Turkish Online Journal of Qualitative Inquiry (TOJQI) Volume12, Issue 10, December 2021: 6266-6276

Preliminary Feasibility Study of Colorimetric Properties as An Assessment Tool for Cost-Effective Dye Impregnated Paper Gamma Dosimeters

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Abstract

Gamma radiations are known to bring about radiolysis of myriad compounds / dyes which is used to measure of the energy of the incident radiation on the system. The use of various dye solutions for chemical dosimetry is reported in literature. Various thin film dosimeters, semi-conductor dosimeters are also reported and widely used. Similarly γ - dose quantification using paper or polymer impregnated with dyes has also been reported. In the present study, decolouration due to gamma radiation of various dye impregnated papers viz. Gentian Violet (GV), Malachite Blue (MB), Malachite Green (MG), Brilliant Yellow (BY) and Congo Red (CR) has been investigated using device independent colour parameters. The colour analysis was done by standard procedures of *Commission Internationale de l'Eclairage* CIE. Color has mind dependency so to eliminate the errors in determination colour parameters are evaluated.

Keywords: colour analysis, dye impregnated paper strips, gamma radiation

Article Highlights

- > Paper based dosimeters are economical and easy to prepare.
- > The colour parameters studied are device independent and requires minimal instrumentation.
- > The method can be developed as rugged method for dose determination.

1.0 Introduction

Gamma radiations are used for terminal stage sterilization of various commodities like food, medicines, surgical equipment and medical implants etc. Terminal sterilization is beneficial in many ways. Rigorous maintenance of aseptic conditions is not required and sterilization can be effectively done after final packaging. Moreover, such sterilization technique does not leave any chemical residue which may induce toxicity as in case of chemical sterilizing agents. Moreover, gamma radiation is also used effectively to treat wastewater. The organic impurities are known to mineralize by these high energy radiations. These applications generally require high dose of energy of about 25 kGy. Thus, it is of utmost importance that the energy of these radiations be quantified. The dosimeters are the tools used to assess the amount of energy absorbed by the particular system.

The primary dosimeters measure the energy by the ionization of the known quantity of gas present in the ionization chamber. The secondary dosimeters are generally chemical dosimeters. They work on the principle that gamma radiations bring about changes in chemical structure on which the radiation is incident. The high energy radiation may lead to formation or degradation of a particular chemical species depending on the material on which it is incident. If these chemical changes show linear response with the energy absorbed then such systems can be used as chemical dosimeters. Most commonly these radiations cause radiolysis of the compounds/dyes i.e. degradation due to the radiations. The colour intensity of the dye generally decreases due to either bleaching (formation of leuco-base) or degradation of the dye species. The use of various dye solutions for chemical dosimetry is well-known (Vereshchinski and Pikaev, 1964; el–Assy et. al., 1991; Melendez-Lopez, et. al., 2018). Also, γ - dose quantification using paper / polymer impregnated with dyes have been reported (Gupta and Bhat, 1983; Saisomboon and Siri-Upathum, 1987; Malav, 2014).

In the present study, decolouration due to gamma radiation of Gentian Violet (GV), Methylene Blue (MB), Malachite Green (MG), Brilliant Yellow (BY) and Congo Red (CR) dye impregnated paper has been investigated. The colour parameters of these dye impregnated papers were analyzed. The Commission Internationale de l'Eclairage (CIE) approach was used for description of various colour parameters.

2.0 Materials and method

2.1 Samples-GV (colour index 42535), MB (colour index 52015), MG (colour index 42000), BY (colour index 24890) and CR (colour index 22120) were obtained from BDH / Qualigen and used without further purification. Strips of Whatman paper no. 1 of dimensions 2.5 cm×5.0 cm were soaked in aqueous solutions having various concentrations of the above dyes / indicator for 20 minutes and then air dried in dust free environment at room temperature (30°C). The solutions used had dye concentrations of w/v 6.25×10^{-4} %, 1.25×10^{-3} %, 2.50×10^{-3} % and 5.00×10^{-3} %.

2.2 Irradiation-The strips were exposed to various gamma doses at dose rate of 0.90 kGy hr⁻¹. The irradiation was performed in GC-900 ⁶⁰Co source housed in Department of Chemistry, R. T. M. Nagpur University, Nagpur. The dose rate of the source was calibrated by Fricke dosimeter.

2.3 Diffuse Reflectance Spectra-The reflectance spectra were recorded using integrating sphere assembly (sphere diameter: 63 mm, port / sphere area ratio: 8%, sample incident angle: 8°) of Cintra 20e (GBC, Australia) spectrophotometer against standard plate.

2.4 Colour Analysis-The post irradiation decolouration was evaluated using device-independent colour parameters. The standard procedures of CIE were used for colour analysis. This is required as there is mind dependency of colour.

Correct evaluation of the colour can be done by converting reflectance spectrum data to colour parameters which truly represents human eye capabilities. The colour emerges due to interaction of three components i.e. light source, object's reflectance characteristics, and human vision system. The CIE XYZ color space is suitable because, in this colour space, CIE XYZ tristimulus values are calculated from CIE 2° observing field (standard observer function) considering illumination and reflectance spectrum of object's surface. The standard illuminant source is D65, which is actual spectral measurement of daylight having correlated colour temperature of 6,504 K. Under daylight condition, the vision process is mainly dependent on the fovea, a part of the retina occupying the area where the visual angle of observation is equal to 2° in the centre of vision field (Wyszecki and Stiles, 1967). Hence, the hypothetical observer used is 2° CIE standard observer. The calculation for XYZ is performed using the following equations:

$$X = K \sum_{380}^{780} \rho_{\lambda} H_{\lambda} \overline{x}_{\lambda} \Delta \lambda$$
$$Y = K \sum_{380}^{780} \rho_{\lambda} H_{\lambda} \overline{y}_{\lambda} \Delta \lambda$$
$$Z = K \sum_{380}^{780} \rho_{\lambda} H_{\lambda} \overline{z}_{\lambda} \Delta \lambda$$

where

 ho_{λ} spectral reflectance of the object at λ

 $H_{\lambda}\,$ illuminant function (D65) at λ

 $\overline{x}_{\lambda}, \overline{y}_{\lambda}, \overline{z}_{\lambda}$ colour matching functions of standard observer at λ

 $\Delta \lambda$ spectral resolution or data interval (1 nm)

The tristimulus values X, Y, and Z are coordinates of a three-dimensional vector space and mathematically describe a colour. This colour system does not form a physiologically equivalent colour space. So, it cannot mimic the nonlinear response of human eye but the values obtained do

form the starting point for the calculation of other colour parameters that are closer to human response.

2.4.1 CIE Lab and ΔE_{ab}^*

The human perception of chromaticity follows a space in which the two axes are redness vs greenness and yellowness vs blueness. Considering this, a new colour space called CIE Lab which is very close to human response was formulated. Traditionally the colour space is designated as L*a*b*, where the asterisks indicates nonlinearity of the variables. It is computed from CIE XYZ tristimulus as shown below (Nassau, 1998).

$$L^* = 116 \cdot Y^* - 16; \ a^* = 500 \cdot (X^* - Y^*); \ b^* = 200 \cdot (Y^* - Z^*)$$

Considering, $U \in \{X, Y, Z\}$

$$U^{*} = \begin{cases} \sqrt[3]{\frac{U}{U_{n}}} & \text{for } \frac{U}{U_{n}} > 0.008856 \\ 7.787 \frac{U}{U_{n}} + 0.138 & \text{for } \frac{U}{U_{n}} \le 0.008856 \end{cases}$$

The subscript n indicates the tristimulus values of the perfect diffuser for the given illuminant and standard observer. The exponential 1/3 in equation for tristimulus values greater than 0.008856 provides the nonlinearity. For values less than 0.008856, linearity is maintained to simplify conversion of Lab to XYZ

The CIE Lab expresses color as three values namely L* for lightness i.e., from black to white, a* from green to red and b* from blue to yellow. The space is a three-dimensional real number space as shown in Fig. 1. The spatial distribution is usually mapped onto a three-dimensional integer space and thus L*, a*, and b* values are generally absolute having pre-defined range. The lightness value, L* represents the darkest black at L* = 0, and the brightest white at L* = 100. The color coordinates, a* and b* represent true neutral grey at a* = 0 and b* = 0. The a* axis represents the green-red component, with green in the negative direction and red in the positive direction. Similarly, b* axis represents the blue-yellow component, with blue in the negative direction and yellow in the positive. The scaling and limits of the a* and b* axes also depends on specific implementation as shown in Fig. 1.



Fig: 1 Spatial representation of CIE Lab colour space

From CIE Lab values of pre- and post- irradiated dye strips color difference (ΔE_{ab}^*) is calculated using following equation [7] $\Delta E_{ab}^* \approx \sqrt{(L_u^* - L_i^*)^2 + (a_u^* - a_i^*)^2 + (b_u^* - b_i^*)^2}$ The subscripts u and i refer to the pre - and post- irradiated dye strips respectively. The ΔE_{ab}^* value is useful for quantitation of colour difference.

2.4.2 Yellowness Index (ASTM Method E313)

The yellowness index shows a degree where the hue leaves white or achromatic colour toward yellow. If it takes a negative value, it moves in the blue direction. The yellowness index for 2° observer and D65 illuminant is calculated as

$$YI = \left[100 \frac{(1.2985X - 1.1335Z)}{Y}\right]$$

The change of yellowness index is shown as the difference in yellowness indices of pre- and postirradiated dye strips.

 $\Delta YI = YI_i - YI_u$

where, subscripts i and u denotes post- and pre-irradiated dye strips respectively.

2.4.3 Whiteness Index (ASTM Method E313)

Whiteness is measure of how closely a surface matches the properties of a perfect reflecting diffuser, i.e. an ideal reflecting surface that neither absorbs nor transmits light, but reflects it at equal intensities in all directions. For the purposes of this standard, the color of such a surface is known as preferred white.

It is calculated as -

$$W_2 = Y_2 + 800(x_{n,2} - x_2) + 1700(y_{n,2} - y_2)$$

where

Y is the Y tristimulus value (relative luminance),

(x,y) is the chromaticity coordinate in the CIE 1931 color space

 (x_n, y_n) is the chromaticity coordinate of the perfect diffuser (reference white)

The 2 in the subscript indicates 2° observer for the CIE 1931.

The change of whiteness index is shown as the difference in whiteness indices of pre- and postirradiated dye strips.

 $\Delta W = W_i - W_u$

where, subscripts i and u denotes post- and pre-irradiated dye strips respectively.

2.4.4 Dominant Wavelength

The dominant wavelength of a color correlates in an approximate way with what would be called as the hue of the color as observed under everyday conditions (Singh, et. al, 2009). In other words dominant wavelength is the single wavelength that is perceived by the human eye. Single light source consists of multiple wavelength rather than one single wavelength. Human brain compiles these multiple spectra into a single color of light consistent with a single specific wavelength which is known as dominant wavelength, perceivable to human eye.

2.4.5 RGB Color Gamut and Color Palette

Most of the visible spectrum is represented by mixing three basic coloured light, red, green and blue in various proportions. The primary colour space is used in monitor display and the fill colour options of most of the softwares. For 2° observer and D65 illuminant, the XYZ to RGB conversion is given as X' = X/100

$$\begin{split} Y' &= Y/100 \\ Z' &= Z/100 \\ R' &= X \times 3.2406 + Y \times (-1.5375) + Z \times (-0.4986) \\ G' &= X \times (-0.9689) + Y \times 1.8758 + Z \times 0.0415 \\ B' &= X \times 0.0557 + Y \times (-0.2040) + Z \times (1.0570) \\ U' &\in \{R', G', B'\} \\ if (U' > 0.0031308), U' &= 1.055 \times (U'^{(1)}(1/2.4)) - 0.055 \text{ else } U' &= 12.92 \times U' \\ U &= U' \times 255 \end{split}$$

The RGB values calculated from XYZ tristimulus values were used to display the colour palette. The colour given in the palette may differ from the original colour of the compound, as RGB colour space is not equivalent to human perception but is used for simplification of data.

3.0 Results and Discussion

The diffuse reflectance spectra obtained for the various dyes at different doses are shown in Fig. 2.





Fig.2 Reflectance spectra of GV, MB, MG, BY and CR strips dyed with 2.5x10⁻³ % w/v solution with respective dyes / indicators

The representative values for various colour parameters such as tristimulus value, CIE L*a*b* values, colour difference, ΔE_{ab}^* , dominant wavelength, Yellowness index as well as difference of yellowness indices, Δ YI for CR3 is given in Table -1.

Colour	CR 3,	CR 3,	CR 3,	CR 3,	CR 3,
Parameters	0 kGy	1 kGy	5 kGy	10 kGy	15 kGy
Tristimulus	59.2766	59.5854	70.0332	65.4622	64.0385
value	49.9165	50.0836	60.7803	55.6948	57.2344
	51.8225	51.0229	61.2915	54.3643	59.5783
CIE	76.018	76.1206	82.2605	79.4398	80.3113
L*a*b*	30.5535	30.852	28.0634	30.1747	23.1936
	2.5071	3.4913	4.2866	5.8945	2.479
Dominant	495.64	495.1	494.4	493.78	495.16
Wavelength					
(nm)					
ΔE^*_{ab}		1.033576	6.952411	4.829771	8.520642
YI	36.5133	39.0007	35.3072	41.9701	27.2907
ΔYI		2.4874	-1.2061	5.4568	-9.2226
RGB &	243	244	258	254	243
colour	166	166	185	176	184
palette	184	182	198	187	195

Table-1 Various colour parameter for CR3.

It is expected that with increase in dose the colour intensity of the dye impregnated strips would tend to decrease as higher energy tends to increase radiolysis of the dyes. This is evident from the diffuse reflectance spectra of the five dyes as shown in Fig. 2. The absorbance at absorption maxima tends to decrease with increasing dose. However, the decrease in colour intensity seems to be negligible between 0 to 10 kGy. Thus it is very difficult to find a relationship between dose and absorbance. So, colour analysis is done to investigate the relation between dose and colour intensity.

CIE L*a*b* values are computed from tristimulus values as they are near to the colour perceived by human eyes. CIE L*a*b* values does show decrease or increase in one of the chromaticity coordinates with increasing dose depending on the colour for instance, incase of CR, a* values changes from 30 to 23 which indicates decrease in red hue and so on. However, it is difficult to establish any linear relationship with change in the co-ordinate values and dose. So, the most common colour difference, ΔE_{ab}^* is investigated.

The colour difference shows quite good response with dose upto 10 kGy beyond which there is marked deviation as is evident from the R-value. The R-value obtained is 0.9524 and 0.9946 for GV3 and BY3 respectively upto 10 kGy. Beyond which the R-value decreases showing non-linearity in the

response. This deviation is reflected in dominant wavelength, which generally indicates the hue as shown in Table-5. This is also evident from the change in RGB colour palaette shown in Table-6. The observation is further supported by the diffuse reflectance spectra as shown in Fig. 2.

Fig. 2 depicts shift in absorption maxima for diffuse reflectance spectra with increasing γ -dose (15 kGy) with almost all the dyes which may be attributed to yellowing of paper due to γ radiation. Gamma-radiation is known to cause depolymerization in polymeric chain (cellulose as well as polyethylene) initiating free radical formation (Adamo et. al., 1988; Kömmling, 2017). This induces yellowness in the paper substrate which hampers lightness of the paper (L*) and chromaticity coordinate (b*) shifts to yellow from blue. This consequently affects the colour estimation of the strips. The colour degradation occurs due to γ -radiation reducing the colour intensity however beyond 10 kGy there is severe interference due to yellowing of the paper.

The non-linearity of the ΔE_{ab}^* at 15 kGy could be attributed to yellowing of paper due to γ radiations which is evident from increase in Δ YI.

The relation between the gamma dose and Δ YI and Δ W for four different concentrations of BY, GV, MB, MG, CR is given is Table-3 and 4. It is observed that Δ YI shows good correlation in assessing radiation induced decolouration for BY (R= 0.9769), GV (0.9585) and CR (0.9860) upto 10 kGy whereas Δ W incase of MB (R= 0.9999) and MG (R= 1). It is observed that for decolouration of dyes having blue or green hue can be better assessed using whiteness index which is quite evident from the definition of the latter.

4.0 Conclusion

It may thus be concluded that dye strips were effective upto dose of 10 kGy and ΔE_{ab}^* may be used as

a tool to assess radiation damage. Out of all the dye investigated BY is found to be the most suitable probably could be due to its hue. However, if yellowing of paper due to γ radiation could be avoided then higher dosages could also be studied. This can be achieved by chemical modification of the paper. The analysis done by CIE L*a*b* coordinates which is device independent system, with advent of electronics and software, this system can be easily integrated to form a cheap technology for dose detection.

5.0 Acknowledgement

The authors thank Head, Department of Chemistry, Rashtrasant Tukadoji Maharaj Nagpur University for providing irradiation and laboratory facilities.

6.0 CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

7.0 FUNDING

No funding was received for the above research work.

8.0 AUTHOR CONTRIBUTIONS STATEMENTS

This is to certify that all the three cuthors have contributed jointly to the paper. The main manuscript was written by I. B. Das Sarma and D. V. Parwate. The data analysis was jointly done by I. B. Das Sarma, D. V. Parwate and D. S. Bhowmick. The figures and data tables (1-6) were prepared by D. S. Bhowmick. All the authors reviewed the manuscript.

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Table 2- ΔE_{ab}^* values as function of dose for various concentrations of BY, GV, MB, MG and CR. Correlation coefficient, R was computed from R² value obtained on plotting the ΔE_{ab}^* against dose upto10 kGy.

Dos	BY1	BY2	BY3	BY4	GV1	GV2	GV3	GV4	MB1	MB2	MB3	MB4
e.			_								_	
kGy												
1	1.080	0.500	2.174	4.538	4.221	2.127	3.806	3.952	1.881	1.555	2.441	4.296
5	4.871	5.280	5.128	6.445	12.62	20.94	15.53	21.29	5.202	4.381	2.738	2.970
					9	9	7	9				
10	6.269	8.255	7.699	5.199	14.05	20.35	20.15	17.30	0.917	1.569	1.961	5.583
					3	5	9	9				
15	1.492	0.932	3.137	5.679	15.19	27.38	34.94	35.40	5.364	4.880	4.856	3.142
					9	8	9	5				
\mathbf{R}^2	0.898	0.961	0.989	0.078	0.808	0.666	0.907	0.476	0.076	0.003	0.437	0.299
	5	5	2	6	2	7	0	3	4	5	3	6
R	0.947	0.980	0.994	0.280	0.899	0.816	0.952	0.690	0.276	0.059	0.661	0.547
	9	6	6	4	0	5	4	1	4	2	3	4

Dose,	MG1	MG2	MG3	MG4	CR1	CR2	CR3	CR4
kGy								
1	6.873	6.084	4.599	8.277	0.890	1.684	1.034	1.722
5	10.960	13.831	17.326	17.243	4.993	5.150	6.952	5.259
10	8.362	10.964	14.214	12.647	4.007	3.891	4.830	3.440

15	7.449	12.664	17.708	18.748	4.623	7.989	8.521	5.416
R ²	0.0897	0.3267	0.4611	0.3267	0.3389	0.3340	0.4655	0.1837
R	0.2995	0.5716	0.6790	0.5716	0.5822	0.5779	0.6823	0.4286

Table 3- Δ YI values as function of dose for various concentrations of BY, GV, MB, MG and CR. Correlation coefficient, R was computed from R² value obtained on plotting the Δ YI against dose upto10 kGy.

Dose,	BY1	BY2	BY3	BY4	GV1	GV2	GV3	GV4	MB1	MB2	MB3	MB4
kGy												
1							-	-				
	1.194	0.842	2.110	6.301	-6.867	-5.103	10.487	12.217	3.772	3.149	6.720	12.866
5					-	-	-	-				
	1.158	-1.827	1.788	5.392	17.550	35.556	36.897	57.858	-1.775	-3.638	1.027	6.515
10					-	-	-	-				
	-7.261	-9.764	-8.226	-0.994	20.145	36.780	48.310	49.078	-0.381	-0.080	0.518	10.901
15					-	-	-	-			-	-
	2.369	1.467	4.578	7.919	22.890	44.991	68.944	85.430	-8.328	-9.983	12.649	10.627
R	0.8979	0.9769	0.9081	0.9411	0.9202	0.8506	0.9585	0.7179	0.6736	0.4183	0.8709	0.2406

Dose,	MG1	MG2	MG3	MG4	CR1	CR2	CR3	CR4
kGy								
1	-			-				
	11.504	-8.618	-7.070	13.521	0.335	1.038	2.487	2.773
5	-	-	-	-				
	14.410	19.916	27.468	27.785	-1.227	-0.578	-1.206	-1.934
10	-	-	-	-				
	15.885	17.936	25.334	24.882	-7.158	-4.433	5.457	-7.402
15	-	-	-	-				
	13.798	19.724	30.086	31.861	2.063	7.053	-9.223	5.890
R	0.9688	0.7300	0.7757	0.7099	0.9662	0.9860	0.5012	0.9860

Table 4- ΔW values as function of dose for various concentrations of BY, GV, MB, MG and CR. Correlation coefficient, R was computed from R² value obtained on plotting the ΔW against dose upto10 kGy.

Dose,	BY1	BY2	BY3	BY4	GV1	GV2	GV3	GV4	MB1	MB2	MB3	MB4
kGy												
1			-	-							-	-
	-5.378	-2.355	11.227	25.205	13.280	7.521	14.596	14.571	-9.512	-5.548	11.215	17.683
5	-		-	-								-
	14.496	-3.721	16.441	30.930	27.011	56.468	50.643	73.488	-8.856	-3.170	-6.882	12.502
10				-								-
	13.526	21.938	18.084	10.501	33.287	65.554	76.167	64.873	1.201	-1.362	-1.739	13.295
15			-	-								
	-7.471	-4.106	17.811	29.274	45.141	78.758	113.844	124.650	5.150	11.007	15.128	13.282
R	0.7080	0.8743	0.8253	0.7421	0.9621	0.9040	0.9869	0.7495	0.9191	0.9898	0.9999	0.7451

Dose,	MG1	MG2	MG3	MG4	CR1	CR2	CR3	CR4
kGy								
1	9.882	4.378	4.184	10.148	1.058	-0.602	4.793	-2.590
5	3.591	8.672	16.850	17.814	-2.333	-0.517	-2.885	5.409
10	18.647	13.445	22.324	27.455	11.151	10.267	10.486	17.908
15	16.586	14.253	25.310	27.029	2.154	-3.759	-7.570	-0.015

R	0.6306	0.9994	0.9585	1.0000	0.7625	0.8993	0.4812	0.9981
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Dose,	BY1	BY2	BY3	BY4	GV1	GV2	GV3	GV4	MB1	MB2	MB3	MB4
kGy												
0	570.1	570.8	571.7	572.7	456.3	447.5	437.7	566.1	487.1	486.0	484.7	482.4
1	569.8	570.6	571.5	572.2	458.0	445.1	436.2	566.1	486.1	485.5	483.9	481.4
5	569.8	570.7	571.4	572.1	460.8	456.1	430.6	566.2	486.8	485.9	484.3	481.9
10	571.1	571.9	572.7	573.3	461.8	456.7	421.1	566.2	486.8	485.5	484.0	481.3
15	569.7	570.5	571.3	572.0	469.9	467.0	459.1	432.0	485.9	485.5	484.3	482.1

Table 5- Dominant wavelength as function of dose for various concentrations of BY, GV, MB, MG and CR.

Dose,	MG1	MG2	MG3	MG4	CR1	CR2	CR3	CR4
kGy								
0	486.2	488.0	487.8	488.0	501.1	497.5	495.6	494.1
1	480.7	486.1	487.1	486.9	500.9	497.3	495.1	494.1
5	480.6	484.1	488.0	488.2	498.3	495.9	494.4	658.2
10	482.7	490.4	490.3	490.1	495.6	494.9	493.8	647.3
15	476.8	477.3	480.9	481.5	500.0	497.1	495.2	493.5

Table 6- RGB Colour palettes as function of dose for various concentrations of BY, GV, MB, MG and CR.

Dose.	BY1	BY2	BY3	BY4	GV1	GV2	GV3	GV4	MB1	MB2	MB3	MB4
kGy												
0	230	230	230	233	208	189	175	161	177	149	119	86
	231	229	225	222	203	179	155	126	221	213	199	177
	206	189	163	138	237	232	229	218	231	233	229	220
1	232	230	235	235	212	193	178	163	177	147	115	80
	233	230	231	227	209	182	160	131	222	211	197	171
	209	190	170	151	236	232	228	217	236	233	230	220
5	244	244	244	248	229	221	198	185	192	163	125	87
	245	243	240	240	228	218	183	163	235	225	206	181
	220	197	176	158	245	241	236	227	247	244	238	229
10	243	245	245	250	230	212	193	171	176	151	122	81
	241	240	234	235	229	210	181	149	218	212	196	165
	206	185	160	147	242	231	223	215	230	232	227	213
15	230	229	231	232	224	224	211	190	196	167	140	101
	231	229	228	225	226	224	209	179	225	215	201	177
	209	190	172	152	234	236	230	220	235	232	228	217

Dose,	MG1	MG2	MG3	MG4	CR1	CR2	CR3	CR4
kGy								
0	203	186	165	160	240	244	243	243
	225	223	217	216	202	184	166	146
	233	230	227	226	216	201	184	163
1	226	207	182	190	238	245	244	244
	231	227	221	222	202	187	166	150
	235	234	230	231	215	203	182	166
5	243	236	230	225	251	255	255	255
	246	242	242	240	215	197	185	159
	248	245	245	243	226	210	198	170
10	229	225	217	205	250	250	254	245

	231	238	236	227	207	191	176	146
	233	239	237	229	216	202	187	157
15	225	228	226	225	236	240	243	242
	227	231	230	230	208	197	184	156
	230	235	235	234	217	208	195	167