. Mc Dowell and D.J. Christian, 1974. An Application of Pulse Shape Discrimination to Liquid Scintillation Counting. Health Physics, 27: 123.
15. Mcklveen, J.W. and W.R. Johnson, 1975. Simultaneous Alpha and Beta Particle Assay Using Liquid Scintillation Counting with Pulse Shape Discrimination. Health Physics, 28: 5.