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A COMPARISON BETWEEN THERMAL AND X RADIOGRAPHY FOR STUDYING THE INTERNAL STRUCTURE OF BIOLOGICAL SAMPLES

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ABSTRACT

Background: With respect to the difference in the interaction of thermal neutron and X rays with matter, using two radiography systems of thermal neutron and X rays will yield highly valuable information for studying the inner structure of biologic samples.

Methods: The high sensitivity of thermal neutron to hydrogen, in particular, has led to recognizing this system as a useful tool in medical studies in as much to substitute this system as a non-destructive-testing (NDT) technique in the pathology studies for the common microscopic method.

Results: In this study, by using two neutron and X radiography systems available at the Atomic Energy Organization Research Center, the inner structure of field mouse bone as a biologic sample was evaluated.

Conclusion: The difference in the interaction of thermal neutron and X ray with organic and inorganic elements of bone led to development of different images that would supplement each other and we tried to show those differences by presenting the diagram and table obtained by measuring the optic density.

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INTRODUCTION

Essentially, using neutron radiography systems in both industry and medicine is the result of difference of neutron interaction and X ray with the matter. In X radiography, attenuation is a function of the thickness and density of matter and its weakness range increases by an increase in the atomic value of the matter. In the radiography image of neutron, the amount of weaknesses of neutrons depends on the thickness of the sample and the cross section of neutron reaction and is independent from the atomic number of the matter in as much that, even for the isotopes of an element, the prosperities of absorbing thermal neutron might vary significantly. Figure 1 shows the difference in the mass absorption coefficient of X ray and neutrons by an increase in the atomic number of elements.

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MATERIAL AND METHODS

The neutron radiography system

The existing neutron radiography system at Tehran Atomic Energy Organization Research Center was used to develop radiography images of neutron. This system uses a 5MW reactor system of Tehran as a neutron flux. The neutron flux in the paralleling discharge is equal to 4.54 x 10^4 n/cm². Due to lack of sensitivity of film emulsion to the neutron non-charge particles of neutron, the gadolinium converter has been used to convert neutron to electron for radiating radiography film. During the neutron hit to the converter sheet, electrons with 70 keV is produced as a result of inner conversion. Radiography film of Kodak Company known as Industrex AA400 was used as a two-layer radiography film with high speed and contrast. The radiation time to the film has been one hour and forty-five minutes per 2.5 M/W reactor power.

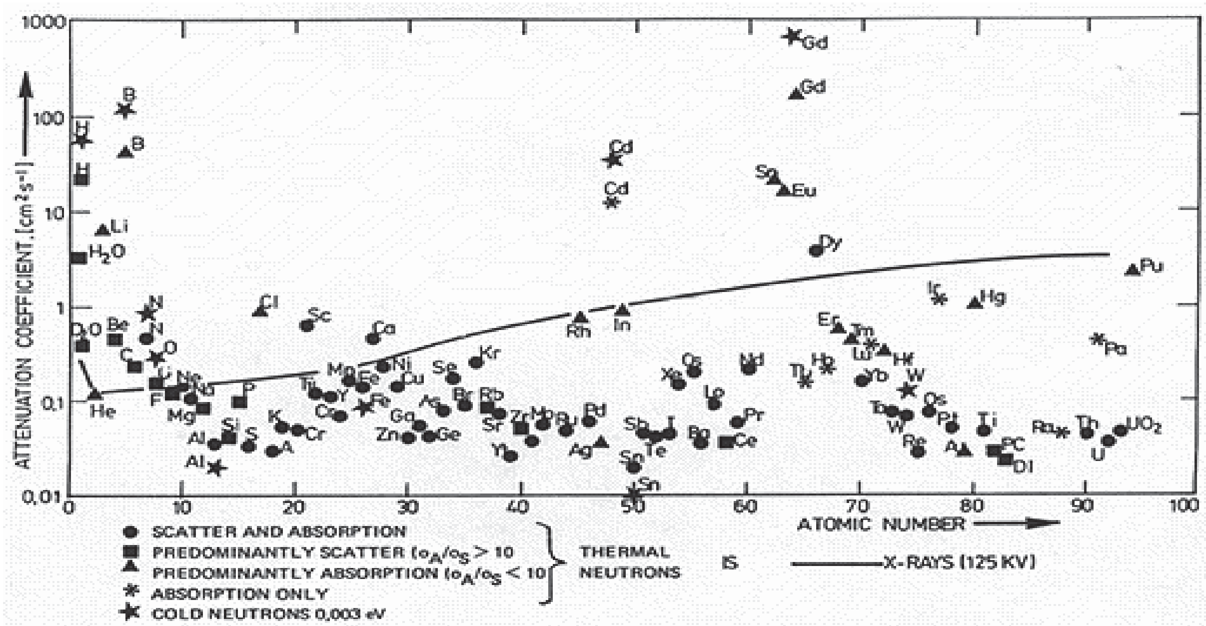

Fig. 1. Variation in the coefficients of massive weakness of X rays and neutron by an increase in atomic number.

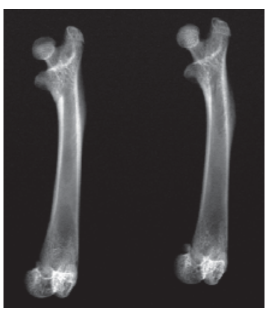

Fig. 2-a. X radiography image of normal bone.

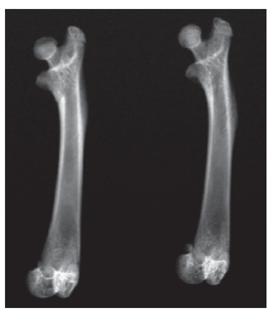

Fig. 2-b. X radiography image of calcified bone.

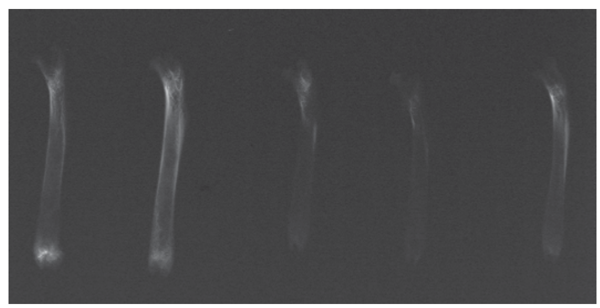

Fig. 3. X radiography image of decalcified bone.

The X Radiography System

The Tube X, available at the health physics department of the organization was used to prepare the X radiography images. This tube is of Muller MG 150 type and the radiography film used is Industrex MX 125. The radiography X images were developed in 5 mA, 40 kVp and 10s radiation time. By using this quantity of voltage for X rays, the development of Campton dispersion of rays upon contact of photon to calcium and phosphorus atoms- that have converted major part of the bone has been prevented; for this dispersion would lead to lowering image contrast. Also, to prevent a decrease in the image differentiation power, no intensive film has been used to improve detection sensitivities.

The biologic sample and its preparation

The animal rooms and radio-drug laboratory of the organization were used for the preparation of biologic samples. 15 mature field mice were killed and their left and right femur bones were separated and their surrounding soft tissues were removed; for the high dispersion cross section of thermal neutrons for Industrex water, which forms the major part of soft tissues causes neutron dispersions and subsequently, the image contrast decreases greatly. We divided the bones samples into three sections: normal bones (the neutron radiography and X ray images were developed in frequent hours post mortem), calcifying bones (calcified samples were prepared by placing a part of samples in a furnace at 600 degrees centigrade for five hours) and decalcified bones (prepared by placing another section of samples in EDTA 15% solution for 24 hours)

RESULTS

The X radiography images

No difference was observed in the X radiography images of normal and calcified bones (Figure 2-a). In the X radiography image, made from fully de-calcified bone, the image has a very low contrast (Figure 3). Since the samples were placed in EDTA solution, the decalcification of samples would vary due to the different dimensions of the

Fig. 4-a. neutron radiography image of normal bone

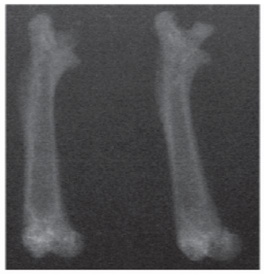

Fig. 4-b. Neutron radiography image of decalcified bone

samples. The resulted images show this difference in contrast loss fairly well. The X radiography images taken from normal bones in post mortem frequent time intervals show no changes. The exhibition of inner structure of samples in these images is similar to those of images in Figure 2.

The neutron radiography images

The neutron radiography images of calcified bones show no contrast and there is only a homogenous lowering of neutron which is observed (therefore, the images do not exhibit the details of inner structure of samples and their monitoring is not presented in this part). The neutron radiography images of normal and decalcified bones are family inseparable due to the mineral phase of bone as a result of decalcification and subsequently, lowering in the volume of samples. Regardless of this lowering the volume, the exhibition of the inner section of normal and decalcified bones by use of this system is the same. The neutron radiography images of normal bones in post mortem subsequent hours with 4 hours interval and 1:45 minutes time periods shows no distinction between the membrane part of the bone and its middle region; however, by lapse of time, this distinction becomes more observable (Figure 5).

Calcification of bone leads to its organic phase, with collagen nature, to disappear, leaving only the minerals.

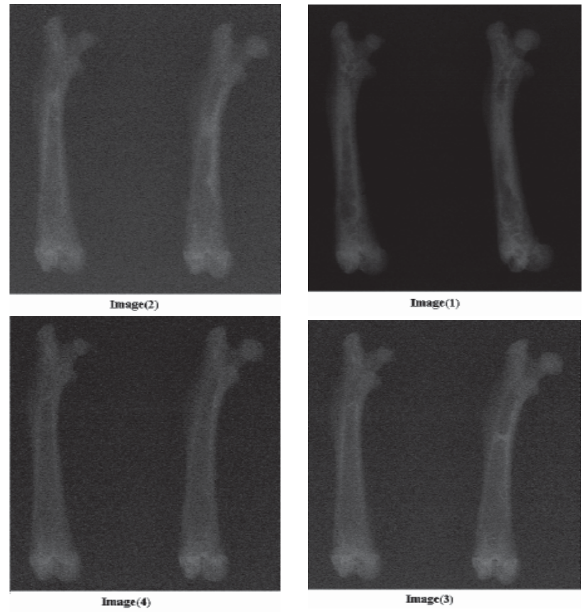

Fig. 5. Neutron radiography of calcified bone

The homogenous X radiography images of normal and calcified bone, absence of high contrast in neutron radiography images of calcified bone, trivial decrease and homogenous optic density of the images imply a good exhibition of mineral bone with the X radiography system. On the other hand, the neutron radiography system is not able to show details of the mineral phase of bone. The difference in the neutron and X rays interaction with matter and the differentiation in the coefficient of weakness of various elements by X and neutron rays show this point. Contrary to the high weakness coefficient of calcium and phosphorus, minerals in general, against X rays, and low weakness coefficient of light elements such as hydrogen against X rays- on the other hand- the weakness coefficient of these elements have diverse specification against

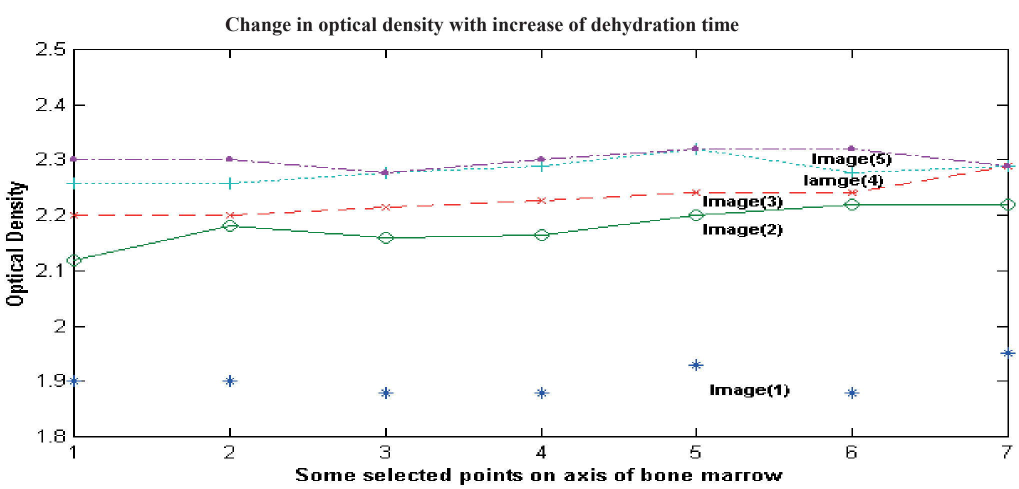

Fig. 6. Optical density changes of neutron radiography images from some parts of post mortem bone marrow.

neutron beam. Since calcification of bone has led to the discharge of its organic phase and it is only its mineral element that remains- the so-called calcification - it is not unexpected that the neutron radiography image could not exhibit the details of inner structure of calcified bone. The X radiography images of normal and calcified bones show no differences.

The decalcification of bones leads to discharge of its minerals and its organic phase remains. Lowering the contrast of X radiography image of decalcified bones reveals that the X radiography system is not able to show the organic part of the bone in as much that, if the sample is fully decalcified, with the trivial decrease in the ray charges, there is a homogeneity in optic density of the image.

On the other hand, the neutron radiography image of decalcified and normal bones show this fact that this system is suitable for exhibiting the organic phase of biological samples. The above-mentioned table shows the difference in absorbing X and neutron rays in different parts of normal, calcified and decalcified bones in short and based on the texts.

In another test, the X radiography images of the sample taken within 14-16 hours post mortem show no observable change.

This is due to lack of sensitivity of these rays to hydrogen; however high sensitivity of thermal neutron to hydrogen leads in obtaining different images which have been taken subsequently in this time interval (the bones are dehydrated during this time depending on its volume and the physical condition of the environment). Fig. 6. shows the change of optical density of some points of neutron radiography images taken from normal bone marrow throughout time.

CONCLUSION

With respect to the results, despite the apparent similarity of neutron and X radiography images of a particular sample, the nature of the images totally differs. The neutron radiography system shows the organic phase of bone samples while the X radiography system exhibits its mineral phase. With respect to the high dispersion cross section of thermal neutron for water which is found in soft tissues abundantly,this system can be used only for tissue pathology and it could be suggested to be used, along with other histology devices, to achieve method of organic materials distribution and dehydration of Biologic samples in various environment.This system could be also used for determining the mortal time of living existence.

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