International Journal of Current Research and Academic Review

ISSN: 2347-3215 Volume 3 Number 8 (August-2015) pp. 196-207

www.ijcrar.com

Faster disintegration of radioactive substances using energy of specially-processed water and theoretical prediction of a half-life of radionuclide

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KEYWORDS

Half-life,
Radionuclide,
Stable element,
Specially-processed water,
Long-wavelength synthesis,
Energy shifted-LED light

A B S T R A C T

Many methods for reducing radioactive contamination have been proposed, most of which rely on the use of materials such as zeolites or plants to adsorb radionuclides, and just shielding in a certain container. In such processes, the absorbents become radioactive and should require subsequent disposal, usually by long-term burial. The purpose of this research is to propose the key technology to solve the radioactive wastes fundamentally resulting in reduction of radioactivity. Here is a basic technology to deactivate radioactive substances using the contrived-common materials such as specially processed water. It repeated many experiments using the specially-processed water to confirm the results to reduce a half-life of radionuclide than usual decay to follow up for 3 years. Our major results are deactivation of 60% in the soils for 5days and for mushrooms from 111 Bq/kg to non-detectable level etc. Furthermore, we found some stable elements such as barium, lanthanum and cerium in the processed soils with discussion for the mechanism of the reaction. So our method is easier, lower cost and safer disintegration for some of radionuclides.

Introduction

How can it be possible to reduce the half-life of radioactive substances? The accepted view among the scientific community is that this is just not possible other than the method to use extremely high energy, which has not been practically employed yet. Meanwhile, the methods to reduce radioactivity is shielding by concrete, lead, steel, etc.; adsorption by plants or by materials such as zeolites, and nuclear wastes are maintained in the concrete after radioactive vitrification, and/or is processed with radioactive waste treatment system or spent fuel recycle system. However, the idea of Pd complexes permeating heavy hydrogen was reported in view point of the low-energy transmutation (Iwamura, et al., 2002). Furthermore, PdZr oxide nano-powders were reported in the phenomenon of heat and ^4He generation by D_2 gas absorption (Kitamura, et.al., 2009) where they discussed as the reaction in the

condensed material. As another example, without a large energy, the case of ^{7}Be encapsulated with C60 was reported by Ohtsuki *et al.* (2004) where they stated shorter half life of 1.5% than usual beryllium (half-life is 53.82 days) in the space of sub-nanometer, although they did not discuss the mechanism. However, we found that some kinds of radionuclides generated in a nuclear power plant can be possible to deactivate although heavier nucleus like uranium, plutonium etc., are difficult to deactivate for the time being. Here is our proposal to reduce a half-life of caesium134 and 137 leading to reduction of radioactivity by way of making faster disintegration of them. The present method in experiment relates to just usage of usual tap water. That is the specially-processed water pressurized at more than 2 MPa resulting in hydrogen bond-broken water. We named it SIGN water (Spin Information Gauge Network), and the LED lights (i.e., energy shifted-light) possessing a little longer wavelength (difference; 149μm= 2THz) than that of ones on the market. The unprecedented phenomenon that we describe can be theoretically explained by considering an extended particle, similar to an elementary particle by Yukawa (1950). Furthermore, we may consider another idea that water is a dielectric medium as Brillouin (1960) suggested that the interior of the electron is a region of space through which a signal can be transmitted faster than light in a certain medium. Here we propose the basic ideas on elementary particle-like behaviors which is hypothetical particle, infoton, $<H^{+}\sim e^{-}>$ by Sugihara (2008), in a small space and time in a gauge field. The present study postulated that this particle can move with enough energy to enter into caesium nucleus despite the velocity less than that of 10% of the light speed in a vacuum. Relativistic treatment of a particle may play a role to consider the reaction of nucleus along with gravitational forces, although they are quite unimportant in atomic phenomena according to Dirac (1958). We focused on the caesium for theoretical discussion as ^{134}Cs and ^{137}Cs radionuclides are now actual existence in certain area after the nuclear power plant disaster in 2011. We also provide the follow-up data collected over three-year period to show decreasing the radiation from the radionuclides and experimental analysis to confirm this mechanism resulting in existing of stable elements (Sugihara, 2013).

Materials and Methods

Starting material is just usual tap water, and processed with high pressure (more than 2MPa). The second material is usual white LED, but it's wavelength shifts to be longer by putting over the specially processed water at a distance of several cm in a room temperature for 1~2 days. And chromaticity spectrometer is employed for characteristics relating to changed-wavelength of the LED. Then we call the field under SIGN medium irradiating LED the light SIGN/LED hereafter. The method of treatment of contaminated soil and another substance with caesium 134 and 137 is to immerse into the processed water (1:1 in volume) for certain time and a period depending on the purpose. We also employed contaminated mushrooms and pasturages as well. The measurement of radioactivity was carried out after drying the objects because water itself possesses some shielding function of radioactivity generally. We use GM counter and a high-purity germanium detector (for β and γ ray), scintillation counter for the detection of radioactive energy (Ge semiconductor type), and atomic-emission spectrometry (ICP-AES), inductively coupled plasma/mass spectrometry (ICP-MS), and X-ray fluorescence (XRF) for element analysis. Adding to these

instruments, we employ the nuclear magnetic resonance (NMR) to infer feature of the specially-processed water (such as estimation for size of water molecule).

Theoretical aspects of disintegration of radionuclides

Spontaneous disintegration

We focused on the caesium134 and caesium137 possessing a half-life which are approx.2 and 30 years, respectively. These elements were a large amount in the soils right after the nuclear disaster occurred in March 11th, 2011 in Fukushima in Japan. Iodine 131 and xenon 133 were also released in a large amount, which are gases and shorter half-lives. The caesium137 disintegrates emitting β and γ rays as well known, and then a half of them becomes to non-radioactive barium for 30 years by way of a meta stable barium. Spontaneous decays of Cs137, for instance, are illustrated in figure 1. Mean while, figure 2 shows the residual amount of radioactivity of each element which has the half-life more than one year as calculated by the usual differential equation indicating residual radioactivity;

$$n= (\ln 2/T_{1/2}) [N_A \times n(t)/M] \quad \text{------ (1)}$$

where N_A ; Avogadro's number (1/mol), n(t); mass of radioactive substance (g) at time t and M; g/mol, then the parenthesis indicates a number of atom of radioactive at time *t*.

Figure.1 Spontaneous disintegration of caesium 137, for instances

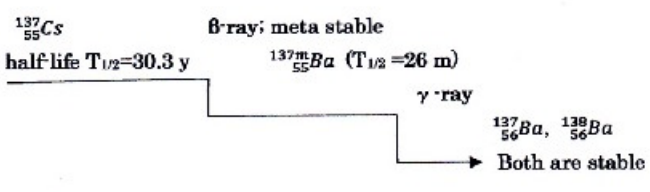


Figure 1 Spontaneous disintegration of caesium 137, for instances.

Figure 2 shows the residual radioactivity of caesium and ruthenium radionuclides with half-lives of more than one year (strontium and plutonium radionuclides are omitted here). As you can see, Ru106 (half-life; approx. one year) indicates a half-residual amount after one year and a half of Cs134 remains corresponding to spontaneous decay for 2 years.

Scenarios for faster decay of radionuclides

Natures of the specially-processed water

It is better to introduce the water before discussion of faster disintegration of radionuclides. The changes of the water does not seem to associate with chemical constituents but with the sense of physics; the specially-processed water is defined in which a tap water is pressurized leading to the smaller molecules of water by breaking hydrogen bonds. As the result, we postulate that the water involves infoton $<H^+ \sim e^->$which is neither ion nor atom and seems to be an extended particle and we are not sure how much water molecules involve in the dissolution of hydrogen bond depending on a pressure. Moreover, infoton is stable as it is (Sugihara, 2013), although we have not experimentally found it at present moment. The infoton in the water functions as a few angstrom medium which quantum effect associates with electromagnetic phenomena emitting far infrared and/or terahertz due to the rotation and vibration of infoton. Furthermore, the information (or energy) of the angular momentum of the spin by infotoncan be transferred to another substances in space and time, i.e., as radiation when the substance is distant from the water. Meanwhile the information can be transferred in the network through a gage field (as a space transmitting energy and/or information although we do not discuss the

detail mathematically) when the water contacts directly to another one. Taking into consideration of the water macroscopically, the water after dissolution of hydrogen bonds relates to energy generation (or possessing information) like plasma frequency (Sugihara, 2013). The plasma frequency in our system is given by the expression $\omega_p^2 \approx 4\pi ne^2/(m^*\varepsilon_\infty)$ just like plasmon in a metal surface, and this calculation shows it to be approximately 3 THz as mentioned previously (the symbols are used conventionally: m*; mass of infoton= proton plus electron, and n= Avogadro's number as the number of infoton, and relative permittivity ε_∞ was experimentally measured in the region of terahertz). The precise data of the water are indicated with NMR spectra in figure 3.

Faster disintegration by the reaction between infoton and caesium

For faster decay, the first scenario is that we can consider the interaction between caesium nucleus and infoton. The smaller space and shorter time in the gauge field may provide a chance for the interaction, where the potential generated by caesium and infoton can be regarded as following; The particle moves with a velocity *v* (which is much less than the speed of light, c as discussed later) and an acceleration *a*.

The infoton (provided charge: e) moves on the orbit **r** = r(t) emitting energy (*E*) per unit time into a solid angle *d* Ω (where radius r, OP=OR=OQ, forms sphere PQR where center is O) generated by the acceleration and the angle θ:

$$E=\{(ae)^2/c^3\}\sin^2\theta \cdot d\Omega/4\pi \quad \text{------ (2)}$$

The equation can be derived by calculation of the Liénard–Wiechert potential, which is shown in the following relationship such as equation (3) between the electromagnetic potential and the retardation time *t'*, associated with the solution of the equation,

$$t' = t - R(t')/c.$$

The energy *E* increases with θ being vertical to the *x*-axis. This means that the curvature is larger, and information from the infoton can easily transfer to the caesium atom (ϵ_0 and μ_0 are usual constant). The second term in the denominator in equation (3) describes a change of the effective charge due to movement of the infoton which is seen by the observer (x) on the arbitrary point of sphere PQR; **v**(r) = dr/dt, **R**=**x** - **r**

R=|**R**|;

$$\varphi(x,t) = [\varepsilon/4\pi\varepsilon_0]\{1/[R(t')-v(t')R(t')/c]\},$$
$$A(x,t) = [\mu_0 e / 4\pi]\{v(t')/[R(t')-v(t')R(t')/c]\} \text{------ (3)}$$

Here are examples of the reaction;

$^{137}_{55}Cs + \langle H^+ - e^- \rangle_{p/e.} \rightarrow {}^{138}_{56}Ba$, $^{137}_{55}Cs + 2\langle H^+ - e^- \rangle_{p/e.} \rightarrow {}^{139}_{56}La$ as a particle.

The second scenario can be postulated that the long-wavelength wave (far infrared and/or THz) can play a role for the faster decay by the scattering and/or absorption of gamma ray (photon) through the specially-processed water.

We define it LOWS (the long-wavelength synthesis).

Furthermore, we theoretically discussed the multiplication method of group theory to result in generation of the stable elements such as barium, lanthanum and cerium (Sugihara, 2013) as shown in actual chemical analysis.

Results and Discussion

Change of water and LED

Characteristics of the specially-processed water

It is distinguished that the water possess different characteristics by some pressure, which associates with creation of the physical state of water, i.e. infoton as explained in section "Natures of the specially-processed water". We have researched the water itself and/or water-activated substances by some methods such as NMR, isotope analysis, FTIR and SQUID (superconducting quantum interference device) connecting to nucleus and spin of hydrogen. At present moment, we focused on the NMR analysis (under 2.5 tesla with heavy water-locked); The change of water has been observed with NMR spectra which involve results of relaxation time (T_2) and free induction decay (FID) as shown in figure 3 and figure 4.

The specially-processed water as explained in previous section was made of usual tap water, and the water molecules can be dissolved into smaller ones which show some different characteristics of usual water. Here we focus on the results of NMR associating with spin-spin interaction.

We can postulate how water changes with the specially-processing: Firstly, the free induction decay (FID) pattern can tell activeness of the water. Here is the interaction among nuclear magnetic moment μ, angular momentum J and external magnetic field B_0 (2.5 Tesla in the NMR equipment) as indicated in the equation; $dJ/dt = \mu \times B_0$. The magnetic field is applied in the pulse and time or period of vibration (T_0) is measured to resonate with the outer magnetic moment, and the expression is indicated with I, moment of inertia as following; $T_0=2\pi(I/\mu H)^{1/2}$. The smaller magnetic moment is, the larger period (T_0). That is to say, what the magnetic moment is larger can be considered a smaller period T_0, and larger angular velocity which means smaller water molecules formed by pressurization. Secondly, on the other side, half-width on Lorentz curve against Δν in the horizontal line has a relationship as indicated in the following equation;

The relaxation time; $T_2=1/(\pi\Delta\nu)$ that is to say, water molecule becomes smaller when Δν corresponding to a half-width is narrower. Therefore, it can be said that the water with smaller FID period (0.356 seconds) and a larger T_2 value (0.202) is the specially-processed one created with a higher pressure. Furthermore, we found that pressure-dependency of T_2 and FID in inverse relation between them as shown in figure 4. Furthermore, we can observe the magnetic hysteresis indicating a larger magnetic moment on the "activated" non-magnetic specimen by the water involving infotons. Consequently infotons seem to contribute to possessing of magnetic information even for the non-magnetic material (Sugihara *et al.*, 2014).

Energy shifted-LED light

It is interested in that the wavelength of white LED was changed by 1.47 % longer with the specially-processed water. As the result, we found that the chromaticity spectral showed the shift of white LED to longer wavelength (by approx.2 terahertz). Now we discuss the relationship between the medium and LED light. The water after dissolution of hydrogen bonds relates to energy generation like plasma frequency as shown in section "Natures of the specially-processed water". The terahertz and far-infrared rays become easier to transmit

through the water involving Infotonal though the electromagnetic wave of THz is usually absorbed in water (Sugihara *et al.*, 2014). These long electromagnetic waves from the medium may change the LED light to a little longer wavelength according to our chromaticity data. It is assumed that the energy of original LED provides near infrared and/or infrared (ω_3), and the LED treated by the special-processed water emits lower energy such as$\boldsymbol{\omega_1}$ (far infrared**)** and terahertz **($\boldsymbol{\omega_2}$),** which mechanism seems to be a parametric oscillation ($\boldsymbol{\omega_3 \rightarrow \omega_1 + \omega_2}$). Fuchs and Gatterer (2008) reported that the co-doped yttrium-aluminum-borate crystals changed colour under illumination with different white light sources, whose light is composed of a blue LED and the coating of yellow fluorescence as well known. They explained that absorption and transition by the doped ion can be assigned to the spin allowed and spin-forbidden transition.

Reactivity changes of soils, mushrooms and pasturages

Figure 5 shows a follow-up of radioactivity of more than 600,000 Bq/kg at June 29th, 2011 where 92% reduction of radioactivity in the soil has been reached for approx.3 years. The calculated graphs based on the usual decay constant are illustrated in inserted figures, where radioactivity of caesium 134 (a half-life $T_{1/2}$; approx.2 years) is clearly reduced to 50% from the initial value, for instance. We found the reduction of radioactivity not only in the contaminated soils but also plants, and rice plants were reported previously. Here mushrooms are shown in table 1. The mushrooms containing total cesium of 2878 Bq/kg were immersed in SIGN water, then dried by 50% in weight which showed approx. 70% reduction of radioactivity, and then another half-dried specimen was put under the SIGN/LED to result in 78% reduction approximately. Furthermore, we also measured the reduction of radioactivity (111Bq/kg) in mushrooms to non-detectable level after immersion into the specially-processed water for a couple days.

Radioactivity changes in Cs134 and 137 of the pasturages in the pot were illustrated in figure 6. The first group of 72 hr-test showed the reduction rate of radioactivity of 26.5 % in the before/after-treatment, and the second group of 72 hr-SIGN/LED test indicated 33.9% reduction. Finally, 58.1 % reduction was reached for 216 hr-SIGN/LED test.

We analysed each element in the soils(μg/L) sampled in 2011/9/15 as following:

Control (treated with tap water); *Cs133* (0.65), *Ba137*(35.6), *La139*(2.06), *Ce140*(0.172), and sample (treated with SIGN water); (1.65), (2293), (113.9), (29.5), respectively, although ICP-MS and ICP-AES could not identify Cs134 (or 137), Ba138 etc. We found repeatability although the absolute values of elements were different depending on the location of sampled soils.

Newly proposed equation for half-life calculation

According to our previous experiments (Sugihara, 2013) using contaminated soil and processed water, however, we found that the half-life could be reduced by the presence of infotons $<H^+ \sim e^->$ in specially processed water. Therefore, the common decay equation described above should include another term besides the spontaneous decay. The shape of the potential space generated by caesium and the infoton is assumed to be a Gaussian curvature when the caesium nucleus and infoton move in the smaller space and

shorter time in the gauge field, as discussed previously. This field can help to set a new equation for the accelerated disintegration, along with the movement of the infoton and the caesium nucleus. We now remind that the left-hand side of Einstein's equation for gravity including Einstein's tensor equates to a distortion (curvature) of space, whereas the right-hand side shows a distribution of the matter field (although the whole equation is abbreviated here). We are interested in the right-hand side of the equation, which includes the following term:

$(8\pi G /c^4)T_{\mu\nu}$ where *G* is the universal gravitation constant, $6.6726\times10^{-11}(m^3/kg)\cdot s^2$,

c is the speed of light, and$T_{\mu\nu}$ is a tensor for

momentum and energy; $F=G(mm'/r^2)$,
(m, m'; mass of each matter, and r is a distance between them).

Equation (4) can be proposed taking into consideration of them

$$\int dN/N=-\lambda\int dt +\int(8\pi G /c^4)\, T_{\mu\nu}\, dt \quad \text{------- (4)}$$

The tensor in the last term relates to the momentum P = M·v(where M is the mass and v is the velocity of the infoton. The

values of $8\pi G/c^4$ in the integral are constant,

and the tensor is associated with energy. We can propose that the velocity of infoton is 2~3 % (approx.6×10^6 m/s corresponding to 2%) light speed which gives the amount for energy to overcome a Coulomb barrier of caesium, adding to obtain photon energy from caesium. The integral equation can then be solved as follows:

$$-\ln N =\lambda t +(Mv/d^2)$$
$$N=N_0\exp(-)\{\lambda t +(Mv/d^2)\} \quad \text{------ (5)}$$

where *d* is the distance between the caesium nucleus and the infoton. Therefore,

$$N/N_0= \exp(-)\{\lambda t +(Mv/d^2)\} \quad \text{------ (6)}$$

Table.1 Radioactivity changes of mushrooms by the process. Starting mushrooms are dried from 825 to 118 g (86%) and milled, then immersed into SIGN medium for 3 weeks following by GM001A and GM001B；GM001A, immersed in SIGN medium, and GM001B, under LED. (GM001A and 001B were measured after 85 % drying)

Starting material (dried)	Specimen; Radioactivity (Bq/kg)	
Original Bq/kg	GM001A	GM001B
Cs 134 832 Cs137 2046	Cs134 245 Cs137 631	175 460
Total 2878	Total 876 Reduction -69.6 %	636 -77.9%
Process	Raw mushrooms is dried by 50%	A half-dried ones are exposed to LED for 72 hrs.

Table.2 Residual percentage of radioactivity of radionuclides with half-lives more than 1 year corresponding to spontaneous disintegration, and two kinds of infoton coefficient comparing with experimental values

Time	Nuclide	Calculated from $T_{1/2}$[a]	Infoton coefficient[b] = 1.53	Infoton coefficient[b] = 1.02	Experimental value
92 h	Cs-137	100	21.6	49.5	
	Cs-134	99.6	21.6	35.9	18 36 (total)
	Ru-106	99.3	21.5		
6 months	Cs-137	98.9	21.4	35.7	
	Cs-134	84.8	18.4	30.6	14–34 (total)
	Ru-106	71.6	15.5	–	
9 months	Cs-137	98.3	21.3	35.5	43
	Cs-134	78	16.9	28.1	31
	Ru-106	60.6	13.1	–	–
15.6 months	Cs-137	97.1	21	35	28
	Cs-134	64.6	14	23.3	18
	Ru-106	41.5	9	–	–
24 months	Cs-137	95.5	20.7	34.4	22
	Cs-134	51.1	11.1	18.4	12
	Ru-106	25.8	5.6	–	–

[a] Expected value calculated from the half-life of the nuclide corresponding to a spontaneous decay.[b] The values of 1.02 and 1.53 are calculated from (6) by assuming that the Infoton travels at 2% and 3% of the light speed, respectively.

Figure.2 Residual amount of radioactivity of each element which has the half-life more than one year

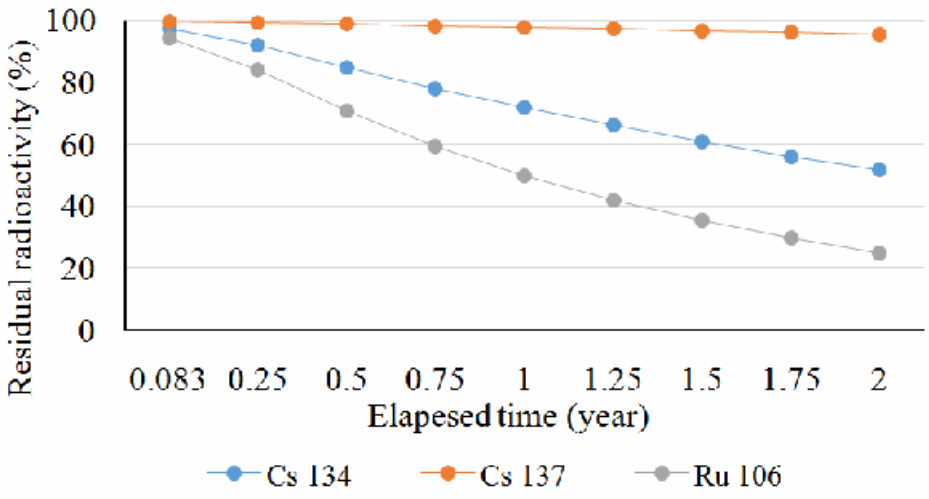


Figure.3 NMR results of an original tap water (pet water) as a control, and SIGN/LED; Upper: free- induction decay spectrum, and lower: relaxation time (T_2)

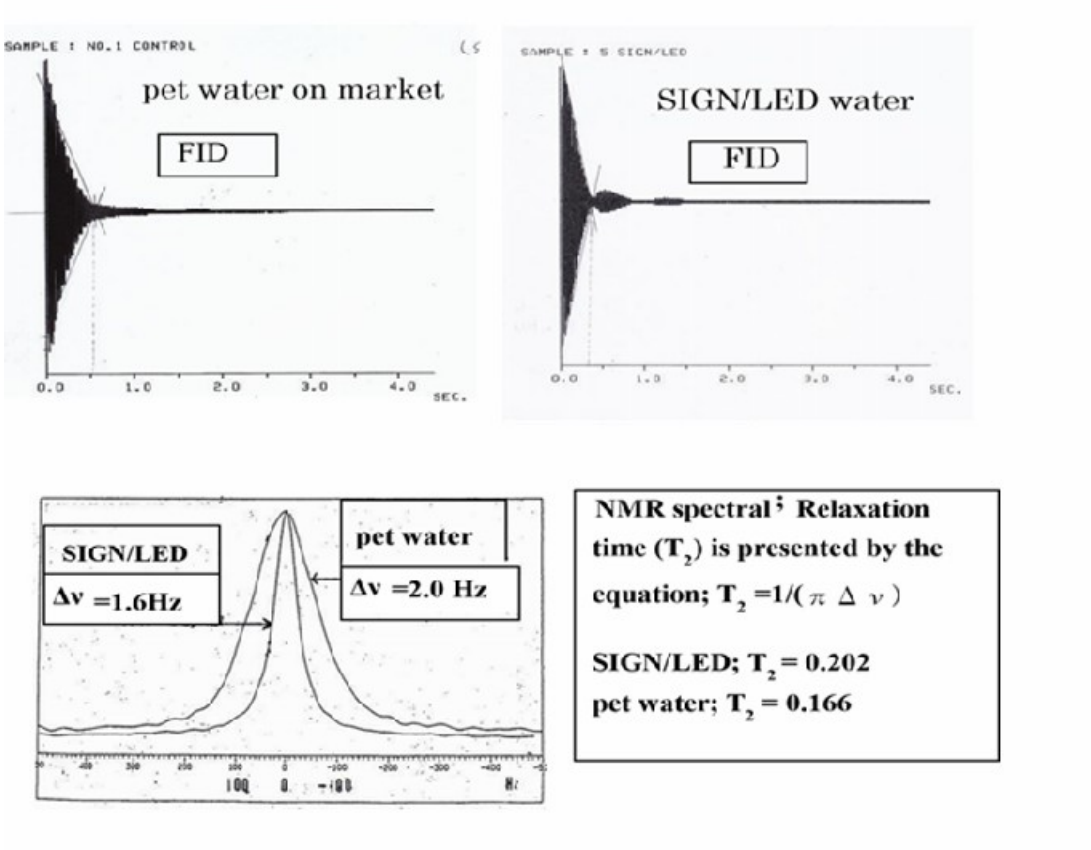


Figure.4 Relaxation time T_2 and free induction decay (FID) in NMR measurements; pressurized-tap water at 112MPa, pet water on market/LED, (SIGN field), 6 MPa RO (reverse osmosis), tap water, etc

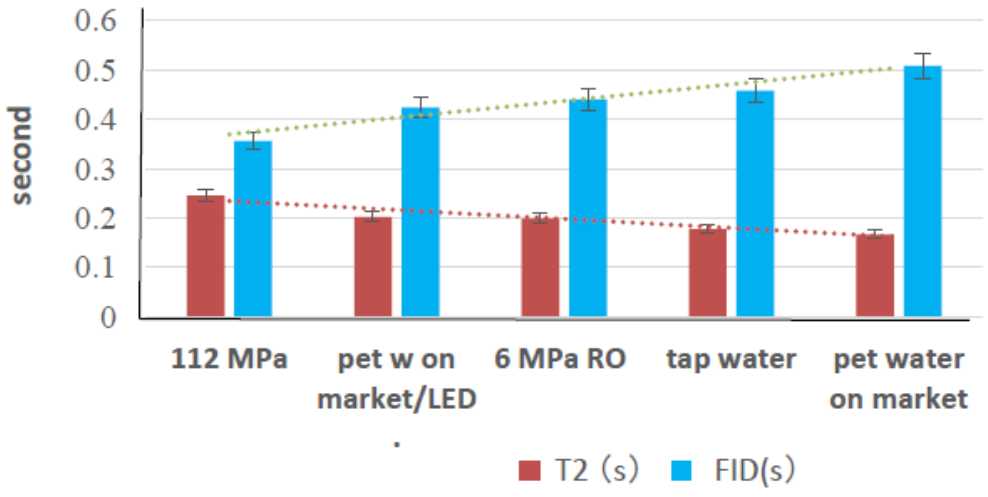


Figure.5 Follow up of radioactivity for 3 years in the contaminated soils after decontamination. The inserted figure shows calculation based on usual decay-mode of each nucleus

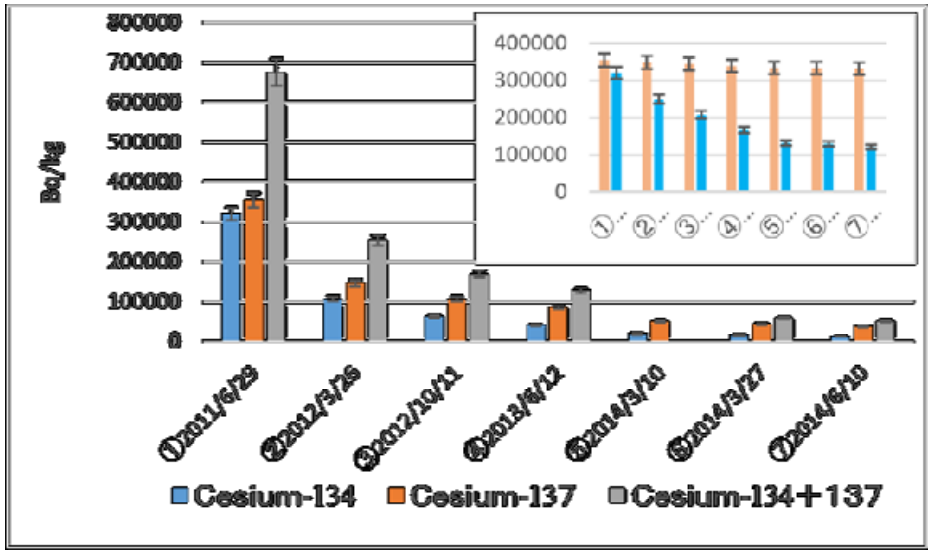


Figure.6 Radioactivity changes of Cs 134, 137 and total in the pasturages by the treatment of SIGN medium and/or under irradiating LED white light. The bars of each element and total; left: 72 hrs in the pot, middle: 72hrs in pot of the H2O under irradiating LED, right:216 hrs in the pot of the water under irradiating LED. The first 3 groups show before processing and the last 3 groups after processing

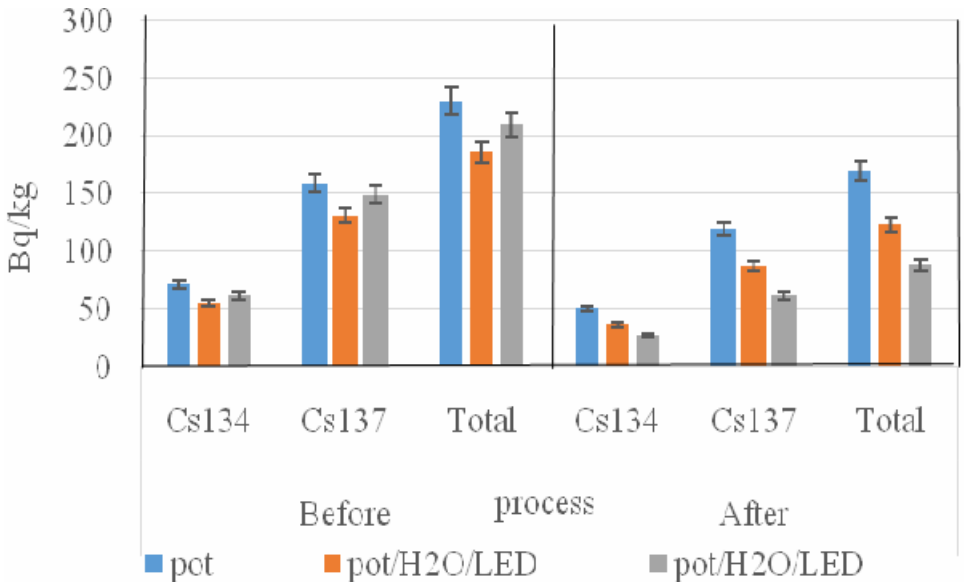
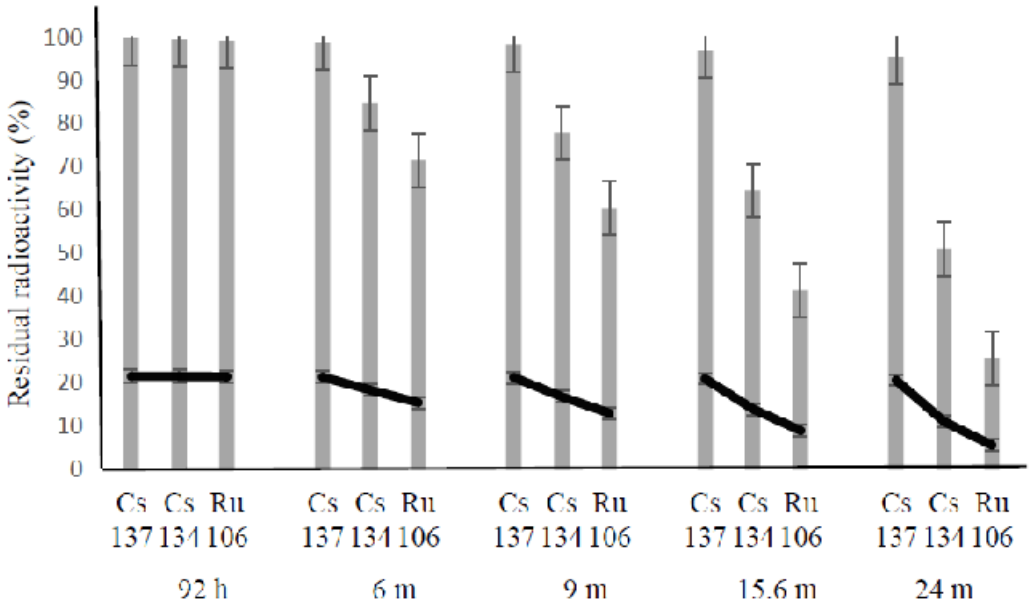


Figure.7 Effect of the Infoton coefficient on the half-lives of radionuclides. ^{137}Cs, ^{134}Cs, and ^{106}Ru; spontaneous decay by grey bars (showing half-life for each element), and black solid lines; calculated by using an Infoton coefficient of 1.53



Thus we found the infoton coefficient attributable to reduction of a half life shown in the term of (Mv/d^2).This equation means the rate of residual radioactive substance at a certain time after interaction of infoton and caesium. As results, we can recognize that the existing radioactivity decreases rapidly with time, i.e., reduction of a half-lie that means rapid deactivation of radioactive materials.

Half-life changes of radioactive nuclei in contaminated soils, mushrooms and pasturages have still been studied since the issue is beyond unusual. However, we confirmed the facts of it by following-up the contaminated soils for approx. 3 years since June of 2011, and also the facts of reduction of radioactivity for rice and mushrooms. Rapid changes of radioactivity means reduction of half-lives of the radionuclides as compared to spontaneous decay of caesium134 and 137 as shown in well-known differential equations (as discussed in section "Spontaneous disintegration"); $dN/dt = N_0 \exp(-)(\lambda t)$, *N*; the number of atom at time *t*, N_0; the initial number of atom, λ decay constant. $dN/dt=N_0 \exp(-)(\lambda t)$

Verification of experimental data for reduction of radioactivity

Figure 7 and table 2 show residual radioactivity of caesiums and ruthenium emitted from the nuclear power reactors except for strontium and plutonium. Table 2 includes the calculated values from a half-life in the $T_{1/2}$ column, infoton coefficient of 1.53 and 1.02determined from the speed of infoton (calculated from 3% and 2% of light speed) in a small distance and short time between Cs and infoton, which correspond to 702 keV and 468 keV, respectively, and the values are seemed to be conservative. We can see that the energies corresponding to infoton coefficient are cross to the photon energy of 661.6 keV and 563□1365 keV which ^{137}Cs and ^{134}Cs emit, respectively as known. We verified the case of ^{7}Be encapsulated with C60 reported by Ohtsuki

et al. (2004) where they reported a shorter half life of 1.5% than usual beryllium, while it is 2% according to our prediction equation described above (velocity of electron is assumed to be 2.3×10^6 m/s in the atom, and $T_{1/2}$ = 52 days).

Conclusion

A half-lives of radioactive nuclides can be drastically shortened by long wavelength synthesis (LOWS) due to the specially-processed SIGN water and/or LED. As the results, we confirmed the reduction of radioactivity of contaminated soils, pasturages and mushrooms, and analytically obtained another stable element in the soils by LOWS. We are able to apply to reduce radioactive substances and to reduce their volumes by employing our methods in low cost and speedy, except for heavier uranium, plutonium etc., at present.

Acknowledgement

We thank senator and famer of Nihonmatsu city, Mr. G.Satoh for providing a warehouse and rice field for a large scale test. We express our gratitude to Professor A. Kitamura of Kobe University for radioactivity measurement with energy discrimination using Ge semiconductor and to Mr. Y. Nagasaka and N. Iwamoto for sampling and measurement. We also express our gratitude to Mr. S. Katanahara of Alps engineering Co., for the 100-L facility fabricating the specially-processed water.

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