Journal of Associated Medical Sciences 2018; 51(3): 119-121

JAMS Journal of Associated Medical Sciences

Thai-Journal Citation Index Centre (TCI) & ASEAN Citation Index (ACI)

Journal of Associated Medical Sciences

Journal homepage: https://www.tci-thaijo.org/index.php/bulletinAMS/index

Effect of diagnostic medical X-rays in the range of 50 keV up to 100 keV of energy on ferrous sulfate solution with saturated O_2 gas: preliminary study

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ARTICLE INFO

Article history:
Received 27 April 2018
Accepted as revised 18 July 2018
Available online 18 July 2018

Keywords:
Radiation, Radiation exposure, Diagnostic medical X-rays

ABSTRACT

Background: Ferrous sulfate solution is the most widely used as an aqueous chemical dosimeter. In this preliminary present study, we applied ferrous sulfate solution in diagnostic radiology.

Objectives: The aim of preliminary present study was to measure absorbance spectrum of ferrous sulfate solution after exposure to diagnostic medical X-rays in the range of 50 keV up to 100 keV of energy.

Materials and methods: Diagnostic medical X-rays were generated by a medical X-ray machine. Radiation exposure was measured by mean of ionization chamber. Ferrous sulfate sulfate solution with saturated O_2 gas was irradiated, resulting in ferric ion production in solution. The optical density of irradiated ferrous sulfate solution was determined by spectrophotometer.

Results: A positive correlation was shown in diagnostic medical X-ray energy with radiation exposure. The optical density at a wavelength of 304 nm was increased as a function of X-ray energy.

Conclusion: This preliminary finding suggested that ferrous sulfate solution with saturated O_2 gas showed feasibility to measure radiation dose of diagnostic medical X-rays at 50-100 keV of energy.

Introduction

There are various methods used to measure radiation dosages including air-filled detectors such as Geiger counters and ionization chambers. Solid detectors make use of thermal luminescence detection (TLD) and optically stimulated luminescence (OSL). Such methods are commonly used in radiation measurement due to ease of use compared with chemical or biological systems. However, those methods can be difficult to apply in determining absorbed dose in soft tissue. Consequently, chemical dosimeters are used when absorbed dosages in soft tissue must be determined. If a chemical dosimeter is constituted of an aqueous solution, it can be predicted that radiation will have a major interaction with water.[1,2] Moreover, aqueous solutions can be made to fill every variability in the shape of the volume.[3]

Ferrous sulfate solution is the most widely used as an aqueous chemical dosimeter. Ferrous ion (Fe^{2+}) is oxidized to ferric ion (Fe^{3+}) by a free radical. This free radical is generated when ionizing radiation deposits energy to solution.[4] There were several reports mentioned the use of ferrous sulfate solution in measuring radiation dosages.[5-10] However, these radiation dosages were high radiation energy type or used monochromatic energy. In this preliminary present study, we applied ferrous sulfate solution in diagnostic radiology. The aim of preliminary present study was to measure optical density of ferrous sulfate solution with saturated O_2 gas after exposure to diagnostic medical X-rays in the range of 50 keV up to 100 keV of energy.

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doi: 10.14456/jams.2018.16
E-ISSN: 2539-6056

Materials and methods

Diagnostic medical X-ray generator used is a diagnostic medical X-ray machine (Quantum Medical Imaging, High frequency series™ X-ray Generator 125 kVp, 400 mA) at Department of Radiologic Technology, Faculty of Associated Medical Sciences, Chiang Mai University. This X-ray machine needed to be able to generate several energies of X-rays by adjusting the kilovoltage peak (kVp) setting (Figure 1). Other equipment included a multichannel analyzer (Detector XR-100T-CdTe, Amptek), an ionization chamber (Capintec), barometer, and thermometer. Hydrochloric acid (HCl), sulfuric acid (H_2SO_4), and ferrous ammonium sulfate were the materials used in this study.

Determination of X-ray spectrum

A multichannel analyzer (MCA) was placed perpendicular to the central axis of radiation beam at a distance of 100 cm from X-ray tube. X-ray spectrum was recorded on 50 keV up to 100 keV (100 mAs) of X-ray energy.

Ferrous sulfate solution with saturated O_2 gas

A ferrous sulfate solution contained 1 mM ferrous ammonium sulfate in 0.4 M H_2SO_4, 0.01 M HCl and was saturated with O_2 gas. Solution was prepared using water redistilled in a flask from $1x10^{-4}$ M potassium permanganate solution. All glasses were heated at 100 °C for 6 hours before being used. Ferrous sulfate solution was placed perpendicular to the central axis of radiation beam at distance of 100 cm from the X-ray tube. The irradiated ferrous sulfate solution produced ferric ion in solution. The optical density of irradiated ferrous sulfate solution was determined by spectrophotometer (Agilent 8453).

Measurement of radiation exposure by ionization chamber

Ionization chamber was placed perpendicular to the central axis of radiation beam at a distance of 100 cm from X-ray tube. Radiation exposure was recorded in nanocoulomb (nC). Pressure and temperature at experimental room also was recorded for correcting radiation exposure values.

Statistical analysis

An origin lab program was used for data analysis. Linear correlation analysis was carried out using Pearson correlation. Simple regression analysis was also used for analyzing data.

Results and Discussions

Diagnostic medical X-ray spectra of X-ray energy at 50 keV up to 100 keV (100 mAs) is showed in Figure 1. These X-rays shows continuous spectra that related to previously our report.[11]

An optical density of ferric ion produced after X-ray irradiation against diagnostic medical X-ray energy is showed in Figure 2. The optical density at a wavelength of 304 nm was increased as a function of X-ray energy. A quantity of ferric ion produced depends on the radiation energy absorbed by ferrous sulfate solution.[12] It seems reasonable that if quantity of ferric ion produced was increased when radiation energy increased, then absorbed dosage would also have increased when radiation energy increased, as well.

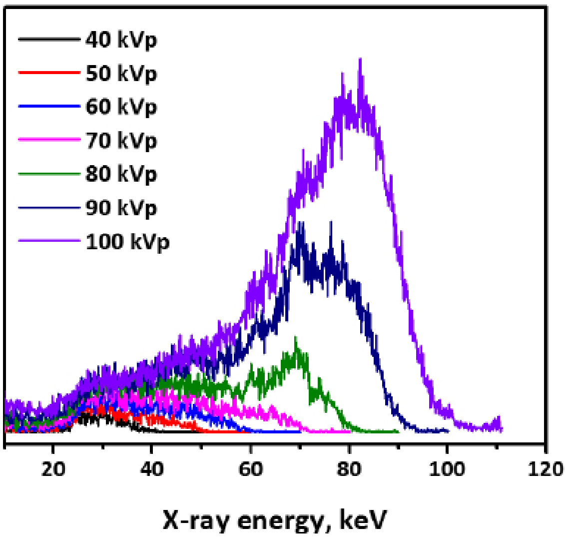

Figure 1. *Diagnostic medical X-ray spectra of X-ray energy at 50 - 100 keV (100 mAs).*

Radiation exposure against diagnostic medical X-ray energy is showed in Figure 3. Radiation exposure was increased when X-ray energy increased (Pearson's r=0.992, R^2=0.980). High radiation energy can produce ionization in medium, resulting in radiation exposures that are high.[13]

However, a ferrous sulfate solution was used to measure low energy X-ray dose.[14] In addition, the ferrous sulfate solution could enhance response by added a radiosensitizer under X-ray irradiation.[15] In conclusion, this preliminary finding suggested that the ferrous sulfate solution showed feasibility for use in diagnostic radiology. However, further development and study of it are needed to fully determine feasibility.

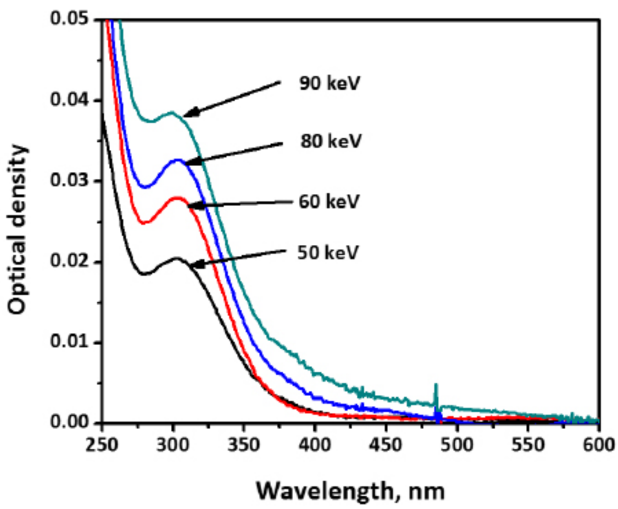

Figure 2. *An spectra of ferric ion produced after X-ray irradiation against diagnostic medical X-ray energy.*

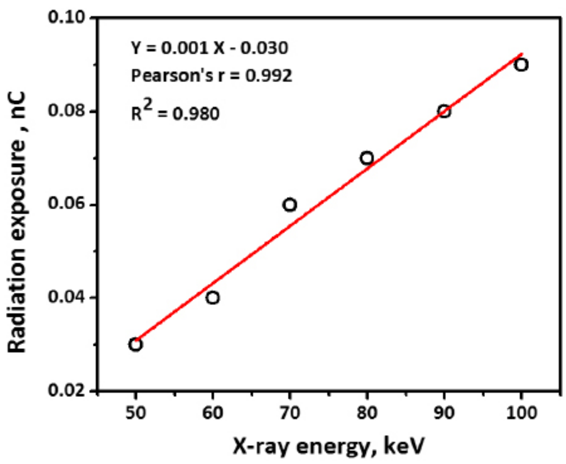

Figure 3. *Radiation exposures against diagnostic medical X-ray energy.*

Acknowledgements

We would like to thank the Department of Radiologic Technology, Faculty of Associated Medical Sciences, Chiang Mai University, Thailand for allowing us to use of all facilities, and truly appreciate their support throughout this study.

Conflict of intersets

None.

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