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The Risk of Ionizing Radiation Arising from Waste on Workers at Regions in Some landfills in West Bank

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Dedication

This thesis is dedicated with gratitude to:

My grandmother and grandfather (may God have mercy upon them) who were the most effective people in my life. It's also dedicated to my mother who was always being there for me, supported and prayed for me, as well as to my father who was my helpful in time of need. Finally I will dedicate this to my life partner who encouraged me all the time.

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First of all I heartily thank Allah for giving me the patience to complete my master's degree successfully. I am also deeply grateful to my supervisor Prof. Issam Rashid Abdelraziq for guiding and supporting me in this study and also to the examining committee members. Special thanks to my workmate Natalie Tabone and my friends Jaafar Diab and Mohammad Bsharat for helping me in some translations and finally a lot of thanks and appreciation to my parents and friends for their support.

After all, I would like to thank dumpsites workers specially Zahret Al-Finjan and Almenia workers.

الاقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

The Risk of Ionizing Radiation Arising from Waste on Workers at Regions in Some landfills in West Bank

أقر بأن ما اشتملت عليه هذه الرسالة إنما هو نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وأن هذه الرسالة ككل من او جزء منها لم يقدم من قبل لنيل أية درجة أو بحث علمي أو بحثي لدى أية مؤسسة تعليمية أو بحثية أخرى.

<u>Declaration</u>

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: **اسم الطالب:**

Signature: **التوقيع:**

Date: **التاريخ:**

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List of Abbreviations

Symbol	Abbreviation
NIR	Non-Ionizing Radiation
IR	Ionizing Radiation
α	Alpha
β	Beta
γ	Gamma
n	Neutron
Ra_{eq}	Radium Equivalent Activity
ICRP	International Commission on Radiological Protection
NORM	Naturally Occurring Radioactive Materials
CNSC	Canadian Nuclear Safety Commission
CPEP	Contemporary Physics Education Project
ATSDR	Agency for Toxic Substances and Disease Registry
Gy	Gray
D	Absorbed Dose
$d\epsilon$	The mean energy imparted by ionizing radiation to matter in a volume element
dm	The mass of min the volume element
mSv/y	Mmillisievert per year
Bq/m^3	Becquerel per meter cube
nGy/h	Nanogray per hour
Bq/kg	Becquerel per kilogram
KBq/L	KiloBecquerel per litre
nSv/h	Nanosievert per hour
µSv/y	Microsievert per year
W_R	Radiation weighting factor
SI	International System of Units
H	Equivalent Dose
H_T	The total equivalent dose in a tissue
D_{TR}	The absorbed dose from a specific type of radiation in a tissue
W_T	Radiation weighting factor for a specific tissue
E	Effective Dose
Q	the number of particles per second
Φ	Flux

r	Radius
P	Probability
R	Pearson Correlation Coefficient
L	Landfill
SPO_2%	Blood Oxygen Saturation
T	Tympanic Temperature
HPR	Heart Pulse Rate
SBP	Systolic Blood Pressure
DBP	Diastolic Blood Pressure
He	Helium
b	before
a	after

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Abstract

The study sample consists of 74 workers who were chosen randomly from different seven landfills in West Bank.

In this study, gamma dose equivalent rate and beta particles flux density were measured. In addition, the health parameters were measured to study the effect of ionizing radiation which arises from waste on landfill workers.

The measured gamma dose equivalent rate is ranged from 0.815 mSv/y to 3.506 mSv/y for all landfills. Six of these landfills have values above the international standard value which is 1 mSv/y. The calculated beta dose equivalent rate is ranged from 0.019 mSv/y to 2.384 mSv/y for all landfills. Three of these landfills have values above the international standard value which is 1 mSv/y.

Measurements of arterial blood pressure (systolic and diastolic), tympanic temperature, heart pulse rate and blood oxygen saturation showed a change before and after a work day, but this change is in the normal human range.

Chapter One

Introduction

1.1 Background

Electromagnetic radiations are found everywhere in our environment. Humans are exposed to these radiations in every minute of their daily life. Naturally, electromagnetic radiations come from two main sources: cosmic radiations and terrestrial radiations. Cosmic radiations come from stars and outer space, while terrestrial radiations are due to the presence of radioactive elements such as uranium and thorium in our surroundings. For example, radioactive elements are present in all salts, rocks, water and soil, emit radiation which forms a part of the terrestrial radiation. In the last century, some other artificial sources were added to these natural background radiations. The artificial sources include all radiations which come from human activities, such as: occupational exposure to radiations, medical uses of electromagnetic radiations and radioactive waste (Martin *et al*, 2012).

Radiation is energy in the form of waves or streams of particles (CNSC, 2012). This energy is categorized in the electromagnetic spectrum according to their frequencies. The electromagnetic spectrum consists of: radio waves, microwaves, infrared rays, visible light rays, ultraviolet rays, X-rays and gamma rays as shown in Fig 1.1 (Zamanian and Haradiman, 2005).

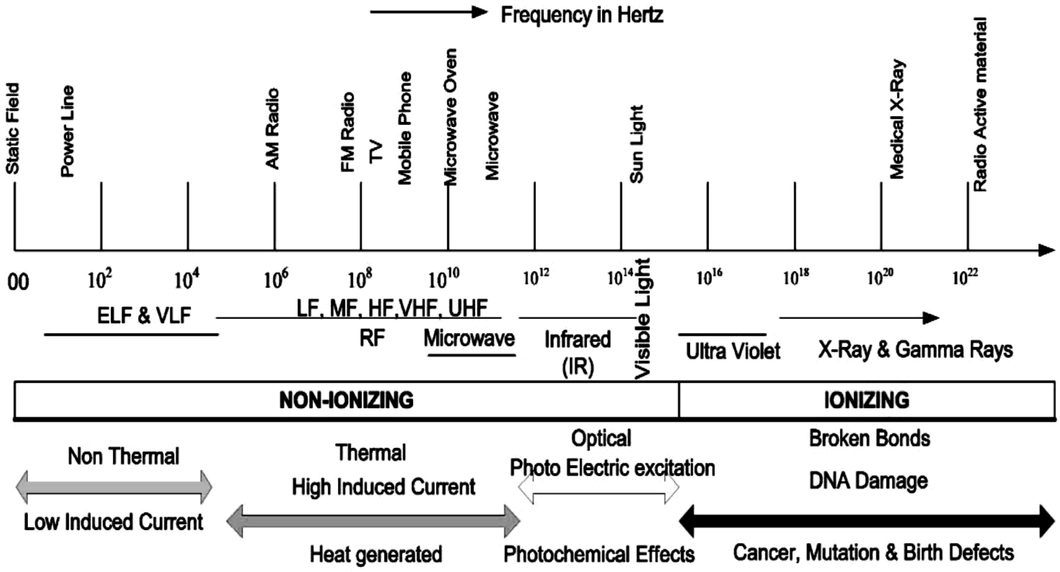

Fig. 1.1 Electromagnetic spectrum

Electromagnetic radiations can be classified into two major types according to its ability to ionizing matter: Non-Ionizing Radiation (NIR) and Ionizing Radiation (IR).

Non-ionizing radiation has the long wavelength and low photon energy portion of the electromagnetic spectrum. It doesn’t produce charge ions when it passes through matter, but it has a sufficient energy that excites it (Kwan, 2003). Non-Ionizing Radiation includes: radio waves, microwaves, infrared rays and visible light as it is shown in Fig. 1.1.

Ionizing radiation has higher frequency and shorter wavelength rather than non-ionizing radiation. This radiation has enough energy to disrupt atoms and remove bound electrons from atoms to create ions which cause biological harm (CPEP, 2003). Ionizing radiation includes: alpha particles, beta particles, gamma rays, neutrons and X-rays.

Alpha (α) particles are Helium (He) atoms without electrons consisting of two protons and two neutrons. It doesn't travel very far in the air and cannot penetrate the skin. It's only dangerous if it is ingested or inhaled (Zakariya and Khan, 2014).

Beta (β) particles are high speed electrons or positrons that can travel much further through air. It's different from alpha particles that it can penetrate the skin, but can be shielded with a sheet of plastic. Beta rays are more harmful than alpha rays if it is ingested or inhaled (Zakariya and Khan, 2014).

Gamma (γ) rays and X-rays are high energy photons. This means that these radiations consist of packets of energy transmitted in the form of a wave motion (Martin *et al*, 2012). Gamma radiations consist of photons that originate from within the nucleus but X-rays consist of photons that originate from outside the nucleus, and they are typically lower in energy than gamma radiations (CNSC, 2012). Photon radiation can penetrate very deeply than alpha and beta particles, and can only be reduced by materials that are very dense, such as lead (CNSC, 2012).

Neutron radiation (n) is a neutron emitted by an unstable nucleus during atomic fission. Neutrons are electrically neutral particles, so they can deeply penetrate. Therefore it requires heavy shielding to reduce exposures (IAEA, 2004).

Exposure to ionizing radiation carries a health risk. High doses of ionizing radiation in a short time can lead to various effects, such as loss in weight, loss of hair, nausea, vomiting and cancer (ATSDR, 1999). However, the low doses of ionizing radiation may cause harmful effects in the long term (Martin *et al*, 2012).

1.2 Literature survey

During recent years, many researchers have conducted a large number of studies on the effect of ionizing radiations emitted by many sources. Most of these studies were conducted to assess the radiological risks by calculating the absorbed dose rate and the equivalent dose rate and compared them with the standard values which is 60 nGy/h for absorbed dose rate and 1 mSv/y for dose equivalent rate (ICRP, 1990). Where Gy is Gray and Sv is Sievert.

Building materials considered as a sources which cause a direct radiation exposure. Beretka and Mathew showed in their study in Australia that the ionizing radiation released from building materials and industrial waste is higher than the permissible limits, therefore it posed significant radiation hazard (Beretka and Mathew, 1985).

Brenner and his team concluded that the exposure to high doses of ionizing radiation clearly produce deleterious diseases in humans including cancer, while for very low doses the situation is much less clear (Brenner *et al*, 2003).

Bahari and his team studied the radiological risk associated with amang processing of two amang plants in the States of Selangor and Perak, Malaysia. They found that the maximum activity concentrations of ^{238}U, ^{232}Th,^{226}Ra and ^{40}K are higher than Malaysia's and the world's natural averages 25 Bq/Kg, 25 Bq/Kg, 74 Bq/Kg, and 370 Bq/Kg, respectively. They also found that the maximum value of gamma effective dose rate is 3.165 mSv/y which is higher than the typical world's value which is 1 mSv/y. (Bahari *et al*, 2007).

Ortega and his team studied the environmental radiological conditions in the phosphate industrial landfill in Tarragona, Spain. They found that the average value of gamma dose equivalent rate in this landfill is 0.7 mSv/y, so the effective dose which is received by workers due to radioactive waste is lower than 1 mSv/y. In addition, they found that the average concentration of radon in the landfill is 30 Bq/m^3, which is slightly higher than the slandered value 10 Bq/m^3 (Ortega *et al,* 2008).

Omar and his group measured the activity concentrations of radionuclides in naturally occurring radioactive materials (NORM) wastes. They found that some of these NORM waste such as iron waste had a very high concentration of parent radionuclides while others such as oil sludge and lead waste showed the reverse (Omar *et al*, 2008).

Al-Jundi and Al-Tarazi estimated the population annual effective dose from gamma radiation in the Ruseifa landfill, Jordan. It was ranged from 58.3 to 103.4 µSv/y. These values are higher than the recommended value by United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) which is 70 µSv/y (Al-Jundi and Al-Tarazi, 2008).

Hughes and his group studied the effect of the buried radioactive waste on the shallow groundwater in Sydney, Australia. They found that the maximum tritium concentration in groundwater is 390 kBq/L and this value is higher than the typical background level (Hughes *et al*, 2011).

Bahari and his team studied the radiological risk associated with radioactive materials waste in Malaysia. They obtained a wide range in the total activity concentrations in the tin slag and tin tailing waste. While for gypsum and oil sludge waste are comparable with the world's values. They also concluded that the occupational effective dose rates in all landfill areas are lower than permissible occupational dose limit which is 20 mSv/y. In addition, the average of excess cancer risk coefficient for residents was estimated to be 3.19×10^{-3} risk per mSv, which is comparable with the average Malaysia's levels (Bahari *et al*, 2011).

Odeyemi and his group determined the radioactive contents of leachate samples from dumpsite of Ekiti State Government Destitute Centre in Nigeria. They found that the average absorbed dose rate and annual effective dose equivalent are 63 nGy/h and 0.08 mSv/y respectively. These values did not constitute any radiological risk to human body (Odeyemi *et al*, 2011).

Avwiri and Olatubosun studied the radiological risk associated with radioactive materials waste in ten dumpsites in Port Harcourt, Rivers State, Nigeria. They found that the maximum value of absorbed dose rate is 123.1 nGy/h which is higher than the world average value of 60 nGy/h. They also found that the average value of equivalent radiation exposure is 0.76 mSv/y which is below the permissible threshold of 1 mSv/y. Therefore the potential risk that came from these dumpsites is significant and may be increased (Avwiri and Olatubosun, 2014).

Pourimani and Nemati measured the activity concentrations of ^{238}U, ^{232}Th, ^{226}Ra, ^{40}K and ^{137}Cs in ground and surface of drinking water resources in Arak city of Iran in order to estimate the average annual effective dose revived by public. They found that the dose exposed by public is 0.2 mSv/y and its below the recommended values by international commission on radiological protection (ICRP) which is 1 mSv/y (Pourimani and Nemati, 2014).

Ademola and his group studied the radiological conditions in five dumpsites near Lagos and Ogun State in Nigeria, to estimate the hazard indices on the human beings. They measured average activity concentrations of ^{226}Ra,^{232}Th, and ^{40}K in soil samples, and they found that the mean activity concentrations of ^{226}Ra and ^{232}Th are lower than the world average values but it is higher for ^{40}K. They also found that the gamma absorbed dose rates in some dumpsites are lower than the world average value which is 60 nGy/h, while in other dumpsites are higher than the average value. In addition, the radium equivalent activity Ra_{eq} is found and it is lower than the maximal permissible value 370 Bq/kg (Ademola *et al*, 2015).

1.3 Objectives of the study

The presence of different types of radioactive materials waste with various activity concentrations is expected to give rise to different levels of radiological risks, so the main purpose of this study is:

- To measure the ambient dose equivalent rate of gamma radiation and the flux density of beta particles at landfills and regions near it (approximately 200 meters around the landfill).
- To calculate the ambient dose equivalent rate of beta particles at landfills and regions near it.
- To measure heart pulse rate, blood pressure, blood oxygen saturation and tympanic temperature for workers at landfills to assess the health impact.
- To compare the measurements of radiations with the corresponding international standards.

Chapter Two

Theoretical Background

This chapter consists of two sections. Section one explains the radiation doses, and section two discusses the flux density of ionizing radiation.

2.1 Radiation Doses

Dose quantities are expressed in three ways: absorbed, equivalent, and effective. This section describes these three types of doses.

2.1.1 Absorbed Dose

Ionizing radiation carries energy. This energy can be absorbed by tissue and possibly cause damage to the tissue. The absorbed dose defined as the amount of energy that is deposited in a medium (tissue) by ionizing radiation (Martin *et al*, 2012). The absorbed dose is measured in SI units by a unit called the Gray (Gy). Mathematically, it can be described as (ICRP, 2012):

$$D\ (Gy) = \frac{d\epsilon}{dm} \qquad (2.1)$$

Where,

D: the absorbed dose (Gy).

$d\epsilon$: the mean energy imparted by ionizing radiation to matter in a volume element (J).

dm: the mass of matter in the volume element (Kg).

A dose of one gray is equivalent to a unit of energy deposited in a kilogram of a substance. For example, if a person has a mass of 80 kilograms absorbs 4 joules of energy, then their absorbed dose is 4 joules divided by 80 kilograms, which is equal 0.05 joules per kilogram. But one gray is one joule absorbed per kilogram, so here the absorbed dose is 0.05 gray. On the other hand, Absorbed dose doesn’t depend on the type of radiation. This means that if a source is alpha or beta or gamma, the absorbed dose still 0.05 gray. However 0.05 grays of alpha will don't harm than 0.05 grays of gamma.

2.1.2 Equivalent Dose

The degree of biological effect produced by the same absorbed dose is depend on the type of radiation. For example, it is found that 0.05 Gy of neutrons can do as much biological damage as 1 Gy of gamma radiation. To take this difference into account, the absorbed dose of each type of radiation must be multiplied by the weighting factor (W_R) , which is used to equate different types of radiation with different biological effectiveness. So the equivalent dose is a quantity that is obtained by multiplying the absorbed dose by the radiation weighting factor. The unit of equivalent dose in SI units is the Sievert (Sv). The Sievert is a measure of the health effect of low levels of ionizing radiation on the human body, which is related to the gray as follows (Martin *et al*, 2012):

$$H\ (Sv) = D\ (Gy) \times W_R \qquad (2.2)$$

Where,

H: the equivalent dose (Sv).

W_R: the radiation weighting factor.

The equivalent dose for a specific tissue (T) can be determined by this relation (Martin *et al*, 2012):

$$H_T\,(Sv) = \sum_R (W_R \times D_{TR}) \qquad (2.3)$$

Where,

H_T: the total equivalent dose in a tissue (Sv).

D_{TR}: the absorbed dose from a specific type of radiation in a tissue (Gy).

The value of radiation weighting factor is depend on the density of ionization caused by the radiation. For example alpha particle produces about 106 ion pairs per millimeter of track in tissue whereas beta particle produces about 10 000 ion pairs per millimeter (Martin *et al*, 2012). The radiation weighting factor is assigned a value of 1 for gamma radiation. Beta radiation causes ionization of a similar density to gamma radiation and so its weighting factor is also 1. In general, the radiation weighting factor for photon and electron radiation has the value 1 and independently of the energy of radiation, but for neutron radiation, the value is energy-dependent as it's shown in table 2.1 (Martin *et al,* 2012). The values for the most commonly radiations are summarized in Table 2.1.

Table 2.1: Summary of values of weighting factor (ICRP, 2007)

Type of radiation	Weighting factor
X-rays and gamma rays	1
Electrons and muons, all energies	1
Neutrons, energy < 10 keV	5
Neutrons, energy: 10 keV–100 k	10
Neutrons, energy >100 keV–2 MeV	20
Neutrons, energy >2 MeV–20 MeV	10
Neutrons, energy >20 MeV	5
Protons, other than recoil, energy >2 MeV	5
Alpha particles	20
fission fragments, heavy nuclei	20

2.1.3 Effective Dose

The biological effect of the same type of radiation is different from one tissue (T) to another because each tissue has it's sensitivity to radiation. For example, the head is less sensitive than the chest. The effective dose is used to obtain an indication of how exposure can affect overall health. This is obtained by summing the equivalent doses to all tissues and organs of the body multiplied by a weighting factor W_T for each tissue or organ. This is written as follows (Martin *et al*, 2012):

$$E\ (Sv) = \sum_T (H_T \times W_T) \qquad (2.4)$$

Where E is the effective dose, and W_T is a factor which reflects the sensitivity of a particular tissue or organ. It's used only if there is non-uniform (partial) irradiation of a body. If the body has been subject to uniform irradiation, the effective dose equals the whole body equivalent dose, and only the radiation weighting factor W_R is used. But if there is partial body irradiation the calculation must take account of the individual organ doses received, because the sensitivity of each organ to irradiation depends on their tissue type. This summed dose from only those organs concerned gives the effective dose for the whole body. (Martin *et al*, 2012). Table 2.2 shows weighting factor values for human organs.

Table 2.2 Tissue weighting factor (ICRP, 2007)

Tissue or organ	W_T	$\sum_T W_T$
Gonads	0.20	0.20
Red marrow, colon, lung, stomach	0.12	0.48
Bladder, breast, liver, esophagus, thyroid, remainder	0.05	0.30
Skin, bone surface	0.01	0.02
Total		1

2.2 Flux Density

Radiation can be expressed as the number of particles or photons crossing an area of 1 cm^2 in 1 minute. This is called the flux. The flux at distance r is the number of particles per minute (Q) passing through an area of 1 cm^2. The particles are being emitted uniformly in all directions, so the flux at distance r is the number of particles emitted per minute divided by the area. This area is $4\pi r^2$ and so the flux is given by (Martin *et al*, 2012):

$$\Phi\ (\text{particle/min.cm}^2) = \frac{Q}{4\pi r^2} \qquad (2.5)$$

Where Φ is the flux density of particles and r is the radius of a given area.

The dose equivalent (H), which arises from beta particles can be determined from the flux density Φ (particle/s.cm^2) as shown in this equation (Johnson and Birky, 1998):

$$H\ (mSv/h) = 1.6 \times 10^{-3}\ \Phi \qquad (2.6)$$

Note that Φ in this equation is measure by this unit (particle/s.cm^2)

Chapter Three

Methodology

This chapter consists of five sections. Section one includes choosing the study sample, section two shows the study procedure, section three discusses timetable of the study, section four contains some information about experimental apparatus and section five discusses the statistical analysis.

3.1 Study Sample

This study was conducted on workers who were working in various landfills which are distributed in several locations in West Bank: Zahrat Al Finjan Landfill near Jenin city, Almenia Landfill near Hebron city, Al Bireh Landfill near Ramallah city, Al Serafi Landfill near Nablus city, Jayyous Landfill near Qalqilia city, Sanour Landfill near Jenin city, and Bit*fourik Landfill* near Nablus city.

On one hand, some of these landfills were closed and contained no workers because they were full of waste, so no health parameters measurements were conducted over it, like Sanour Landfill, Jayyous Landfill and Bitfourik Landfill. On the other hand, the other landfills were bigger and had more workers. But Zahrat Al Finjan is the biggest one in West Bank, so most of workers were chosen from it.

The number of workers in this study is 74, who were chosen randomly from these landfills and the ages are ranging between 18 and 55 years. The workers who work 8 hours per a day and they do not have health problems.

The workers were asked not to eat salty food and not to smoke during the interval of measurements, because these factors affect the health parameters. Ambient dose equivalent rate of gamma radiation and flux density of beta particles were measured in different sites in those landfills. Each landfill has been divided into zones, then equivalent dose rate and flux density of beta particles were calculated in each zone. After that the average value of each landfill was taken. The average values of gamma dose equivalent rate in all locations were ranged from 0.815mSv/y to 3.156 mSv/y, while the average values of beta particles flux density in all locations were found to vary from 0.08 $min^{-1}.cm^{-2}$ to 10.2 $min^{-1}.cm^{-2}$.

The number of workers who had been undergone the study in each landfill are given in Table 3.1.

Table 3.1: Number of sample according to landfill locations

L	Landfill	City	Number of sample
L1	Zahrat Al Finjan	Jenin	55
L2	Almenia	Hebron	9
L3	Al Bireh	Ramallah	6
L4	Al Serafi	Nablus	4
L5	Sanoor	Jenin	-
L6	Jayyous	Qalqilia	-
L7	Bit*fourik*	Nablus	-

3.2 Study Procedure

Study procedure of this study as follows:

1. Visiting each landfill during day light shift.
2. Measuring ambient dose equivalent rate of gamma radiation and beta particles flux density in each landfill location.

3. Choosing workers who work in these landfills and having good health records.
4. Measuring the following health parameters of the study population:

- Blood pressure (systolic and diastolic).
- Tympanic temperature.
- Blood oxygen saturation.
- Heart pulse rate.

3.3 Timetable of the Study

This study was conducted in June and October, 2015. The measurements of gamma and beta dose rates were conducted in each zone of the landfills, and the average value were taken. The measurements of blood pressure (systolic and diastolic), blood oxygen saturation, temperature and heart pulse rate were done twice; the first was before (b) exposing to ionizing radiation at 7:00 a.m, and the second was after (a) the exposure at 3:00 p.m. During each time interval the mentioned health parameters were measured two times, and the average value was recorded.

3.4 Experimental Apparatus

3.4.1 AT6130 Radiation Monitor

The Atomtex AT6130 Radiation Monitor is a compact device used to measure gamma and X-radiation ambient equivalent dose and ambient equivalent dose rate as well as for measurement of beta particle flux density. The instrument has a filter and its position gives specified functions and menu. If its position is changed, the radiation monitor switches automatically over the flux density measuring mode (when the filter is open) or the dose rate measuring mode (when the filter is closed). The measuring range for gamma and X-radiation ambient dose rate is from 0.01µSv/h to 10mSv/h. Whereas Beta radiation flux density measures the rang from 10 to 10^4 particle.min^{-1}.cm^{-2}. The intrinsic relative error of dose rate measurement is ± 20% and the operating temperature range is from -20 °C to +55 °C. Fig. 3.1 shows Atomtex AT6130 Radiation Monitor.

Fig. 3.1 Atomtex AT6130 Radiation Monitor

3.4.2 Pulse Oximeter

Pulse Oximeter (LM-800) is used to measure the blood oxygen saturation with accuracy ± 1%.Pulse Oximeter is shown in Fig 3.2.

Fig. 3.2 Pulse Oximeter

3.4.3 Micro Life Blood Pressure meter

Automatic Blood Pressure Monitor (Micro Life AG, Modno. BP 2BHO) is shown in Fig. 3.3. It's used for measuring arterial blood pressure (systolic, diastolic) and pulse rate. The measurement ranges from 30 to 280 mmHg, with an accuracy of ± 2%. The operating temperature ranges from +10 °C to +40 °C.

Fig. 3.3 Automatic Blood Pressure Monitor

3.4.4 TempScan Thermometer

The U.S.A technology thermometer GT-302 which is shown in Fig. 3.4 is used to measuring human body temperature through the tympanic temperature of the ear. The temperature range is from 32.0 ^{o}C to 42.9 ^{o}C with an accuracy of ± 0.01% .

Fig. 3.4 TempScan Thermometer

3.5 Statistical Analysis

Microsoft Excel and SPSS programs were used to analyze data. The measurements were analyzed statistically as the following: Pearson correlation coefficient (R) and the Probability (P) were used to measure the strength correlation between ionizing radiation exposure and the dependent variables which are blood oxygen saturation, tympanic temperature, heart pulse rate and blood pressure (systolic and diastolic), before and after exposure to this radiation.

P-value is a function of the observed sample results which measures the extreme of the observation. This means that it helps to determine the significance of the results. It ranges from 0 to 1 and values with $P < 0.05$ were considered statistically significant (William *et al*, 2007).

Person correlation coefficient is a statistical measure of the degree to which changes to the value of one variable predict change to the value of another. In positively correlated variables, the value increases or decreases in tandem. In negatively correlated variables, the value of one increases as the value of the other decreases.

Correlation coefficients are expressed as values between +1 and -1. A coefficient of +1 indicates a perfect positive correlation: A change in the value of one variable will predict a change in the same direction in the second variable. A coefficient of -1 indicates a perfect negative correlation: A change in the value of one variable predicts a change in the opposite direction in the second variable. A coefficient of zero indicates there is no discernible relationship between fluctuations of the variables. The strength of the correlation using the guide that Evans (1996) suggests for the absolute value of R as follows (Brown *et al*, 1998):

- $0.00 \leq R \leq 0.39$, weak correlation
- $0.40 \leq R \leq 0.59$, moderate correlation
- $0.60 \leq R \leq 0.79$, strong correlation
- $0.80 \leq R \leq 1.00$, very strong correlation

Chapter Four

Results

This chapter includes the results of this study. Measurements of gamma dose equivalent rate are shown in section 4.1. Measurements of beta particles flux density and beta dose equivalent rate are calculated and explained in section 4.2. Measurements of health parameters are discussed in section 4.3. Statistical analysis will be discussed in section 4.4.

4.1 Results of Gamma Dose Equivalent Rate

Gamma dose equivalent rate was measured in different locations of the seven landfills. Each landfill has been divided into zones, then gamma dose equivalent rate was measured in each zone. After that the average value for each landfill was taken. The results are shown in table 4.1.

Table 4.1 Average values of gamma dose equivalent rate

L	Landfill	Gamma dose equivalent rate (mSv/y)
L1	Zahrat Al Finjan	3.506
L2	Almenia	3.156
L3	Al Bireh	1.402
L4	Al Serafi	1.929
L5	Sanoor	0.815
L6	Jayyous	1.578
L7	Bit*fourik*	1.315

The average value of gamma dose equivalent rate for Sanoor Landfill is lower than the threshold value which is 1 mSv/y (ICRP, 1990). While for other landfills the average values are higher than 1 mSv/y. Fig. 4.1 shows the comparison between the measured values and the ICRP threshold value (the red line).

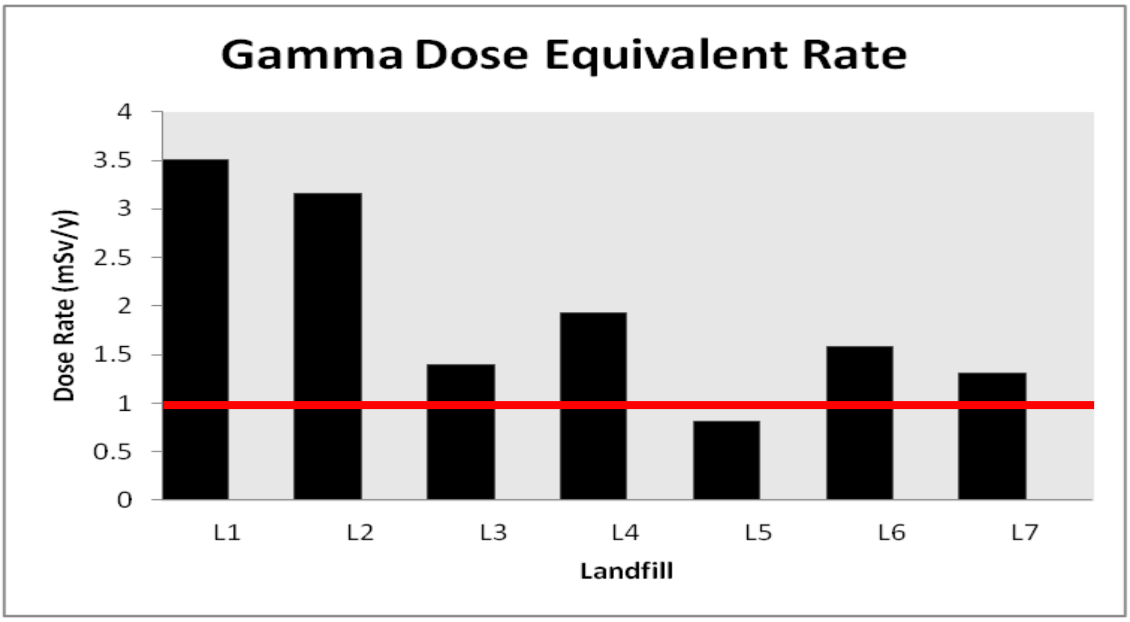

Fig. 4.1 Average values of gamma dose equivalent rate compared the ICRP threshold for seven landfills

4.2 Results of Beta Dose Equivalent Rate

Flux density of beta particles was measured in different sites in those landfills. Each landfill has been divided into zones, then the flux density of beta particles was calculated in each zone. After that the average value for each landfill was taken. The results of beta particles flux density for all landfills are shown in table 4.2.

Table 4.2 Average of beta particles flux density for seven landfills

L	Landfill	Beta flux density ($min^{-1}.cm^{-2}$)	Beta flux density ($s^{-1}.cm^{-2}$)
L1	Zahrat Al Finjan	4.990	0.083
L2	Almenia	0.730	0.012
L3	Al Bireh	0	0
L4	Al Serafi	10.20	0.17
L5	Sanoor	0.080	0.001
L6	Jayyous	0	0
L7	Bit*fourik*	4.410	0.074

The flux density of beta particles for L3 and L6 is zero. This means that there is no any source of beta particles in these two landfills.

On the other hand, Beta dose equivalent rate can be calculated from the flux density of beta particles as shown previously in equation 2.6:

$$H\ (mSv/h) = 1.6 \times 10^{-3}\ \Phi \qquad (2.6)$$

Where:

Φ: is the flux density of beta particles in (particle/cm^2.s) unit.

For example: The flux density of beta particles (Φ) at Al Serafi Landfill was found 0.17 (particle/s.cm^2).

So, $H\ (mSv/h) = 1.6 \times 10^{-4}\ \Phi = 1.6 \times 10^{-3} \times 0.17 = 2.72 \times 10^{-4}$.

$H = 2.72 \times 10^{-4}$ mSv/h $= 2.72 \times 10^{-4} \times 24 \times 365$ (mSv/y)

$= 2.384$ mSv/y.

The results for all landfills are shown in Table 4.3 and Fig. 4.2.

Table 4.3 Average values of beta dose equivalent rate

L	Landfill	Beta dose equivalent rate (mSv/y)
L1	Zahrat Al Finjan	1.166
L2	Almenia	0.171
L3	Al Bireh	0
L4	Al Serafi	2.384
L5	Sanoor	0.019
L6	Jayyous	0
L7	Bit*fourik*	1.031

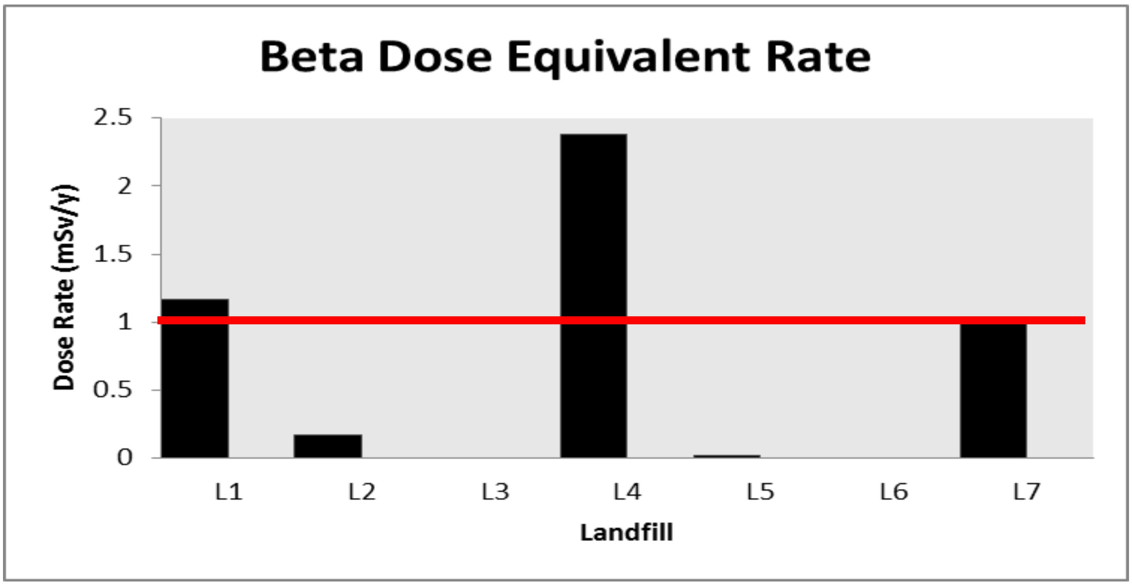

Fig. 4.2 Average values of beta dose equivalent rate compared the ICRP threshold for seven landfills

The average values of beta dose equivalent rate for L1, L4 and L7 are higher than the threshold value (the red line), while for other landfills the average values are lower than the threshold value which is 1 mSv/y (ICRP, 1990).

4.3 Health Effects of Ionizing Radiation Results

The health parameters which depend on ionizing radiation as blood oxygen saturation (SPO_2%), tympanic temperature (T), heart pulse rate (HPR), systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured in the landfills that contain workers. These landfills are Zahrat Al Finjan (L1), Almenia (L2), Al Bireh (L3) and Al Serafi (L4).

The measurements were done twice; the first was before (b) exposing to ionizing radiation at 7:00 a.m, and the second was after (a) the exposure at 3:00 p.m. During each time interval the mentioned health parameters were measured two times, and the average value was recorded.

The average values of the above health parameters for each landfill before (b) and after (a) exposure to ionizing radiation from radioactive waste are shown in Table 4.4.

Table 4.4: Average values of blood oxygen saturation, tympanic temperature, heart pulse rate and blood pressure levels (systolic and diastolic) before (b) and after (a) exposure to ionizing radiation

Landfill	SPO_2%		T ^{o}C		HPR beats/min		SBP mmHg		DBP mmHg	
	b	a	b	a	b	a	b	a	b	a
L1	98	98	34.4	34.7	83	87	124	127	78	80
L2	97	96	34.9	35.3	89	92	124	127	77	80
L3	97	96	34.3	34.6	77	82	125	127	78	80
L4	98	98	33.7	34.3	69	71	120	123	81	83

The normal values of blood oxygen saturation, tympanic temperature, heart pulse rate and blood pressure levels (systolic and diastolic) are shown in Table 4.5.

Table 4.5 Normal values of health parameters

Parameter	Normal value
SPO_2%	95 – 100[(a)]
T (^{o}C)	33.6-37.6[(b)]
HPR (beats/min)	60 - 100[(c)]
SBP (mmHg)	100 – 139[(d)]
DBP (mmHg)	60 – 90[(d)]

(a- Grap M, 1998; b- Elizabeth and Karen, 2002; c-Fuster *et al*, 2001; d- Chobnian *et al*, 2003).

4.3.1 Blood Oxygen Saturation (SPO_2%) Results

Average values of blood oxygen saturation for workers in four landfills before and after exposure to ionizing radiation are shown in Fig. 4.3.

Note that for each figure here, the green line represents the minimum permissible value while the red line represents the maximum permissible value.

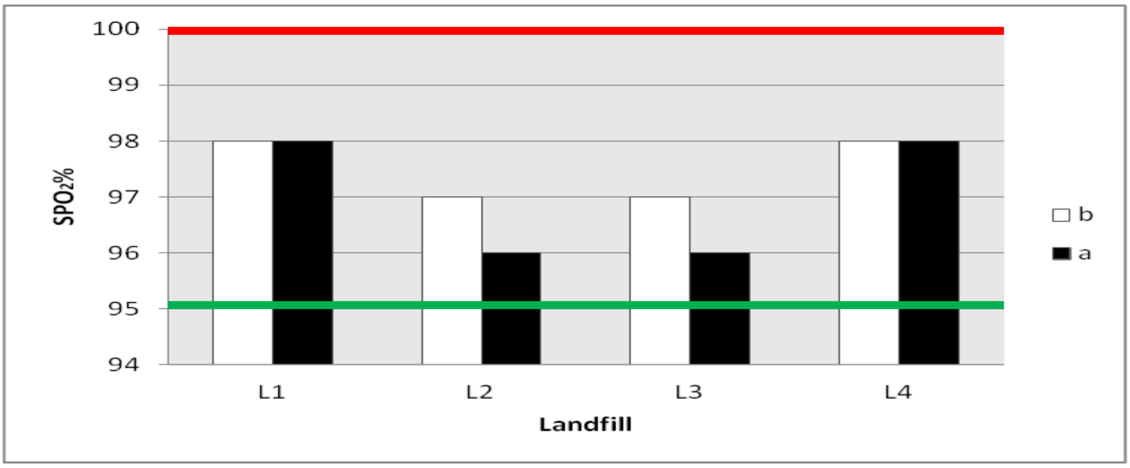

Fig. 4.3 Average values of blood oxygen saturation for workers in four landfills before and after exposure to ionizing radiation from radioactive waste

4.3.2 Tympanic Temperature Results

Average values of blood tympanic temperature for workers in four landfills before and after exposure to ionizing radiation are shown in Fig. 4.4.

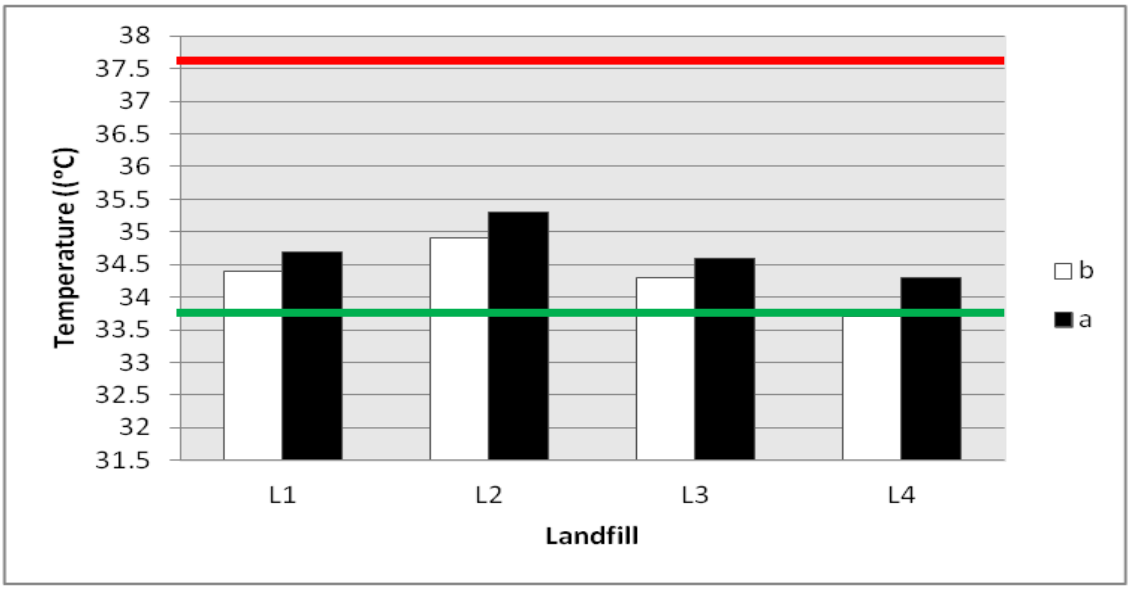

Fig. 4.4 Average values of tympanic temperature for workers of four landfills before and after exposure to ionizing radiation from radioactive waste

4.3.3 Heart Pulse Rate Results

Average values of heart pulse rate for workers in four landfills before and after exposure to ionizing radiation are shown in Fig. 4.5.

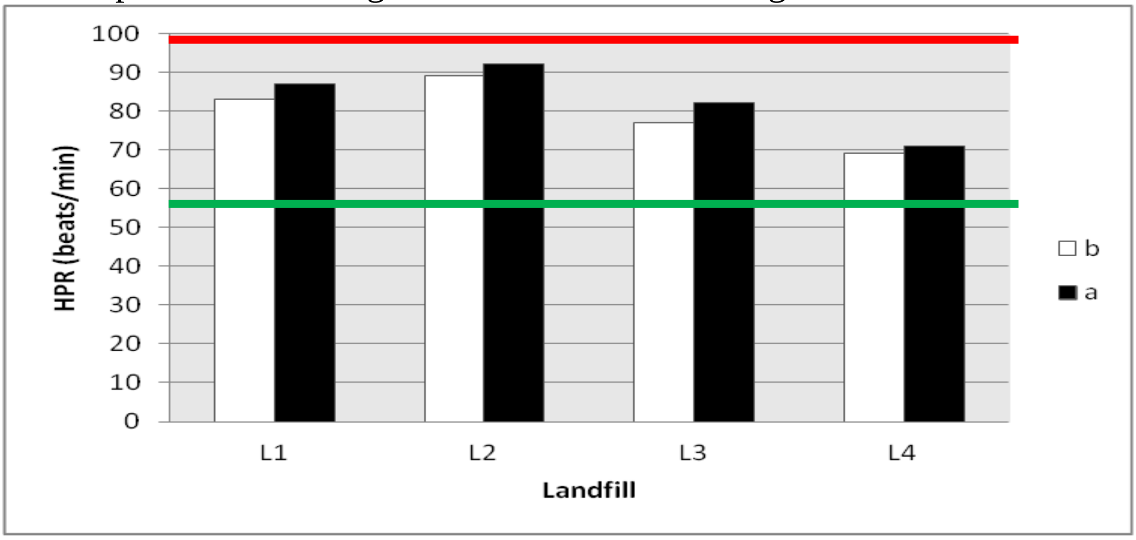

Fig. 4.5 Average values of heart pulse rate for workers in four landfills before and after exposure to ionizing radiation from radioactive waste

4.3.4 Blood Pressure Levels (Systolic and Diastolic) Results

Average values of blood pressure levels (systolic and diastolic)for workers in four landfills before and after exposure to ionizing radiation are shown in Fig. 4.6 and Fig. 4.7.

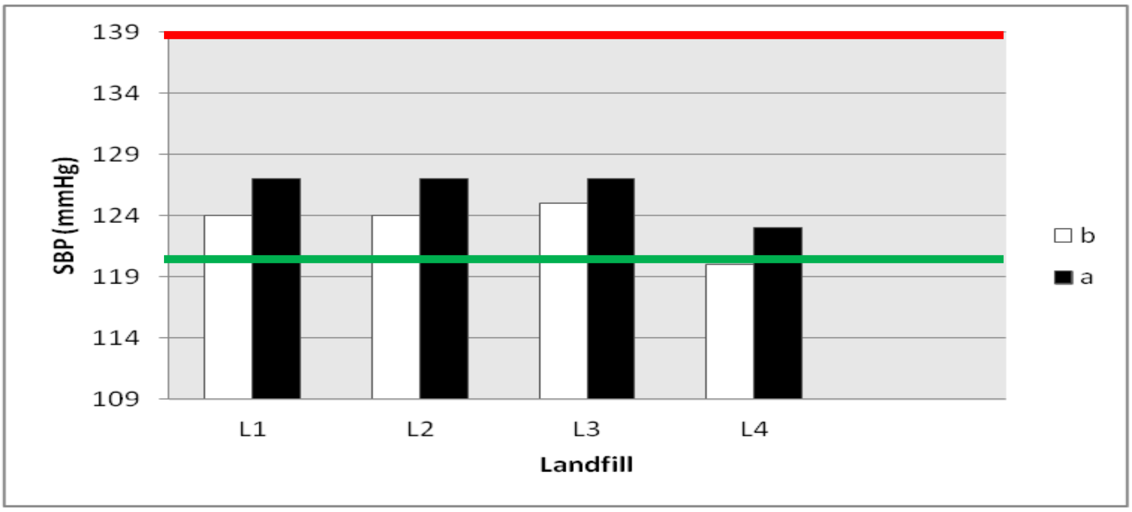

Fig. 4.6 Average values of systolic blood pressure for workers in four landfills before and after exposure to ionizing radiation from radioactive waste

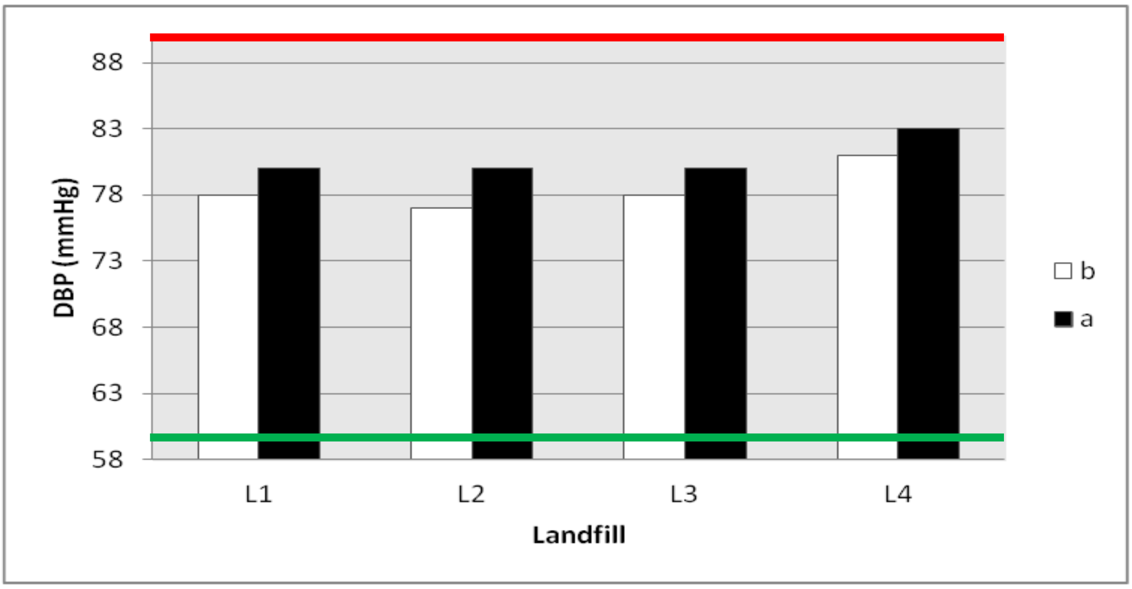

Fig. 4.7 Average values of diastolic blood pressure for workers in four landfills before and after exposure to ionizing radiation from radioactive waste

4.4 Statistical Analysis

Person correlation coefficient (R) and the probability (P) were used to measure the strength correlation between ionizing radiation exposure and the dependent variables, before and after exposure to this radiation.

Results of blood oxygen saturation, tympanic temperature, blood pressure (systolic and diastolic) and pulse rate showed that there is shifting of these measurements after exposure to ionizing radiation. It is found that there is a strong positive correlation (Pearson correlation coefficient) between radiation exposure, as independent variable and blood oxygen saturation, tympanic temperature, blood pressure (systolic and diastolic) and pulse rate as dependent variables. All of these relationships are presented in Table 4.6.

Table 4.6 Parried sample correlation of all studied variables before (b) and after (a) exposure to ionizing radiation for all selected workers in the four dumpsites

Paired Sample	Person Correlation Coefficient (R)	Probability (P)	Correlation
SPO_2%	0.384	0.141	Not significant
T (^oC)	0.922	0.000	Very strong
HPR (beats/min)	0.896	0.000	Very strong
SBP (mmHg)	0.895	0.029	Very strong
DBP (mmHg)	0.979	0.000	Very strong

Table 4.6 shows that there is positive correlation (R) between the independent variable (radiation exposure) and dependent variables (SPO_2%, T, HPR, SBP and DBP). This relation between the dependent and independent variables is significant except for the blood oxygen saturation value.

Chapter Five

Discussion

5.1 Gamma and Beta Dose Equivalent Rates

Gamma dose equivalent rate and beta particles flux density were measured in seven landfills in West Bank using AT6130 radiation monitor. Measured beta particles flux density were used to calculate the beta dose equivalent rate.

The average value of gamma dose equivalent rate is measured at 1m above radioactive waste in the seven landfills. The average value in Sanoor landfill was found below the standard value which is 1mSv/y. while it was found above the standard value in the other six landfills.

The average value of beta dose equivalent rate is calculated in the seven landfills. The average value in two of these landfills, Zahrat Al Finjan and Al Serafi, were found above the standard value which is 1 mSv/y. But for Bit*fourik* landfill, the average value was found approximately 1 mSv/y. While in the other landfills it was found below the standard value.

Wastes in West Bank are collected in sub-dumpsites, like Al-Serafi and Al-Bireh dumpsites. Then these wastes are sorted and transferred to one of the two main dumpsites in West Bank which are Zahrat Al Finjan in the north and Almenia in the south, so most of wastes in West Bank are existed in the main dumpsites.

These wastes include medical, artificial and chemical wastes which are considered as sources of ionizing radiations. For this reason, the value of gamma dose equivalent rate in these two dumpsites is higher than the other dumpsites.

Al Serafi dumpsite contains a zone of metallic and demolition waste which are considered as a source of ionizing radiation. So the value of beta dose equivalent rate for Al Serafi dumpsite is highest compared with the other landfills.

Sanoor, Jayyous and Bitfourik dumpsites were closed several years ago. Sanoor dumpsite is free from waste and no wastes are thrown there, so it's expected that this landfill is the most safety one, and this is exactly what we have got in the results, in which that the value of gamma dose equivalent rate in this dumpsite is the only value that is less than 1 mSv/y, and the value of beta dose equivalent rate is closed to zero. On the other hand, Jayyous and Bitfourik dumpsites are full of waste but no wastes are thrown there, so it's expected that the value of gamma dose equivalent rate in these two landfills are lower than the value in the main landfills and this is exactly what we have got in the results.

These results indicate that there is presence of radioactive nuclei with high concentrations in the soil of these dumpsites. These nuclei may cause several problems on human, plants and animals, so these wastes should be tested from any radiological regulatory control to reduce the risk of ionizing radiations.

5.2 The Effects of Ionizing Radiation on Blood Oxygen Saturation

Average values of blood oxygen saturation for workers were decreased after the workers exposing to ionizing radiation for L2 and L3.While for L1 and

L4 there were no changes. The Person correlation coefficient (R) is 0.384, which shows a weak correlation between radiation exposure and blood oxygen saturation also this relation is not significant since the P-value equal 0.141. The average values of blood oxygen saturation are within the normal range which is between 95% - 100% (Grap M, 1998).

5.3 The Effects of Ionizing Radiation on Blood Pressure Levels (Systolic and Diastolic)

The results of this study showed increasing in systolic blood pressure after exposing workers to ionizing radiation in four landfills, while the diastolic blood pressure was increased after exposing them to ionizing radiation that came from radioactive waste. The Person correlation coefficient (R) for systolic and diastolic blood pressure are 0.895 and 0.979 respectively, which shows very strong correlation between radiation exposure and blood pressure (systolic and diastolic) and these two relations are significant as P-value which is 0.029 for SBP and 0 for DBP. The average values of systolic and diastolic blood pressure for all workers is within the normal range which is 60 -90 mmHg for SPB and 100 -139 mmHg for DPB (Chobnian *et al*, 2003).

5.4 The Effects of Ionizing Radiation on Tympanic Temperature

Exposing the workers to ionizing radiation showed increasing in tympanic temperature for workers in all landfills. The strength of the results is good as can be understood from Person correlation coefficient (R) and the Probability (P). The Pearson correlation R = 0.922 and the probability is zero. The average values of tympanic temperature are within the allowed values which is 33.6 – 37.6 (Elizabeth and Karen, 2002).

5.5 The Effects of Ionizing Radiation on Heart Pulse Rate

The results of heart pulse rate for the tested workers are increase after exposure to ionizing radiation. The Pearson correlation R = 0.896 and the probability is zero. This means that there is very strong correlation between radiation exposure and heart pulse rate. Despite the increase in HPR after exposure to ionizing radiation, it remains within the standard values which is 60-100 beat/min (Fuster *et al*, 2001).

Chapter Six

Recommendation

There are some recommendations that can be made to reduce the effect of ionizing radiation on workers:

1- Explaining the risk of exposing to ionizing radiation to the landfill workers.
2- The waste should be buried in more deep areas.
3- Measuring the gamma dose rate and beta flux density periodically and making sure that it's not increasing with time.
4- Measuring the health parameters periodically to make sure that the workers' health is normal.
5- Workers should wear Anti-Radiation clothes to decrease the absorption of radiation.

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قدمت هذه الأطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في الفيزياء بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس – فلسطين

2016

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الملخص

ألقت هذه الدراسة الضوء على تأثير الإشعاع الكهرومغناطيسي المؤين الناتج من المخلفات الموجودة في مكبات النفايات على العمال اللذين يتعرضون لهذه الأشعة خلال عملهم في بعض مكبات النفايات في الضفة الغربية. شملت عينة الدراسة 74 عاملا تراوحت أعمارهم بين 18-55 سنة. أخذت قياسات معدل نبضات القلب ونسبة الأكسجين في الدم ودرجة حرارة الجسم عن طريق الأذن وضغط الدم الانبساطي والانقباضي مرتين: الأولى قبل بدء الدوام الساعة 7:00 صباحاً والثانية بعد انتهاء الدوام الساعة 3:00 مساءً. أجريت هذه الدراسة خلال شهري حزيران وأكتوبر 2015. ركزت الدراسة على سبعة مكبات للنفايات شملت مكب زهرة الفنجان ومكب المنيا ومكب الصيرفي ومكب بيت فوريك ومكب صانور ومكب جيوس ومكب البيرة. تم قياس معدل جرعة جاما الفعالة في هذه المكبات وتراوحت قيمتها بين 0.815 ميلي سيفرت/سنة الى 3.506 ميلي سيفرت/سنة، حيث كانت أعلى من المعدل المسموح به في معظم هذه المكبات. أما جرعة بيتا الفعالة تراوحت بين 0.019 ميلي سيفرت/سنة الى 2.384 ميلي سيفرت/سنة حيث كانت أعلى من المعدل المسموح به في ثلاث مكبات. ومن خلال استخدام قياس العوامل الصحية لكشف التأثير الصحي على العمال، تبين أن هنالك تغيراً ملحوظاً في المتغيرات المقاسة إلا أنها بقيت ضمن الحد الطبيعي المسموح به للإنسان.