Islamic University - Gaza
Deanship of Graduate Studies
Faculty of Engineering
Water Resources Management

الجامعة الإسلامية – غزة
عمادة الدراسات العليـــا
كلية الهندســــــــــــــة
قسم ادارة مصادر الميـاه

INVESTIGATION OF RADON POLLUTION IN GROUNDWATER IN THE SOUTHERN PART OF GAZA STRIP - PALESTINE

التحقق من تلوث المياه الجوفية بالرادون في منطقة جنوب قطاع غزة ـ فلسطين

By

Samir Mohamed Ali Ibrahim Hararah

Supervised By

Dr. Zeyad Abu Heen
Environmental & Earth Sciences Dept.

Dr. Samir Yassin
Physics Dept.

A Thesis Submitted in Partial Fulfillment of the Requirement for the Degree of Master of Science in Water Resources Management
The Islamic University – Gaza - Palestine

2007- 1428

بسم الله الرحمن الرحيم

﴿ يرفع الله الذين آمنوا منكم والذين أوتوا العلم درجات والله بما تعملون خبير﴾

سورة المجادلة آية (١١)

DEDICATION

TO

MY PARENTS

MY BROTHERS

MY FAMILY

MY WIFE

MY SONS

MY daughters

MY FRIENDS

الإهداء

إلى الأرض التي بارك الله فيها ، وحولها ....
أرض الإسراء والمعراج ... أرض الكرامة والبطولات
إلى الشهداء الأكرم منا جميعا في هذا الوطن الغالي......
إلى أول كلمتين عرفهما لساني ..... إلى من أوصاني الله بهما خيرا........
إلى المرحوم والدي ....
إلى والدتي الحنون حفظها الله وأبقاها الله ذخرا....
إلى الحريصة والصبورة ..... إلى الأمينة والغيورة....
والى من أعطت مثالا رائعا بوفائها وعطائها لزوجها وأولادها ...... زوجتي الغالية
إلى من رأيت فيهم البراءة بأصدق معانيها ......
إلى من حبهم يجري في دمي ......
إلى أبنائي وبناتي الأحباء..........

ACKNOWLEDGEMENT

It gives me pleasure to express my thanks to all those who have assisted me in the preparation of this study. My sincere gratitude goes to my supervisors, Dr. Zeyad Abu Heen, Head of Environmental and Earth Sciences Department and Dr. Samir Yassin, for useful discussions, kind help and guidance throughout this work. Special thanks and appreciation to staff members of Environmental and Earth Sciences, Chemistry and physics departments for their great advice, kind help and endless support. I would also like to express my gratitude to my Wife for the tolerance shown and her patience that kept me stable and productive during the years of studying and writing this thesis.

Thanks are due to Prof. Mohamed Ashour for his cooperation and continuous support. In addition thanks go to all my colleagues in Palestinian water Authority.

ABSTRACT

The major objective of this research is to determine the Radon concentration in groundwater in the southern region of Gaza Strip.

In this study, Groundwater samples were collected from twenty five wells and Radon concentrations were measured as part of a water-quality. These samples were taken from the municipal wells in the southern region of Gaza Strip (Rafah and Khanyonis). The samples were collected from different location covering most of the region that represent the southern part of Gaza Strip. Twelve wells from Rafah Governorate and thirteen wells from Khanyonis Governorate were taken and all these wells were used for domestic water**.** Each sample was duplicated to determine Radon concentration.

CR-39 solid state nuclear track detectors of good quality were used in this survey. Two Detectors were placed inside each water sample. One CR- 39 detector is immersed in the water and the other is in the lid of the container facing the water sample. The detectors were left for a period of time of 120 days (for a period during mid of April to mid of August) to allow Radon gas to come to an equilibrium level. One hundred detectors were exposed to twenty five samples which in concern. The detectors were then collected and chemically etched. Each detector was counted visually using an Optical microscope with a power of (40 x 10), and number of tracks determined.

Results obtained show that the Radon levels in Rafah area ranges of values between 58 and 154 Bq/m^3 with average value of 102.4 Bq/m^3. Also, the average standard deviation (S.D) is 32.7 and in Khanyonis area ranges of values between 22 and 132 Bq/m^3 with average value of 47.8 Bq/m^3, also, the average standard deviation of 31.9. We believe that this variation of levels is mainly due to the difference in rock type, soil type and the geology of the area. Certainly, this study was conducted to provide us with measurements and concentration of Radon. This information can be used to estimate the possible health hazards from Radon in the southern region of Gaza Strip in the future from environmental point view. This data would promote public awareness related to risk of Radon exposure in Gaza Strip.

الخلاصة

لقد تم في هذه الأطروحة التحقق من تلوث المياه الجوفية بالمنطقة الجنوبية لقطاع غزة بغاز الرادون كجزء من دراسة جودة المياه.

لقياس تركيز غاز الرادون في منطقة الدراسة، قمنا باستخدام كواشف الأثر النووي والمعروفة تجاريا بالاسم (CR-39)حيث تم وضعها في عينات المياه الجوفية التي تم إحضارها من آبار بلديات منطقة الدراسة وعددها ٢٥ عينة (12عينة من محافظة رفح و 13 عينة من محافظة خان يونس) بداخل مرطبانات بلاستيكية، وسعة كل مرطبان واحد لتر. ثم اخذنا من كل بئر مياه عينتين ووضع عدد ٢ كاشف أثر نووي في كل عينة مياه (واحد في قاع المرطبان مغموس في الماء والثاني على غطاء المرطبان مواجها للماء)، وتم إغلاق المرطبان إغلاقا محكما، وتركت جميع العينات وبداخلها الكواشف لمدة ١٢٠ يوما، من منتصف ابريل حتى منتصف أغسطس. وبعد ذلك تم معالجة الكواشف كيميائيا، ثم قمنا بعد المسارات المتولدة والموجودة في وحدة المساحة ($1cm^2$) بالإستعانة بمجهر ضوئي قوتة التكبيرية (10x40) عبر 10 مناطق واضحة على الكاشف. وقد وجد أن تركيز غاز الرادون في منطقة الجنوب (مدينة رفح) تتراوح بين $58 – 154\ Bq/m^3$ ، بمتوسط $102.4Bq/m^3$ وبانحراف معياري 32.7 ، وفي مدينة خانيونس يتراوح التركيز بين $22\text{-}132\ Bq/m^3$ بمتوسط $47.9Bq/m^3$ وبانحراف معياري 31.9 . فمن خلال النتائج وجدنا أن تركيز الرادون بمدينة رفح أعلى من مدينة خانيونس وذلك للاختلاف في نوع الصخر ونوع التربة في المنطقة. وكذلك تم معرفة العلاقة بين تركيز الرادون وعمق أبار المياه الجوفية لمنطقة الدراسة.

بكل تأكيد فإن هذه الدراسة قد اجريت لتزويدنا بقياسات واستقراءات عن تركيز غاز الرادون. هذه المعلومات ممكن استخدامها لتقدير الآثار والأضرارالصحية المترتبة عن ذلك في المستقبل، وخصوصا من وجهة النظر البيئية.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

Coastal Aquifer Management Program	CAMP
Cubic meters per hour	m^3/hr
Mean Sea Level	MSL
Milligram per liter	Mg/l
Millimeter	mm
Million Cubic Meter per year	Mm^3/ y
Ministry of Agriculture	MOA
Ministry of Health	MOH
Ministry of Planning	MOP
North North East	NNE
Palestinian Central Bureau of Statistics	PCBS
Palestinian Water Authority	PWA
South South West	SSW
Total Dissolved Solids	TDS
United States Environmental Protection Agency	US EPA
World Health Organization	WHO
Standard Deviation	SD
Becquerel	Bq
Becquerel per cubic meter	Bq/m^3
Curie	Ci
Picocurie per liter	pCi/l

International Commission on Radiological Protection	ICRP
Maximum Contaminant Level	MCL
National Council on Radiation Protection	NCRP
Radon-222	^{222}Rn
Uranium	^{238}U
Radium	^{226}Ra

CHAPTER (1)

INTRODUCTION

1.1 General

On global scale, groundwater has been gaining increasing attention as essential and vital water resource. Its demand has been rising rapidly in the last several decades with the overpopulation and enhanced standards of living. It is the only source of freshwater for many communities owing to its relatively low susceptibility to pollution in comparison to surface water, and its relatively large storage capacity. Both groundwater and surface water may contain many constituents, including microorganisms, gases, radioactive particles, inorganic and organic materials. Scientists assess water quality by measuring the amounts of the various constituents contained in the water. [1].

Several environmental problems are seriously threating Gaza Strip. Deterioration of groundwater quality is considered one of the main problems that exert huge pressure on our economics and need for urgent response because it is not received serious investigation. Exposures to radioactive materials are one of these water quality problems that were not investigated widely and will be under focusing in this study.

1.2 Problem Identification

- Several environmental problems are seriously threating the Gaza Strip, one of these problems is groundwater quality.
- The groundwater is the main type for our study to investigate Radon pollution in the water supply for rafah and khanyonis municipalities as a part of the groundwater quality.
- All the previous studies were concerned on the groundwater quality in Gaza Strip include chemical, physical and microbiological analysis, but not include natural radiation analysis. No real researches have been done in this field. So there is a need to investigate the natural radiation (Radon) in groundwater in Gaza Strip.

1.3 Aim of study

The main objectives of the study is as follows:

To investigate natural radiation pollution in groundwater of the southern part of Gaza Strip, depending on measurements of Radon concentration in selected wells in the area.

1.4 Thesis outline

This study will be consisting of six chapters:

- **Chapter One (Introduction):** General introduction follows by problem identification, aim of study, and finally thesis outline.
- **Chapter Two (Background and literature Review):** Chapter two covers a general introduction about background and literature review on the water types, groundwater contaminants, background on radiation and Radon information in groundwater as well as previous study about Radon in different countries **inside** and outside our region and Guideline values (action levels) of Radon vary among countries.
- **Chapter Three (Area of Study):** this chapter includes an introduction follows by Geography, Geomorphology, Demography, Geology, Groundwater and Environmental situation in Gaza Strip**,** in addition to climate, Rainfall, Hydrology, Hydrogeology, and groundwater balance of Gaza Strip.
- **Chapter Four (Methodology and Techniques):** It discuses the methodology and experimental techniques that include description of water samples sources, sampling location, sampling collection, different types of measurements techniques and calibration technique measurement of Radon concentration.
- **Chapter Five (Result and Discussion):** In this chapter the calculations were be done to get the results for Radon concentration. Microsoft Excel program was used to make some graphs which used for data analysis and discussion. Surfer program was also used for drawing maps.
- **Chapter Six (Conclusions and Recommendations):** This chapter includes the most significant conclusions and recommendations. Glossary, appendices and references are also included at the end of this thesis.

CHAPTER (2)

BACKGROUND AND LITERATURE REVIEW

2.1 Introduction

Groundwater is the main source of water in Gaza Strip most of resident receive drinking water services and supplied by municipal wells after disinfecting water with chlorine. The groundwater is used for domestic, agriculture, and industrial purposes. Extensive pumping has caused serious quantitative and qualitative problems in the aquifer [35].

As a consequence of continuous growth in environmental pollution that is steady increasing in the Gaza Strip, there is a need to investigate the presence of natural radiation in groundwater in Gaza Strip. This may be due to some radioactive minerals that derived from the source rock along the coast of Gaza Strip, where the greatest portion of the radiation exposure comes from naturally occurring radiation sources such as Radon. Therefore, radioactive pollution monitoring system in groundwater should be investigated, because there is no clear cut research has been done in the past.

Despite the usual safety measures in and around the reactors that exist in the adjacent countries of Gaza Strip, there is always a danger of radiation leakage. We believe that a nuclear wastes stored in Israel may have some effect on the environment in Gaza Strip, which raise the water pollution. Therefore, the study of radiation pollution in groundwater is seriously recommended.

Most of studies carried out on the quantitative and qualitative in the water resources in Gaza Strip. However, less attention has given to determine the radionuclide in water. Radon in water is responsible for the whole body internal radiation dose that may be more harmful than Radon in air. Thus, determination of Radon in groundwater has also been of major interest because of its harmful health, which causes lung cancer.

2.2 Water types

There are different types of water on the earth; surface water, groundwater, these types can be used for domestic, agriculture, and industrial purposes. Groundwater is the most important component of the fresh water resources of the world. It is located beneath the ground surface in soil pore spaces and in the fractures of geologic formations. A formation of rock or soil is called an quiafer when it can yield a useable quantity of water. An aquifer is a subterranean geologic unit (or layer) of permeable material (like sand and gravel) that is capable of providing usable quantities of water to a well [1]. Aquifers can be confined or unconfined. A confined aquifer has a low permeability confining layer (an aquitard), such as clay, above it that restricts the upward and downward movement of water.

The quality of groundwater depends on different characteristics: physical, chemical and biological properties. Changes of these properties make the water quality not acceptable. The changes in these characteristics cause pollution in the water, which lead to bad health. Drinking water should be suitable for human consumption and for all usual domestic purposes.

In general groundwater quality depends on a number of factors such as nature of the rain water, nature of the existing groundwater which may be tens of thousands of years old, nature of the soil through which water must percolate and nature of the rock comprising the aquifer [1].

2.3 Groundwater pollution

Groundwater pollution problem is a complex phenomenon results from natural and/ or anthropogenic factors. It has negative impact not only on our health but also on society and the economy and the overall quality of the life. This problem is clear mainly in the coastal areas which considered as the most density populated areas in the world [2].

In many coastal regions in the world, severe deterioration of the quality of groundwater resources has been occurred as a result of overexploitation of the groundwater where good quality groundwater is available. Coastal areas and especially the southern part of the Mediterranean region, faces many causes of unacceptable groundwater quality that related mainly to human activities [3].

Drinking water comes from ground water, which was supplied through public drinking water systems. But many families rely on private, household wells and use groundwater as their source of fresh water. The quality of drinking water is affected by the depth of groundwater from the surface, because there is a chance of being polluted varies from place to place. Human activities can alter the natural composition of groundwater causing undesirable change in groundwater quality in the form of contamination or pollution. Groundwater may contain some natural impurities or contaminants, even with no human activity or pollution. Natural contaminants can come from many conditions in the watershed or in the ground. Water moving through underground rocks and soils may pick up magnesium, calcium and chlorides [3]. Some ground water naturally contains dissolved elements such as arsenic, boron, selenium, or Radon, a gas formed by the natural breakdown of radioactive uranium in soil. Whether these natural contaminants are health problems depends on the amount of the substance present. The elements that produce radiation are called radioactive. Radon itself is radioactive because it also decays, losing an alpha particle and forming the element polonium.

Some people who are exposed to Radon in drinking water may have increased risk of getting cancer over the course of their lifetime, especially lung cancer[6]. Radon accumulates in groundwater due to two different sources, firstly the radioactive decay of dissolved radium (Radon’s immediate parent in the uranium decay chain), and secondly the direct release of Radon from the mineral matrix from minerals (in surrounding rocks) containing members of the uranium decay chain [4].

The relationship between drinking water and indoor Radon concentration is an important problem for environmental radiology and one that is perhaps underestimated. During domestic water use, as the water is heated and the Radon becomes less soluble, Radon from water is degassed into the indoor air[9]. It has been determined that inhalation of the Radon dissolved in and released from water for human consumption [6]**.**

2.4 Sources of Radiation

Radiation is in every part of our life; it is naturally present in our environment and has been since the birth of this planet. Consequently, life has evolved in an environment which has significant levels of ionizing radiation. Radiation comes from outer space (cosmic), the ground (terrestrial), and even from within our own bodies[5]. It presents in the air we breathe, the food we eat, the water we drink, and in the construction materials used to build our homes.

Alpha particle radiation is the major source of natural radiation in our environment. It is derived from radioactive decay of colorless, inert gas, Radon (^{222}Rn) and leading cause to cancer in the most world [5].

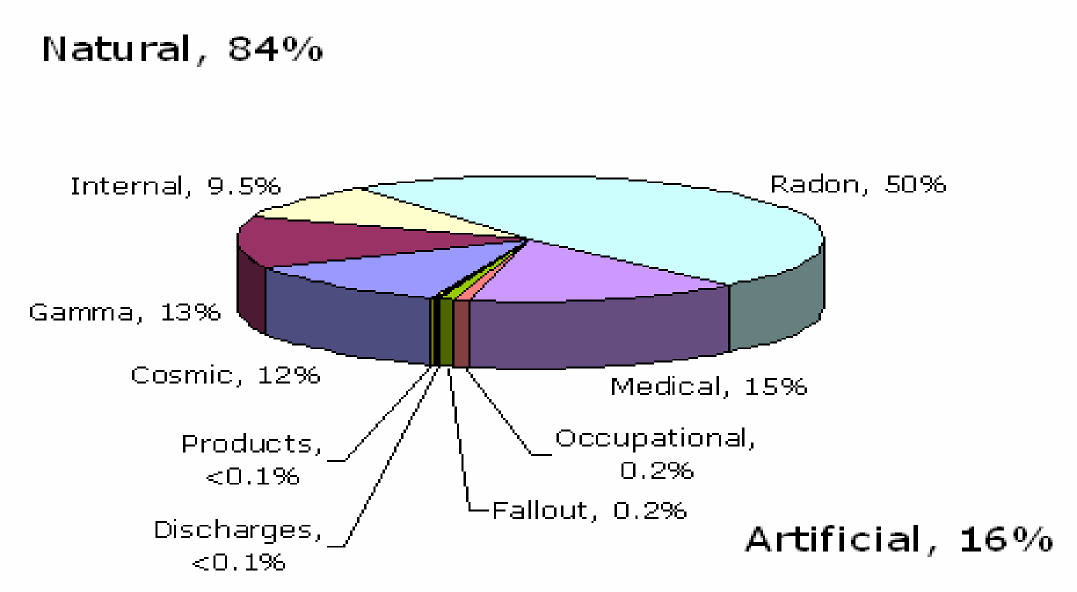


Figure 2.1: Sources and average distribution of natural background radiation for the world population [6]

Figure (2.1) shows that more than eighty percent (84%) of human exposure comes from natural sources: Radon gas, the human body, outer space, rocks and soil. The remaining percent (16%) comes from man-made radiation sources, primarily medical X-rays. Man made radiation is more harmful because it is more concentrated. Natural radiation is more spread out, and less concentrated, and is therefore less harmful [6].The largest fraction of natural radiation exposure comes from Radon, a radioactive gas, due to decay of radium contained in rocks and soil as part of the uranium radionuclide chain. The most abundant sources of natural background radiation are ^{238}U of life time T1/2 = 4.5 billion years, and Thorium ^{232}Th of half life time t =14 billion years in sediment rock. Both of these elements decay to Radon gas but Thorium decays to ^{220}Rn called Thoron which has half life time of only 55 second, whereas Uranium decays to ^{222}Rn called Radon which has half life time of 3.8 days. Because Radon is a gas, it can enter buildings through openings or cracks in the foundation. The Radon gas itself decays into radioactive solids, called Radon daughters. The Radon daughters attach to dust particles in the air, and can be inhaled. The inhalation of Radon daughters has been linked to lung cancer. There are three naturally occurring isotopes of Radon each associated with a different radioactive decay series. One of these is ^{222}Radon ($t_{1/2}$ = 3.82 days) which is part of ^{238}U-(uranium) series. See table (2.1) and Figure (2.2), (2.3)

Table 2.1: Uranium Series and Radon decay products [5]

THE URANIUM DISINTIGRATION SERIES		
ELEMENT	**RADIATION***	**HALF LIFE**
Uranium 238	Alpha	4,500,000,000 years
Thorium 234	Beta	24.1 days
Protactinium 234	Beta	1.17 minutes
Uranium 234	Alpha	247,000 years
Thorium 230	Alpha	80,000 years
Radium 226	Alpha	1602 years
Radon 222	Alpha	3.82 days
Polonium 218	Alpha	3.05 minutes
Lead 214	Beta	27 minutes
Bismuth 214	Beta	19.7 minutes
Polonium 214	Alpha	0.00001 seconds
Lead 210	Beta	19.4 years
Bismuth 210	Beta	5.01 days
Polonium 210	Alpha	138.4 days
Lead 206	None	Stable
*alpha radiation = helium nucleus beta radiation = electron		

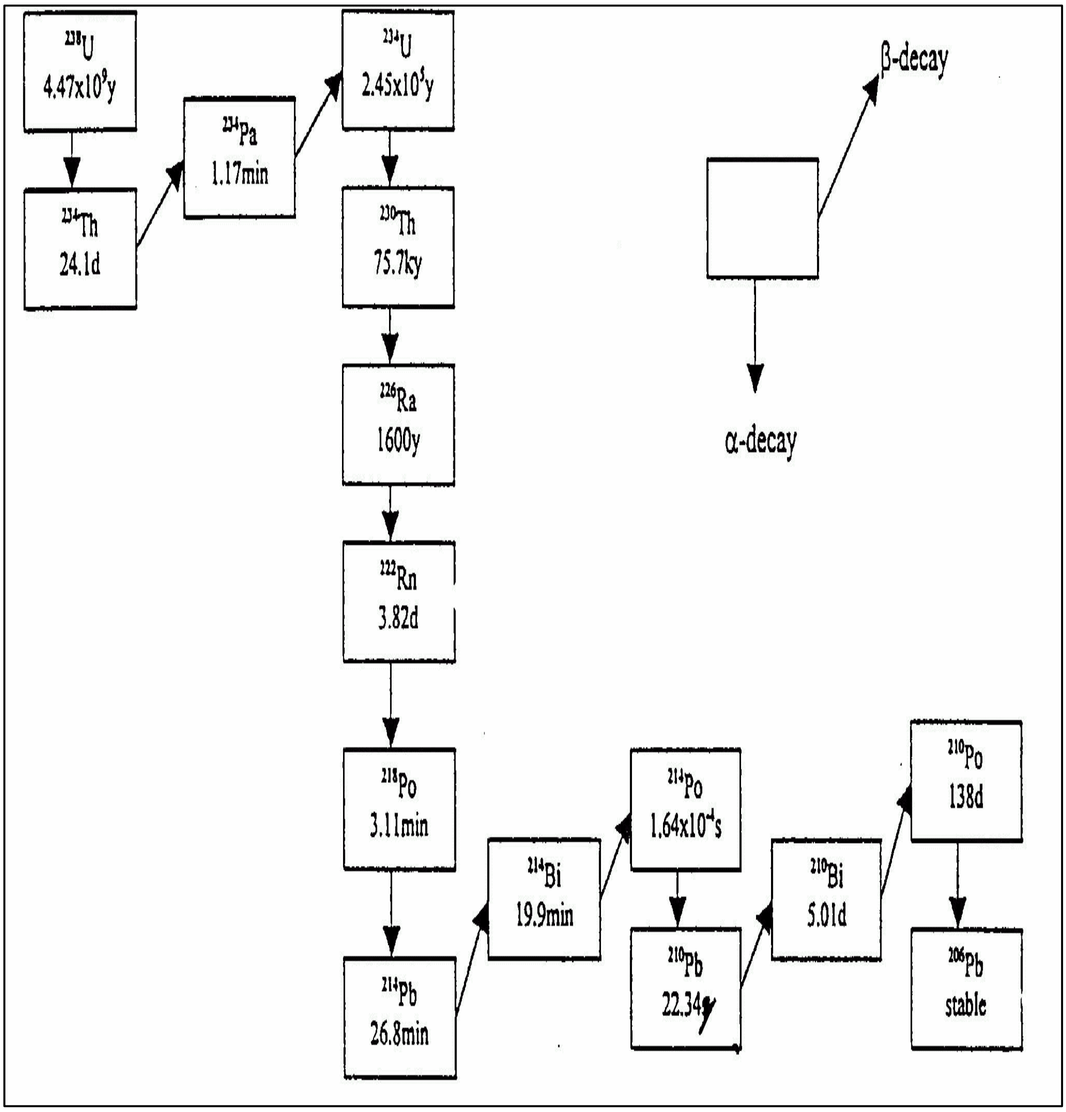


Figure 2.2: Decay series of 238U

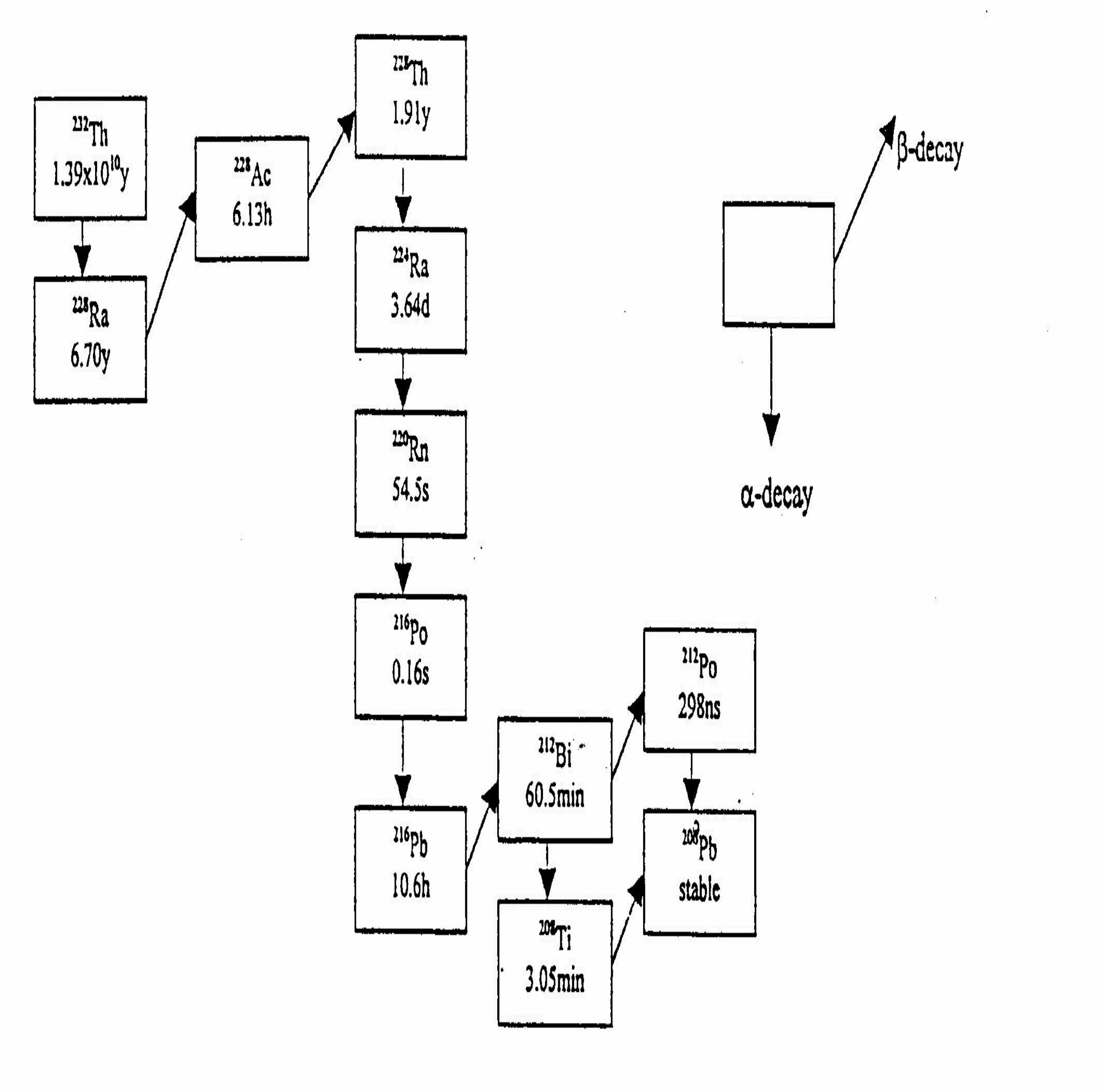


Figure 2.3: Decay series of 232 U Th [7]

The uranium content of sandstone and shale is commonly related to the uranium content of the sediments from which they formed. Radon concentrations in ground water from sandstone and shale can therefore be highly variable if these sediments were derived from different sources [4]. It can accumulate up to dangerous concentrations and may cause substantial health damage after long-term exposure. Radon can also be found in drinking water and this can sometimes present a hazard. This may be due to some radioactive minerals that derived from the source rocks along the coast of Gaza Strip. The aim of the present study is to investigate Radon pollution in groundwater in the southern part of Gaza Strip.

The study area has been selected because it is very close to the Naqab area (South of Palestine) where Israel Nuclear reactor is present. If there any relation between Radon contamination and the Israel Nuclear reactor is present, it could be studied.

2.5 Information about Radon

Radon is a natural radioactive gas discovered in the 1900s by Dorn, who called it radium emanation. Since 1923, it has been called Radon. The atomic number of Radon is 86, and the atomic weight is 222. Radon is a naturally occurring, colorless, odorless gas that is soluble in water. It is radioactive, which means that it breaks down - or "decays" - to form other elements. Radon occurs as a product of uranium decay. Uranium is a natural radioactive material found in varying amounts in all rocks, soil, concrete and bricks. It occurs everywhere on earth, especially in rocky and mountainous areas. Radon occurs as three natural isotopes (see Table 1.2), derived from three different radioactive decay chains, commencing with ^{238}U, ^{232}Th and ^{235}U. ^{222}Rn is that most commonly discussed in this research. Radon-220 ($t_{1/2}$ = 56 sec.) called a part of thorium (^{232}Th) series, also known as thoron in non-porous material is comparable to the activity of Radon-222, the much shorter half-life time of thoron causes its concentration in air to be relatively low and therefore usually of second interest. The third isotopes is Radon-219 ($t_{1/2}$ = 3.92 sec) called actinon in reference to its presence in actinium (^{235}U) decay chain. This nuclide does not contribute to the low natural abundance of (^{235}U) and the very short half-life time of ^{219}Rn as shown in the following table [9].

Table 2.2: Half - life's of the three natural isotopes of Radon

Isotope	Common Name	Half Life	Decay Chain Commencing with
^{222}Rn	Radon	3.8 days	^{238} U
^{220}Rn	Thoron	54.5 seconds	^{235}Th
^{219}Rn	Actinon	3.92 seconds	^{232} U

Radon is an unstable radionuclide that disintegrates through short lived decay products before eventually reaching the end product of stable lead. The short lived decay products of Radon are responsible for most of the hazard by inhalation. The rate of Radon's radioactive decay is defined by its half-life, which is the time required for one half of any amount of the element to break down. The half-life of ^{222}Rn is 3.8 days. A common unit of radioactivity measurement is picocuries per liter [8].

Underground rocks containing natural uranium continuously releases Radon into water in contact with it (groundwater). Radon is readily released from surface water; consequently, groundwater has potentially much higher concentrations of Radon than surface water**.** Radon moves from its source in rocks and soils through voids and fractures. It can enter buildings as a gas through foundation cracks or dissolve in the ground water and be carried to water-supply wells. The amount of Radon in air or water commonly is reported in terms of activity with units of picocuries per liter of air or water. An activity of 1 pCi/L (picocuries per liter) is about equal to the decay of two atoms of Radon per minute in each liter of air or water [4]. This study will refer to Becquerel per m^3 as the Radon concentration (one pCi/l = 37Bq/m^3).

1 Becquerel (1 Bq) = 1 disintegration of atom per second.

While Radon easily dissolves into water, it also easily escapes from water when exposed to the atmosphere, especially if it is stirred or agitated. Consequently, Radon concentrations are very low in rivers and lakes, but could still be high in water pumped from the ground. Some natural springs, contain Radon, and were once considered healthful. Radon that decays in water leaves only solid decay products which will remain in the water as they decay to stable lead. Radon is also found in the water in homes, in particular, homes that have their own well rather than municipal water. Radon can move through cracks in rocks and through pore spaces in soils [6]. Radon moves more rapidly through permeable soils, such as coarse sand and gravel, than through impermeable soils, such as clays [9]. Sand dunes along the coast of the Gaza Strip may well contain elevated concentrations of some of the radioactive minerals, like uranium and thorium, which are derived from the granite sources rocks present around the area.

2.6 Different Sources of Radon

2.6.1 Sources of Radon in Groundwater

It might be supposed that Radon in groundwater could be derived from two different sources [18]:

☻ Radioactive decay of dissolved radium (the immediate precursor to adon in the decay chain).

☻ Direct release of Radon from the mineral matrix from minerals containing members of the uranium/thorium decay series. For these reasons, only the measurement methodology for Radon-222 will be discussed below. Once Radon is formed in radium-bearing material, some of it leaves the grains to the pore space. This fraction is relatively free to move between the pores and its transport is possible as shown below in the figure (1.4). Radon can therefore reach the air or water to which humans have access, provided that transport is sufficiently rapid to be completed before the Radon decays [10].

2.6.2 Soil as a Radon source

The major source of Radon in the atmosphere at least 80% is from emanations from soil that derived from rocks. These rocks contain some uranium, where the decay of ^{238}U through ^{226}Ra gives Radon. Certain types of rock, including granites, dark shale, light-colored volcanic rocks, sedimentary rocks containing phosphate and metamorphic rocks derived from these rocks have higher average uranium contents [13]. Because Radon is a gas, it has much greater mobility than uranium and radium, which are fixed in the solid matter in rocks and soils. Radon can more easily leave the rocks and soils by escaping into fractures and openings in rocks and into the pore spaces between grains of soil as shown in figure2.4.

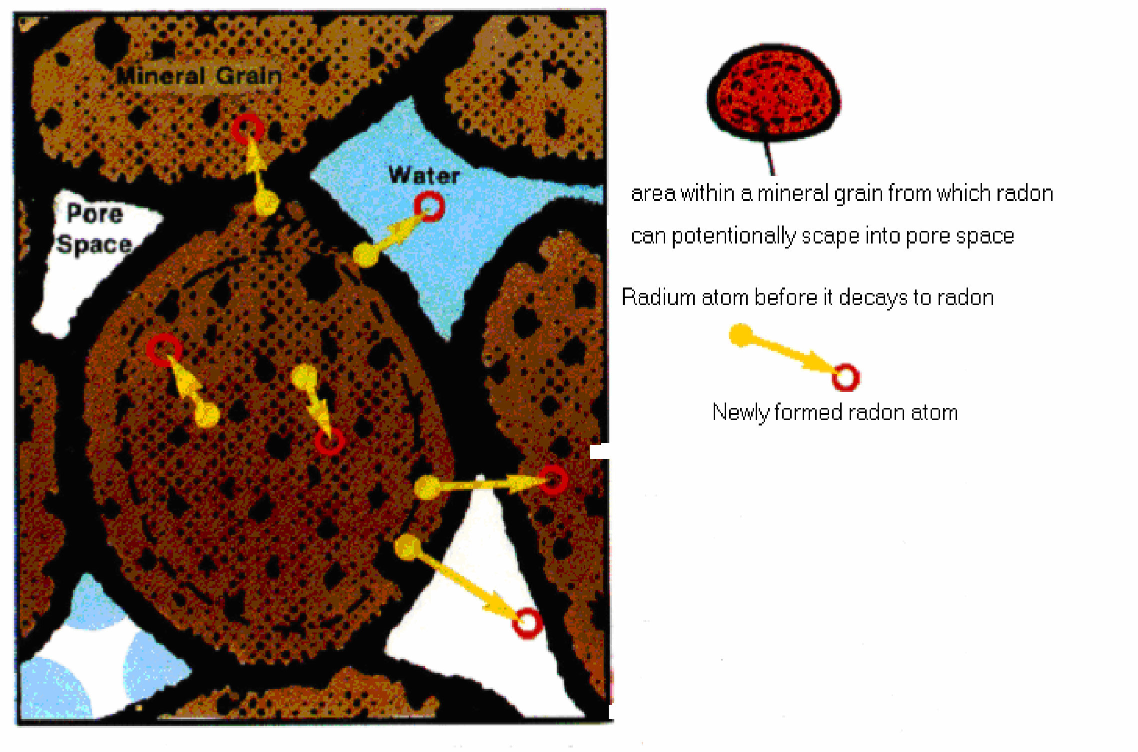


Figure 2.4: Migration of Radon through pore space and water [4]

2.6.3 Water supplies as Radon source

In addition to soil and building material, water supply can be a route of entry of Radon that exists in the ground water. The small water supply systems are often closed systems with short water transit times that do not allow Radon to be completely removed or decayed. Radon then escapes from the water into the indoor environment as people use the water for showers and washing as shown in figure (2.5).

Radon in drinking water is found only in groundwater supplies (the insoluble Radon gas quickly degasses in surface water supplies). In many countries, some homes obtain drinking water from groundwater sources (springs, wells and boreholes). Underground water often moves through rock containing natural uranium and radium that produce Radon. This is why water from deep drilled wells normally has much higher concentrations of Radon than surface water from rivers, lakes, and streams [15]. Most of the Radon in indoor air comes from soil underneath the home. As uranium breaks down, Radon gas forms and seeps into the house. Radon from soil can get into any type of building; homes, offices, and schools; and build up to high levels in the air inside the building. Radon gas can also dissolve and accumulate in water from underground sources, such as wells.

Many factors that affect the formation and movement of Radon in the ground; the uranium content, grain size, and permeability of the host rock and the nature and extent of fracturing in the host rock and these important factors affecting the amount of Radon in groundwater[4]. Radon concentrations in ground water vary from time to time (before and after winter) because of dilution by recharge or changes in contributing areas of the aquifer because of pumping [18].

2.7 Radon entry into buildings

Radon gas enters houses from the ground through cracks in concrete floors and walls, through gaps between floor and slab, and around drains and pipes, and small pores of hollow-block walls (fig 2.5). Consequently, Radon levels are usually higher in basements, cellars and ground floors. Depending on a number of factors, the concentration of Radon indoors varies with the time of the year, from day to day, and from hour to hour. Because of this time-variation, reliable measurements of mean concentrations in air should be made for at least three months [17].

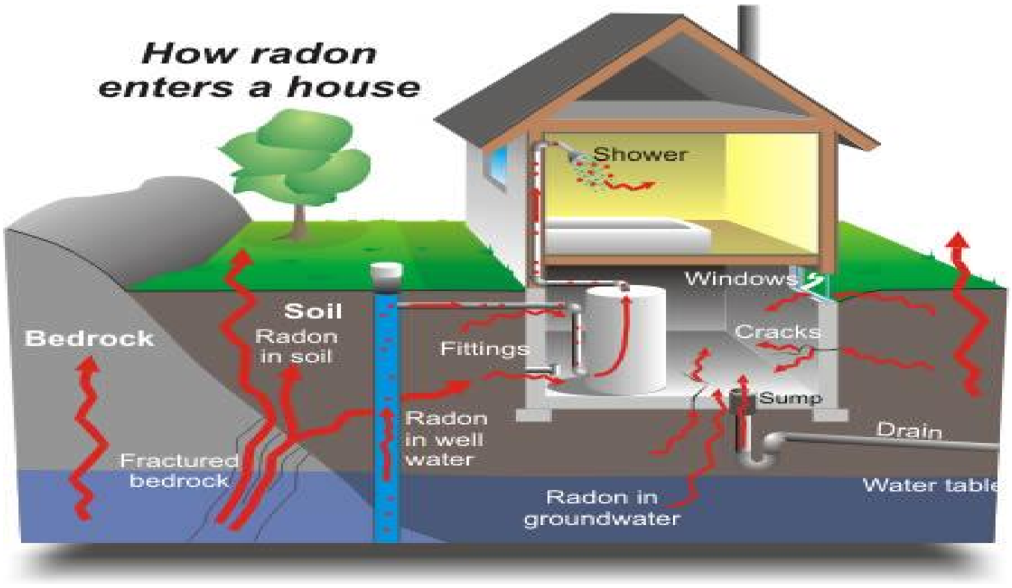


Figure 2.5: How Radon enters a house [21]

2.8 Guidelines for concentrations of Radon in water

The World Health Organization (WHO) Guidelines for Drinking Water Quality and the European Commission recommend that controls (for example repeat measurements) should be implemented if Radon in public drinking water supplies exceeds 100 Bq/m^3, treatment of the water source should be undertaken to reduce the Radon levels to well below 100 Bq/m^3 [16]. The United States has proposed a Maximum Contaminant Level for Radon of 150 Bq/m^3 for private water supplies [16].

Many countries have defined an Action Level of Radon concentration to guide their program to control domestic exposure to Radon. The Action Level is not a boundary between safe and unsafe, but rather a level at which action on reduction of Radon level will usually be justified. Some people may choose to take action when the Action Level is approached. For example, many countries consider Radon concentration in the air of 200 Bq/m^3 as an Action Level at which mitigation measures should be taken to reduce Radon level in homes [16].

In USA People who have private wells should test their well water to ensure that Radon levels meet EPA's newly proposed standard (EPA's Action Level of 150 Bq/m^3).

In addition, exposure to uranium in drinking water may cause toxic effects to the kidney. To protect public health, EPA (Environmental Protection Ajency) has established drinking water standards for several types of radioactive contaminants combined radium 226/228 (200Bq/m^3),gross alpha standard (500Bq/m^3) [20,21]. The Norwegian Radiation Protection Authority has recommended an action level of 500 Bq/m^3 for Radon in domestic water, and 200 Bq/m3 in household air [22]. Radon in water is responsible for the whole body internal radiation dose that may be more harmful than Radon in air. Thus, determination of Radon in groundwater has also been of major interest.

2.9 Radon concentrations in different countries

There is no doubt about Radon being a lung carcinogen for humans. Because of the health risk of Radon and its decay product, many scientists at different countries have given attention to study Radon concentration in air, soil and water in overall the world. They used various experimental and technical possibilities that are available to measure the rad, concentration soil, air and water. A study by Mose and others [10] found that cancer occurrences increase as the amount of Radon in household water increases. This study includes the previously mentioned sources of natural radiation such as Radon in groundwater.

A previous study of Radon concentration in air (Indoor and outdoor) of the middle of Gaza Strip was conducted by M. Rassas (2003). The results showed that the average Radon concentration was 37.83 Bq/m^3 [7]. Another previous study was done in the soil of Northern part of Gaza Strip to measure Radon concentration by N. M. Hamed (2005). The average Radon concentration was 207.24 Bq/m^3 [28]. Therefore we have proposed to investigate the Radon concentration, gross alpha, in different area in groundwater in the southern part of Gaza Strip. So the main interest of our present work is to investigate Radon pollution in the groundwater as part of a water-quality. John F. DeWild and James T. Krohelski [26] have studied Radon concentration in 29 groundwater samples collected from the sand, gravel sediments and crystalline bedrock aquifers. They found that Radon range from 260 to 22,000 pCi/L with an average concentration of 560 pCi/L. The highest Radon concentration was found in groundwater from wells in Wisconsin. The results were obtained by using the scintillation counter with Lucas cell Method [26].

Punjab and Himachal Pradesh States, India, showed that Radon concentration values in drinking water had a wide variation depending on its source and location[26]. The Radon concentration values in hand pump drawn groundwater have been found to be higher than the values from other sources. The recorded Radon concentration in these samples has been found to vary from 10 to 48 Bq/m^3. The Radon concentration has also been measured in some thermal springs and these values have been found to be quite a lot higher than from other sources of groundwater. Mineral water has the minimum Radon concentration compared with groundwater sources [46]. Another study of Radon concentration in groundwater was measured in Israel and found that the decay of Radon in western Galilee was 150-570 pCi/l, and in the Dead Sea area from 2000-5000 pCi/l [25]. Another research was found that 50 % of the drilled wells in Stockholm County have a Radon content exceeding 100 Bq/m^3 and 11 % have as much as 1000 Bq/m^3 [27].

During the 1990s, several surveys of Radon concentrations in Norwegian groundwater have been carried out, including a nationwide study by the Norwegian Radiation Protection Authority and the Geological Survey of Norway. About 13.9 % investigated boreholes in Precambrian and Paleozoic crystalline bedrock yielded water with Radon concentrations excess of the recommended action level of 500 Bq/m^3. The highest levels are usually found in granites (up to 20000 Bq/m^3), but concentrations vary considerably between boreholes within each lithology [22]. Groundwater in superficial Quaternary sediments typically has Radon concentrations well below the recommended action level [27].

Guideline values (action levels) of Radon vary among countries, and have been measured and estimated in different countries. Table (2.3) shows the domestic Radon concentration and action level in different countries.

Table 2.3: Domestic Radon Concentrations and Action Levels in Different Countries [6]

Country	Average Radon concentration ir homes (Bq/m^3)	Action level (Bq/m^3)
Finland	123	400
Germany	50	250
Ireland	60	200
Israel	*	200
Lithuania	37	100
Luxembourg	*	250
Norway	51-60	200
Poland	*	400
Russia	19 – 250	*
Sweden	108	400
Switzerland	75	400
United Kingdom	20	200
European Community	*	400
USA	46	150
Canada	*	800

* Not available

CHAPTER (3)

THE STUDY AREA

3.1 Introduction

This chapter describes the study area, where a Geography, Geology, Groundwater situation, Hydrology and hydrogeology of Gaza Strip. We have chosen a southern part of Gaza Strip in order to investigate the natural radiation pollution in groundwater.

Groundwater in Gaza Strip is the only source of water for domestic, agricultural, industrial uses [30].

3.2 Geography

The geography of the study area includes its location, geomorphology, soil, demography, climate and rainfall.

3.2.1 Location

Gaza Strip is a small portion of the coastal area of Palestine in the southwestern part along the eastern Mediterranean Sea, 45 km long and between (7-12) km wide, with total area of about 365 km^2[42].

It is bordered with Egypt borders from the south, the Negeb desert from the east and the Mediterranean Sea from the west, and located between longitudes 33^o -2′ east and latitudes 31^o -16′ north as shown in (Figure 3.1) [42]. It consists of five governorates, North, Gaza, Middle, Khanyonis, and Rafah. The study focus on two of these governorates, Rafah and Khanyonis, which are located in the southern part of Gaza Strip.

3.2.2 Geomorphology

The study area is characterized by narrow elongated ridges and depressions extend parallel to the shoreline (NNE-SSW). The ridges have an increasing height towards the east, from 20 to 100m above sea level [42]. Among these ridges there are 20-40m deep depressions filled with soils. This geomorphologic shape continues to the west through Sinai Desert, and to north east to Almajdal. Among different quaternary soil deposits, the sand dunes are dominant along the shoreline with elevations up to 50m above mean sea level (MSL) [42].

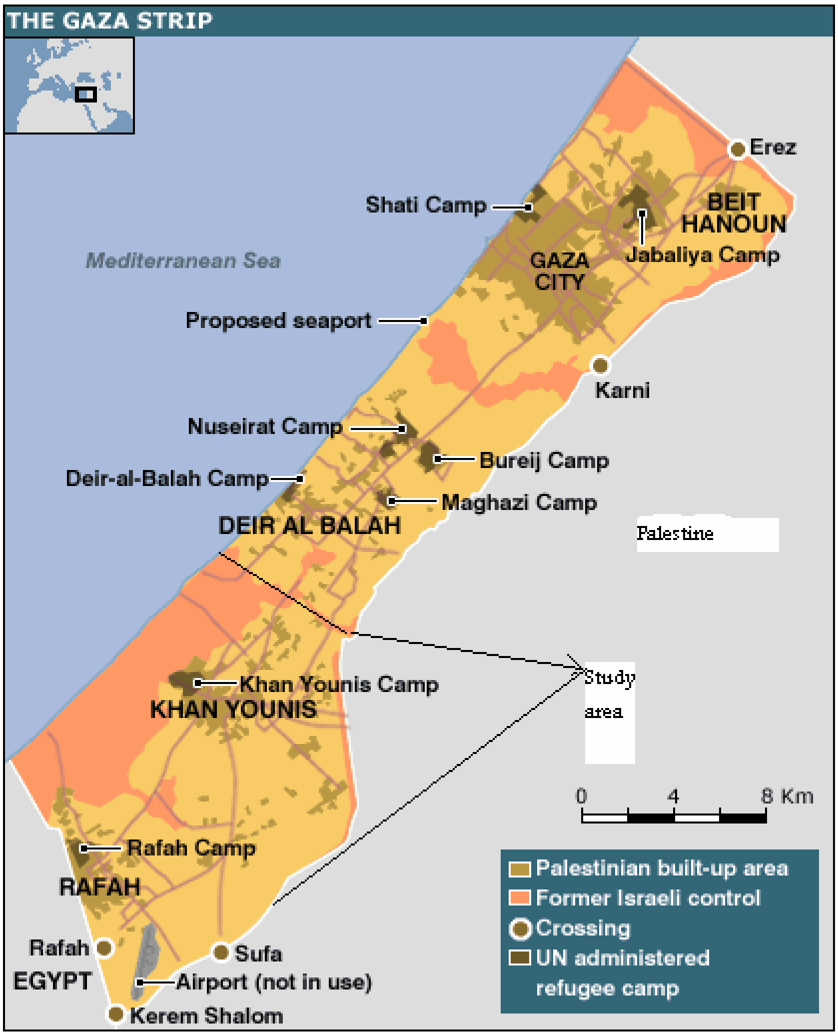


Figure 3.1: Location of Gaza Strip and distribution of Governorates [42]

3.2.3 Soil Classification in Gaza Strip

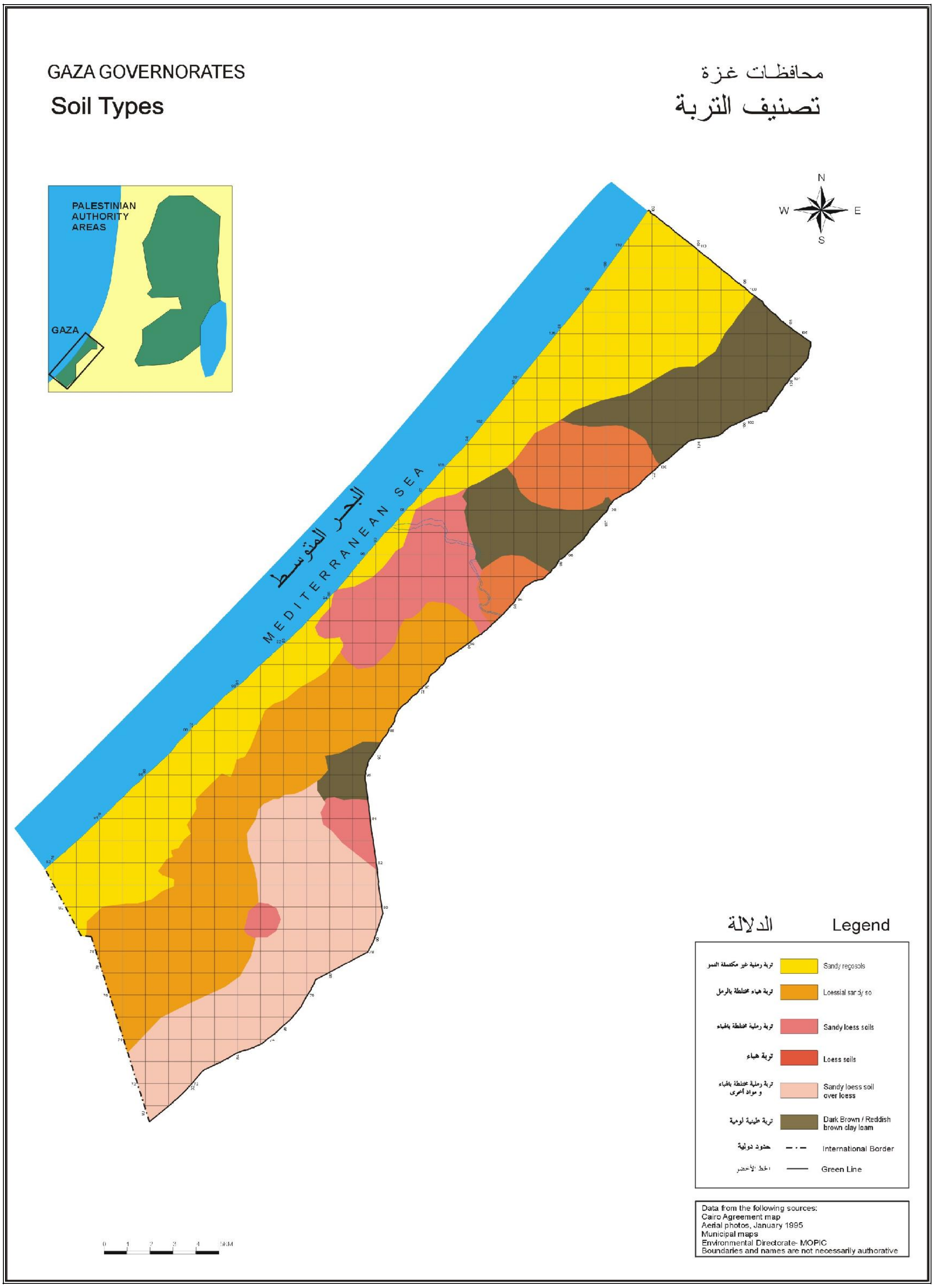
Soil media refers to the upper part of the phreatic zone. Soil media is an important factor in terms of movement pollutants and considered as one of the radiation sources. The soil varies in the study area. It is composed mainly of three types; sands, clay and losses as shown in the soil map (figure 3.2) and table (3.1). Along the shoreline there is a zone of sand dunes with varying in thickness from 2 meters to about 50 m and extends up from 4 to 5 km in land [42]. The study area is wider in south than the north. The dunes have relatively high permeability. Moving eastward, the soil type change and becomes sandy with more silt, clay, and loess.

3.2.4 Demography

According to Palestinian Central Bureau of Statistics [36], the total number of the population in Gaza Strip was 1,364,733 Capita in 2003. The population density in Gaza Strip is very high, so this figure classified that Gaza Strip is considered to be the highest population density in the world.

3.2.5 Climate and rainfall

Gaza Strip is located in the transitional zone between the arid desert climate of the Sinai Peninsula and the semi- humid Mediterranean climate along the coast. The average mean Daily temperature in Gaza Strip ranges from 25º c in summer to 13º c in winter [29]. The average annual rainfall varies from 400 mm/year in the north to 200 mm/year in the south. This is the main conventional source, became insufficient to refresh the groundwater system. Most of the rainfall occurs in the period from October to March [29].



Data from the following sources:
Cairo Agreement map
Aerial photos, January 1995
Municipal maps
Environmental Directorate- MOPIC
Boundaries and names are not necessarily authorative

Figure 3.2: Soil classification in Gaza Strip [42]

Table 3.1: Classification and Characteristics of Different Soil Types in Gaza Strip, [42]

Local classification	location	Description	Texture
Loess soil	Between the Gaza city and Wadi Gaza	Loess soils sediment in Pleistocene until Holocene series. The grain size of loess fluctuates from 0.002 to 0.068mm. Loess has been transported by winds and sedimented in loose from the upper part, and in the lower part of the layers. They are brownish yellow – colored often with accumulation of lime concretions in the subsoil and containing 8 -12% calcium carbonate.	Sandy loam (6 % clay, silt 34%, sand 58%
Dark brown/ reddish brown	Beit Hanoun and Wadi Gaza	These alluvial soils are Usually dark brown to reddish in color, with a well – developed structure At some depth, lime concretions can be found. The calcium carbonate content can be around 15-20%	Sandy clay loam (25% clay, 13% silt,62% sand)
Sandy loess Soil	Deir el Balah and Abssan	This is a transitional soil, characterized by a rather uniform, lighter texture. Apparently, sands mixed with loess deposits	Sandy clay loam (23% clay, 21%silt, 56% sand)
Loess sandy soil	It is found in the central and southern part of the Strip	Forms a transitional zone between the sandy soil and the loess soil, usually with a calcareous loamy sandy texture and a deep uniform pale brown soil profile.	The top layer is sandy loam (14%clay,20% silt,66% sand). The lower profile is loam (21% clay,30% silt,49% sand).
Sandy loess soil over loess	It is found in the east of Rafah and Khanyonis	It is loess or loess soils which have been covered by a 20 to 50 cm thick layer of sand dune.	Sandy loam (17.5%clay,16.5% silt,66% sand)

3.3 Geology of Gaza Strip

Geology of the Gaza Strip was obtained from oil and gas exploitation logs up to depth of about 2000m drilled by Israelis and from the wells drilled during the Coastal Aquifer Management Project (CAMP). Geology of the study area consists of a sequence of geological formations ranging from upper Cretaceous to Holocene [35]. This sequence is gradually sloping westwards as shown in figure (2.3) and table (2.2) summarizes the geological history of the area. The formation of this sequence is [35] :

1. Tertiary Formations

The tertiary formations consist of Saqiya group (upper Eocene to Pliocene) underlined by Eocene Chalks and Limestones as shown in figure (2.3). The Saqiya group composed of shallow marine impervious sediments of Shale, Clay, and Marl. The thickness of this group ranges from 400 m to 1000 m [35].

2. Quaternary Formations

The quaternary deposits in the area have thickness of about 160 m and covering the Pliocene Saqiya group. The overlying Pleistocene deposits "Lower Quaternary", consists of:-

- Marine Kurkar which composed of shell fragments and quartz sands with calcareous cement. The thickness varies between 10 -100 meters on the coast.
- Continental Kurkar which composed of red loamy sand beds (Hamra). The maximum thickness is about 100meters with often calcareous cement [30].
- Sand Dunes, Loess Sand, Gravel Beds, Alluvial Deposits, and Beach Formation, These deposits are found at the top of the Pleistocene formation with thickness up to 25m, which can be divided into many types; such as Sand Dunes, Loess Sand, Gravel Beds, Alluvial Deposits, and Beach Formation, which composed of thin layer of sand with shell fragments.

The Kurkar ridges are classified as Sandstone formation or Kurkar group deposits that include Calcareous Sandstone, Silt, Clay, Unconsolidated Sands and conglomerate. Due to high porosity and permeability it is a very important as water – bearing layer which known as coastal aquifer, it is belonging to Pleistocene age. Most of the groundwater in the Gaza Strip is extracted from this layer. The thickness of the marine Kurkar varies between (10- 100m) showing a tendency to be thicker near the coast. The continental

Kurkar varies from friable to very hard, depending on the degree of cementation,. Alluvial and wind blown sand deposits are found on top of the (Pleistocene) Kurkar formations and can locally reach a thickness of 25m; alluvial deposits can be distinguished at the top. Within the Kurkar formation, a thin layer of clay can be found. The maximum thickness of the Kurkar aquifer is 100 meters. The Kurkar ridges is covered by Sand dunes, the Sand dunes are wide spread in the Southern part of Gaza, In the east there are loess soil which have been formed during the past thousands of years**.** Gaza Strip is underlain by a series of geological formations from the Mesozoic to the Quaternary.

- The coastal aquifer of the Gaza Strip consists of the Pleistocene age Kurkar and recent (Holocene age) sand dunes
- The Kurkar Group consists of marine and aeolian calcareous sandstone (Kurkar), reddish silty sandstone, silts, clays, unconsolidated sands, and conglomerates.
- Regionally, the Kurkar Group is distributed in a belt parallel to the coastline, from north of Haifa to the Sinai in the south.
- Near the Gaza Strip, the belt extends about 15-20 km inland, where it unconformably overlies Eocene age chalks and limestone, or the Miocene-Pliocene age Saqiya Group, a 400-1000 m thick sequence of marls, marine shales, and claystones.
- The transition from the Kurkar Group to the Saqiya Group is sometimes obscured by the presence of a thin, basal conglomerate. the thickness of the Kurkar Group increases from east to west, and ranges from about 70 m near the Gaza border to approximately 200 m near the coast.
- The layered stratigraphy of the Kurkar Group within the Gaza Strip subdivides the coastal aquifer into 4 separate subaquifers near the coast. Further east, the marine clays pinch out and the coastal aquifer can be regarded as one hydrogeological unit. The upper subaquifer “A” is unconfined, whereas subaquifers “B1, B2, and C” become increasingly confined towards the sea.

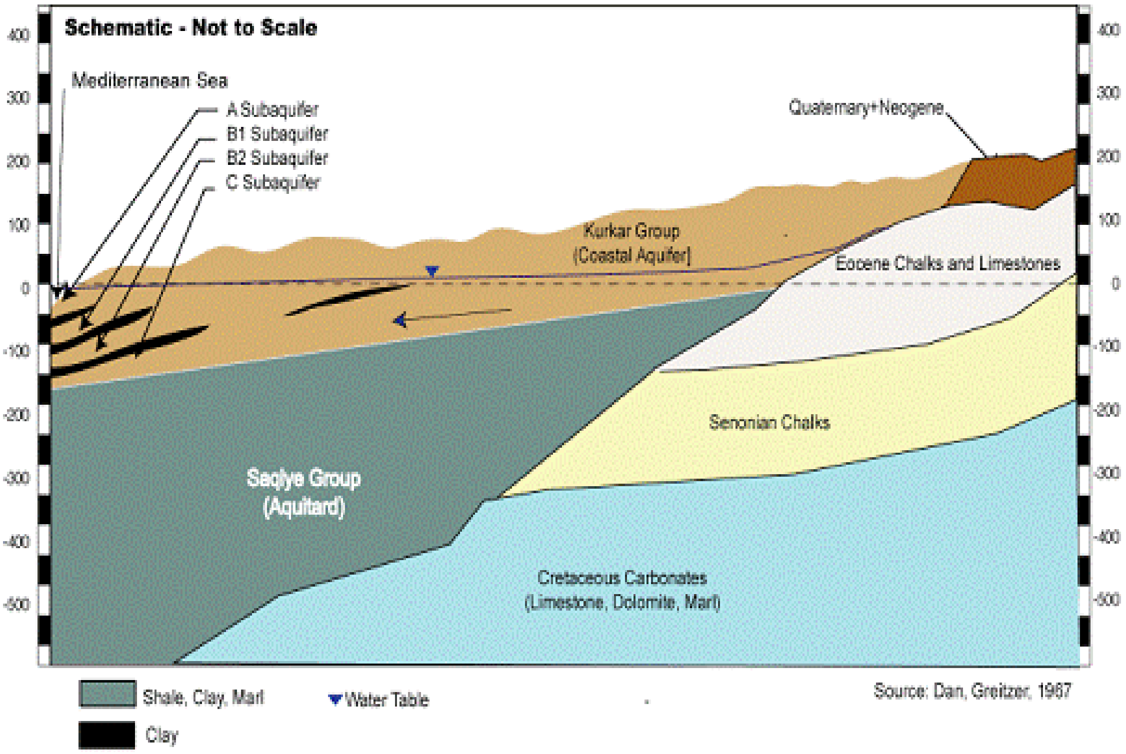
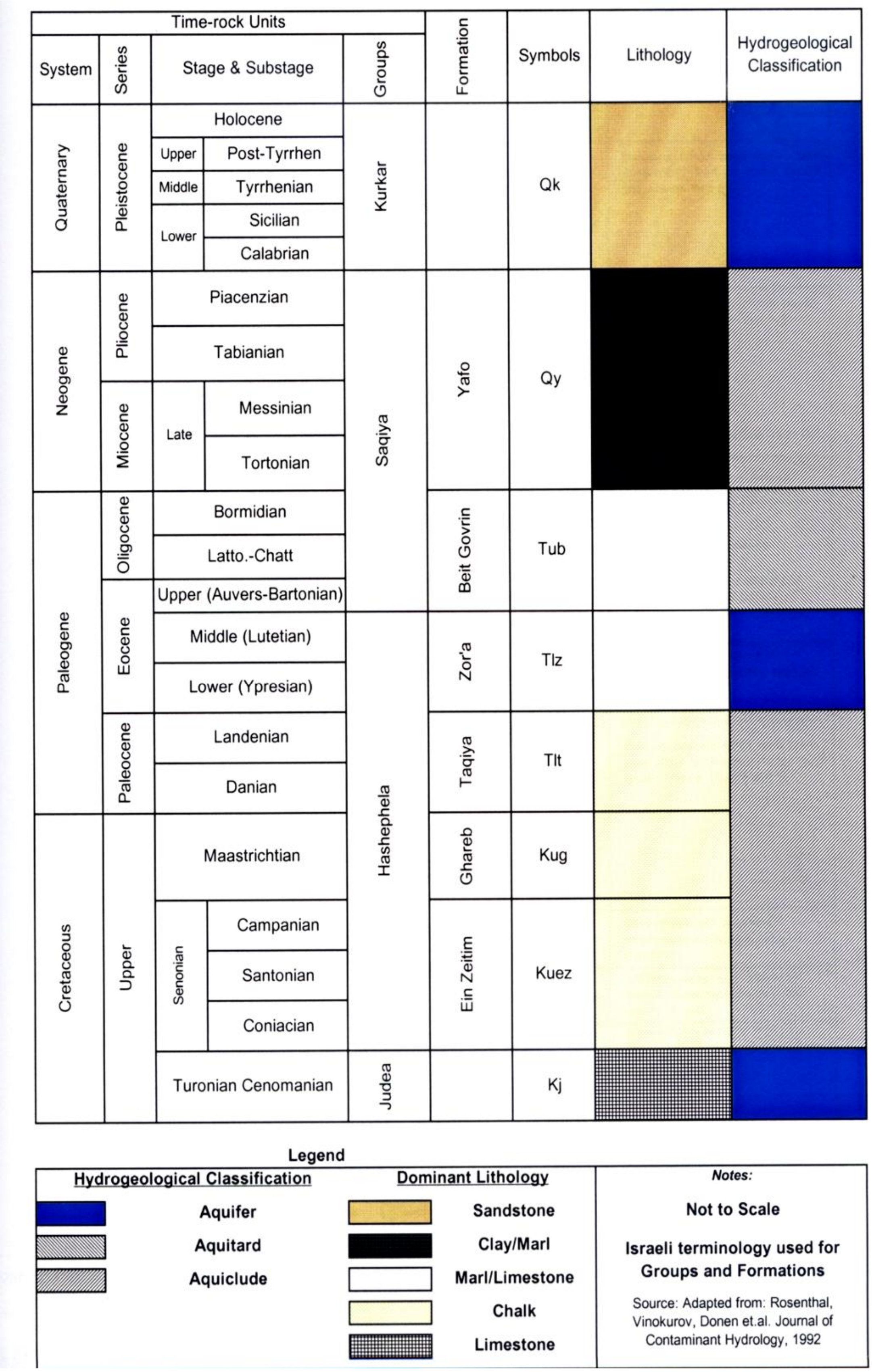


Figure 3.3: Hydrogeological cross-section of the Gaza Strip [35]

Table 3.2: A Summary for the Geological History of the Area [35]



Time-rock Units					Formation	Symbols	Lithology	Hydrogeological Classification
System	Series	Stage & Substage		Groups				
Quaternary	Pleistocene	Holocene		Kurkar		Qk	🟫	🟦
		Upper	Post-Tyrrhen					
		Middle	Tyrrhenian					
		Lower	Sicilian					
			Calabrian					
Neogene	Pliocene	Piacenzian		Saqiya	Yafo	Qy	⬛	▨
		Tabianian						
	Miocene	Late	Messinian					
			Tortonian					
Paleogene	Oligocene	Bormidian			Beit Govrin	Tub	⬜	▧
		Latto.-Chatt						
	Eocene	Upper (Auvers-Bartonian)						
		Middle (Lutetian)		Hashephela	Zor'a	Tlz	⬜	🟦
		Lower (Ypresian)						
	Paleocene	Landenian			Taqiya	Tlt	🟨	▨
		Danian						
Cretaceous	Upper	Maastrichtian			Ghareb	Kug	🟨	
		Senonian	Campanian		Ein Zeitim	Kuez	🟨	
			Santonian					
			Coniacian					
		Turonian Cenomanian		Judea		Kj	▦	🟦

Legend

Hydrogeological Classification		Dominant Lithology	
🟦	**Aquifer**	🟫	**Sandstone**
▧	**Aquitard**	⬛	**Clay/Marl**
▨	**Aquiclude**	⬜	**Marl/Limestone**
		🟨	**Chalk**
		▦	**Limestone**

Notes:

Not to Scale

Israeli terminology used for Groups and Formations

Source: Adapted from: Rosenthal, Vinokurov, Donen et.al. Journal of Contaminant Hydrology, 1992

3.4 Groundwater and Environmental Situation in Gaza Strip

The environmental problem in Gaza Strip is huge. The abnormal situation is result of the influx of a large number of the refugees and the 40 years of occupation which led to the significant degradation of the natural and human environment.

Groundwater from the coastal aquifer is the only source *of* water for the people of Gaza Strip, so groundwater contamination is one of the most serious environmental problems in Gaza Strip**.**

The main groundwater quality problem in Gaza is elevated chloride and nitrate concentrations [37]. Many years of over pumping have resulted in seawater intrusion and upcoming of saline groundwater. Furthermore, human activities including agriculture and inadequate waste management have increased groundwater contamination levels.

According to Abu Heen and Lubad, 2005 [38] decreasing of water quality is a function of time. Chemical analysis of water for eighteen domestic wells in the Gaza City from 1994 to 2004 shows that for the years 1994 , 1999 and 2004 about 33%, 44% and 67% of the samples respectively are unsuitable for drinking based on WHO and Palestinian standards.

Many publications has been discussed the issue of groundwater quality in the Gaza aquifer and all of them mentioned that the quality is generally poor.

Results of groundwater chemical analysis showed high nitrate concentration (more than 50 mg/l; WHO drinking water guideline is 50 mg/l). Elevated nitrate concentrations in drinking water are linked to health problems such as methemoglobinemia in infants and stomach cancer in adults. A health-based guideline value for nitrate of 50 mg/liter was recommended in the second edition of the WHO Guidelines for drinking-water quality to prevent methaemoglobinaemia.

Chloride concentrations in excess of about 250 mg/liter can give rise to detectable taste in water**.** Ensuring the Safety of our drinking water is one of the most importance a critical issues for public health protection [40].

3.5 Hydrology of Gaza Strip

Precipitation falling on land is either returned directly to the atmosphere by evaporation, flows along the land surface to become surface water, or percolate into the ground. Water that infiltrates into the ground is either drawn into plants and returned to the atmosphere by transpiration or continues infiltrating becoming groundwater.

There are no permanent surface resources in the Gaza Strip, like rivers or lakes. Temporary flow run-off owing to rainfall is the only source of ephemeral surface water [32].

The Surface water system in Gaza Strip consists of Wadis, which only flow during short period. Wadis are characterized by short duration flash floods that occur after heavy rainfall, but most of the time, the Wadis are completely dry. The main Wadis are Wadi Gaza that originates in Negev desert. In addition, there are two small insignificant Wadis in Gaza Strip, Wadi El-Salqa in the south without outflow to the sea and Wadi Beit Hanon in the north which flows into Occupied Palestine 1948 [30].

3.6 Hydrogeology of the Gaza Strip

Gaza Strip is characterized by scarcity of natural water resources. The main source of water is the groundwater aquifer that is the sole source of drinking, domestic, irrigation and industrial water supplies.

The coastal aquifer is composed of tertiary –quaternary sands, calcareous sandstone and pebbles interbeded with impervious and semi-pervious clay. The Coastal Aquifer is divided into three sub aquifers which belonging to Pleistocene age and consists primarily of Kurkar Croup deposits that include calcareous sandstone, silt, clay, unconsolidated sands and conglomerates. Saqiya Group is the top base of the coastal aquifer and consists of thick sequences of marls, clay stone and shale which belong to the post- Eocene age.

The groundwater in Gaza Strip originated from the mountain of Hebron (West Bank). During the infiltration and travel of water from the catchment area to Gaza aquifer, different physical and chemical processes a affect its quality. The aquifer depth varies from 10 m in the east to 120 m in the west [31].

According to Environmental planning Directorate (1996) [33], it is believed from studies done by Occupied Palestine 1948 researchers that the deep aquifer under the Negev Desert contains brackish water at depth of about in some areas of 1500 to 3200 meters below the sea level. Groundwater in the Gaza Strip occurs in a shallow sub-aquifer, which is from sands; calcareous sandstone and pebbles with inter beds of impervious semi-pervious clay. Approximately 90% of Gaza Strip water comes from this shallow coastal aquifer [33]. The top of the system consists of recent sand dunes in the western part of the Strip and finer deposits (sands and loess) in the eastern part and beyond, interbeded with soils. [34], where these aquifers described as shown in figure (2.3)

- The upper aquifer lies closest to the sea and extends two km in land at depth mainly below sea level.
- The middle sub-aquifer is situated below the upper aquifer near the coastline. It rises in an eastward direction according to the general slope of the geological layers.
- The lower sub-aquifer extends further inland.

3.7 The groundwater Balance of Gaza Strip

- The Gaza coastal aquifer is a dynamic system with continuously changing inflows and outflows.
- The present net aquifer balance is negative, that mean, there is a water deficit.
- The water balance varies from one year to another as a function of rainfall variations and changes in water demands.
- The water balance of the Gaza coastal aquifer has been developed based on estimates of all water inputs and outputs to the aquifer system.
- The components of the current water balance of the Gaza Strip are:

Inflow (from all available sources) = outflow +/- changes in storage, when the inflow is less than outflow, the water deficit will be happened.

Estimate maximum water balance in 1998 of the Gaza aquifer is shown in the table (2.3). as shown in this, outflows exceed inflows by about 18 Mm^3/y. this quantity of water is belied to be replaced by deep seawater intrusion and / or up coning of deep brines in the study area.

The water deficit is a result of:

- Water consumption greatly exceeds the a available resources, which result in a strong depletion of the groundwater reserve.
- Groundwater extraction from Israel, through wells on the borders of the occupied areas and the construction of upstream dams on Gaza Wadis behind the borders of 1967 to prevent the natural flow of these Wadis with freshwater that coming as a result of rainfall.

The water deficit leads to:

1. A drop of water level in the aquifer.
2. An increase in the salinity content and consequently reduction in availability of fresh groundwater [35].

Table 3.3: Estimate Maximum Water Balance in 1998 of the Gaza Aguifer [35]

Inflow (Mm^3/yr)		**Outflow (Mm^3/yr)**	
Rainfall recharge	45	Municipal abstraction	47
Lateral inflow (Israel)	30	Agriculture abstraction	100
Lateral inflow (Egypt)	5	Israeli abstraction	8
Saltwater intrusion	15	Discharge to the Sea	15
Water system leaks	15		
Waste water return flows	10.5		
Other recharge	3.5		
Irrigation return flows	25		
Loss of aquifer storage	3		
Total	152		170
Net balance	-18		

CHAPTER (4)

METHODOLOGY AND TECHNIQUES

4.1 Methodology

To achieve the objectives of this study, the following methodology has been considered:

4.1.1 Literature Review

The available literatures will be collected any reviewed from all references, book, papers and reports as well as useful sources related to the topic .

4.1.2 Sampling method

The water sampling will be collect from the available domestic water sources in each city in the southern part of Gaza Strip.

4.1.2.1 Samples Locations

25 groundwater Samples were collected from the municipal wells in the Southern part of Gaza Strip. Some of these wells have lithological description and some information comes from the geologists, whom obtain their information from boreholes and geophysical prospecting, geophysical well-logging in the boreholes gives additional geophysical information (see well litholology log in (appendix II) [35]. One liter of each sample was placed in plastic jar. The samples were collected from different locations, 12 wells from Rafah Governorate and 13 wells from Khanyonis Governorate. Al these wells used for domestic water (see figure 4.1 and figure 4.2).

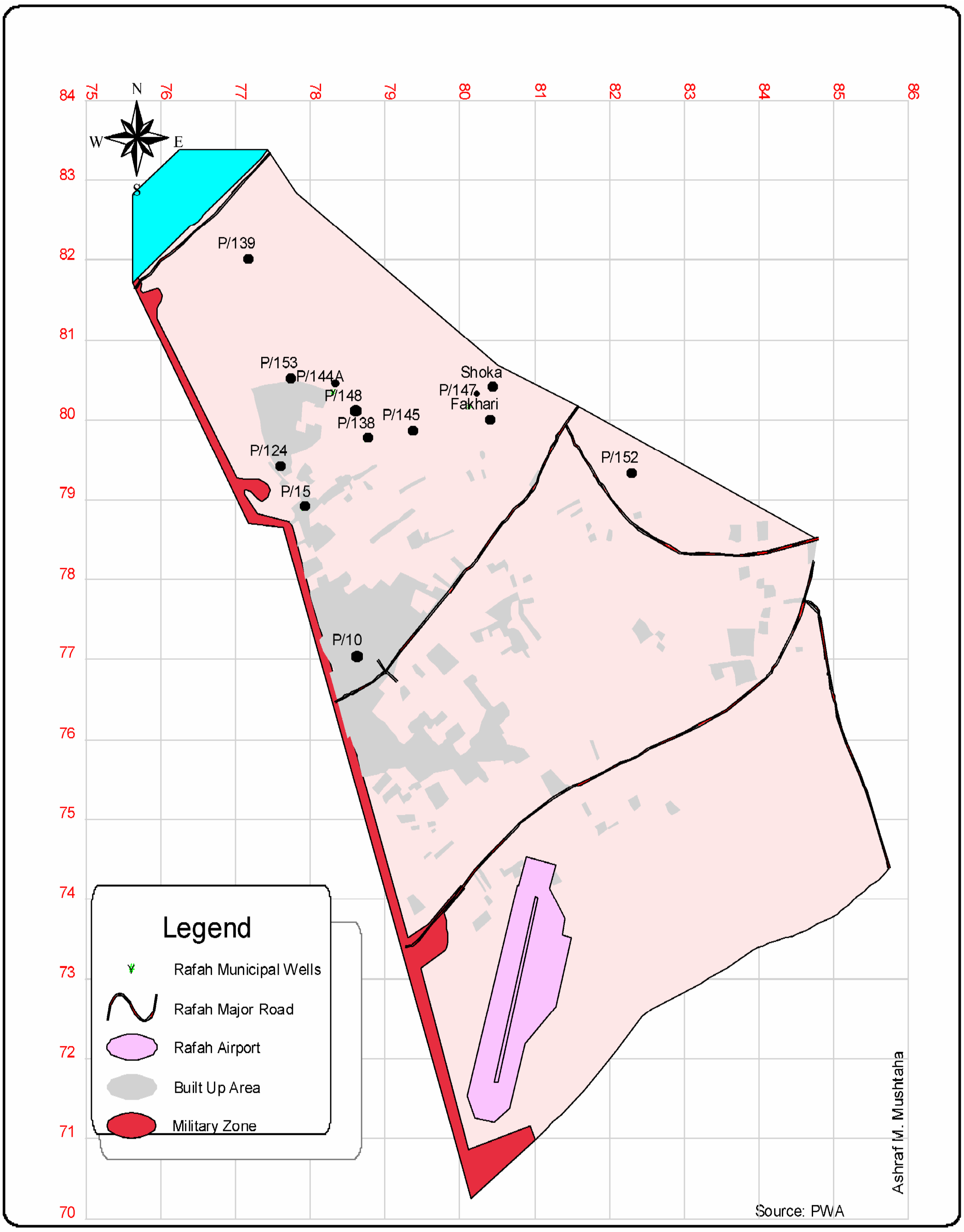


Figure 4.1: Wells location of the samples for Rafah Governorate

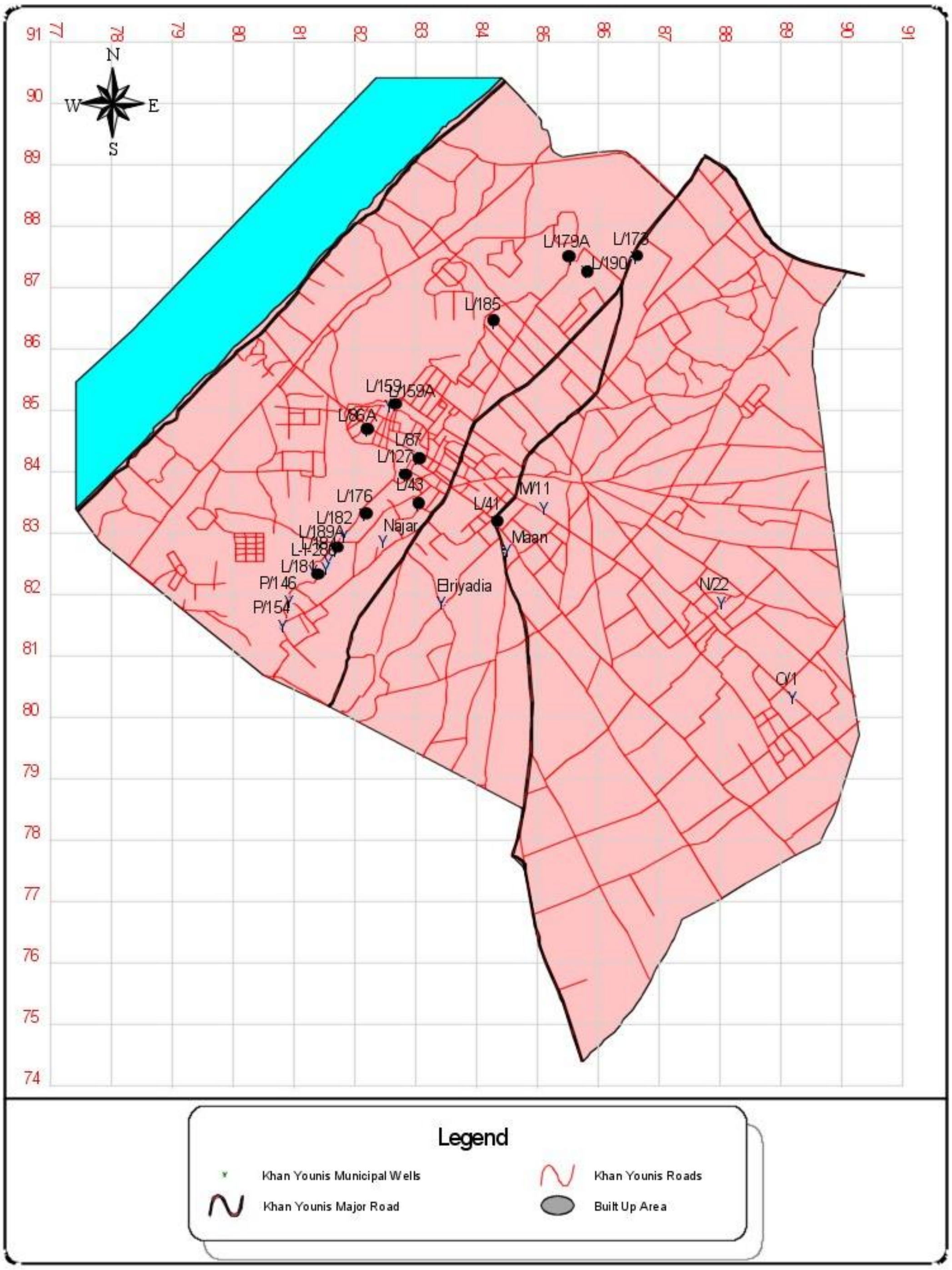


Figure 4.2: Wells location of Samples for Khanyonis Governorate

4.1.2.2 Samples Collection

Each sample was duplicated to determine Radon concentration. The water samples were taken after five minutes from operating the wells, and we put the samples in plastic container, where, information data for each well such as well name, well number, site, data of collection sample and exposure period is registered in a form fixed on Jar. A questionnaire is also accompanied the collection sample include questions regarding collection site, time, and factors that necessary for analysis **(see appendix I).** Two detectors were also fixed inside a plastic container (jar) as shown in figure (4.3). One of these detectors was placed at the plastic cover (lid), and the container tightly sealed. The detectors were left for a total exposure of 120 days (for a period during mid of April to mid of August). The results will be analysis using software surfer 8, and Excel program.

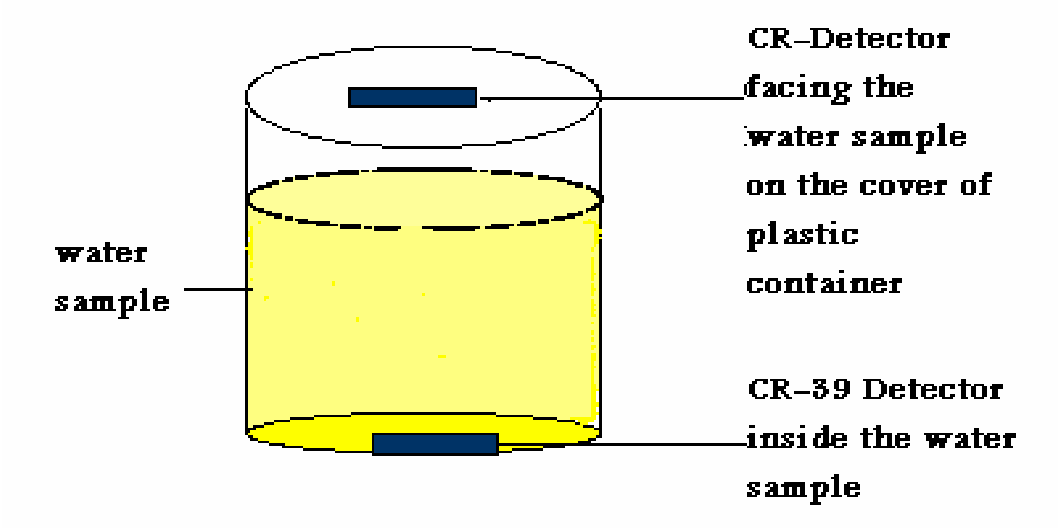


Figure 4.3: The two detectors in water samples

4.2 Measurements Techniques

There are many types of techniques and detectors that used to detect radiation, such as Ionizing Chamber, Proportional Counters, Geiger –Muller Counters, Scintillation Counters and Solid State Nuclear Track Detectors (SSNTDs) CR-39. The most common device for the measurement of Radon concentration is the passive diffusion Radon dosimeter containing solid state nuclear track detector (SSNTD) CR-39. This type of detector is used throughout the present work.

► Solid State Nuclear Track Detectors (SSNTDs)

SSNTDs is passive technique which has several advantages; low cost, cheap and can be easily obtained, long term method, most widely used for measuring Radon and can be used for site assessment both indoors and outdoors. SSNTDs are sensitive to alpha particles in the energy range of the particles emitted by Radon. SSNTDs are largely insensitive to beta and gamma rays. SSNTDs also have the advantage to be mostly unaffected by humidity, low temperatures, moderate heating and light. They of course do not require an energy source to be operated since their detecting property is an intrinsic quality of the material they are made of [8].

There are three types of commercially available SSNTDs

- Polyallyl -diglycol-Carbonate ($C_{12}H_{18}O_7$) was known as CR-39.
- Cellulose Nitrate ($C_6H_8O_8N_2$) was known as CN-85.
- Plastic track detector known as CR- 115

CR-39 a better detector as compared to other detectors used for Radon concentration measurement [19].

4.3 Calibration Technique

Super grade quality of CR-39 solid state nuclear track detectors was prepared at the laboratory. The detectors were cut 1.5 x1.5 cm each, and fixed tightly in a bottom of plastic container and on the container lid, to relate the density of recorded tracks to Radon concentration. The dosimeters were calibrated at the physics laboratory to obtain the obvious tracks. These tracks registration represents the presence of alpha particles through small pits (tracks) in the surface of the detector. The tracks density (tracks/area) is proportional to the total number of alpha particles. To consider these tracks, a calibration process is required to determine the calibration constant in units of tracks.

Images of tracks can be enhanced by special techniques. For applications where only the measurement of track density is required, high contrast techniques have been developed which usually enlarge the track images. The etching most often used for CR-39 are aqueous solution of KOH or NaOH. In the present work, we have chosen (NaOH) as an aqueous solution for chemical treatment.

In practice, the most important parameters for control of the etching speed of the detectors are temperature, concentration of the etching solution and time etching, as indicated in figure (4.4) [7].

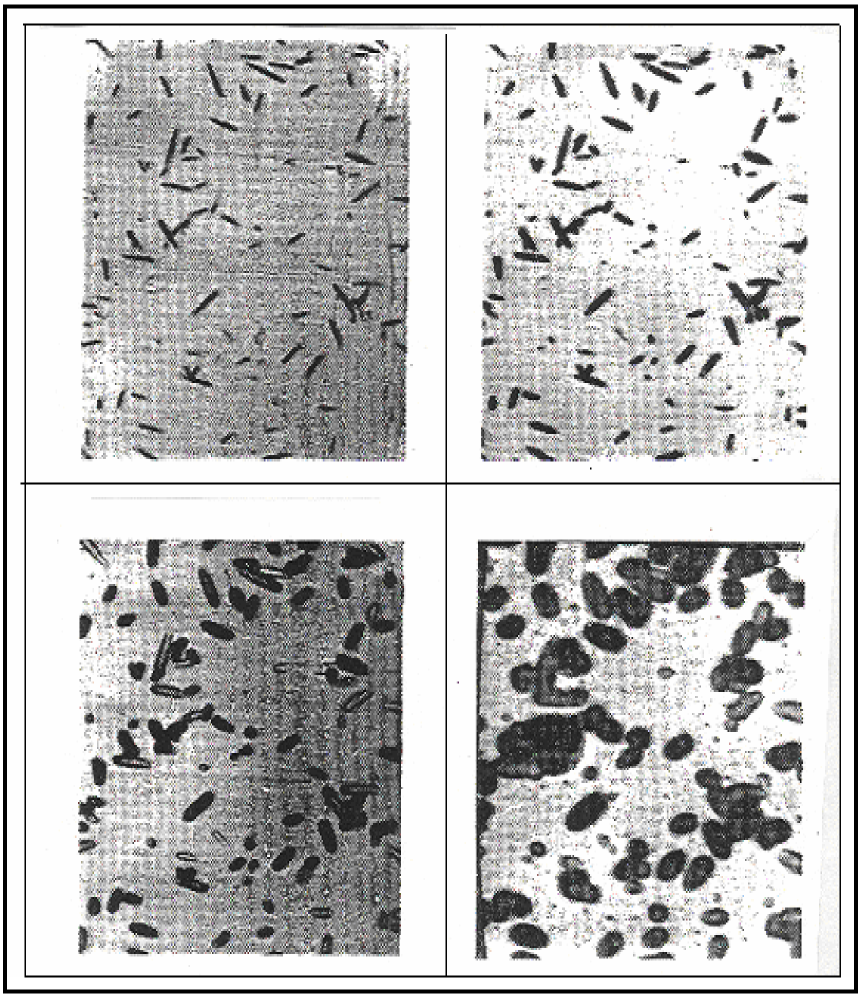


Figure 4.4: Track induced fission fragment for different etching

In fact, to find the best concentration of aqueous solution NaOH, we prepared some detectors so as to calibrate and to determine, suitable concentration of NaOH and suitable etching time. These detectors were exposed to ^{226}Ra (Radon source) of activity concentration 800 Bq/m^3 for (120) days. Then the detectors were chemically etched using different percent of concentration of (NaOH) at constant temperature (70^{0}c) and constant etching time (7 hours). The numbers of tracks per unit area of 1mm^2 were counted using an optical microscope with power of (40×10). Figure (4.5) shows that the variation of the track density (number of track/mm^2) as suitable percent of (NaOH) solution. The maximum numbers of track density was found at 30% concentration of (NaOH), where a clear track observed. As the percent of (NaOH) concentration increased greater than 35%, the detectors were found not valid for track counting and dissolved.

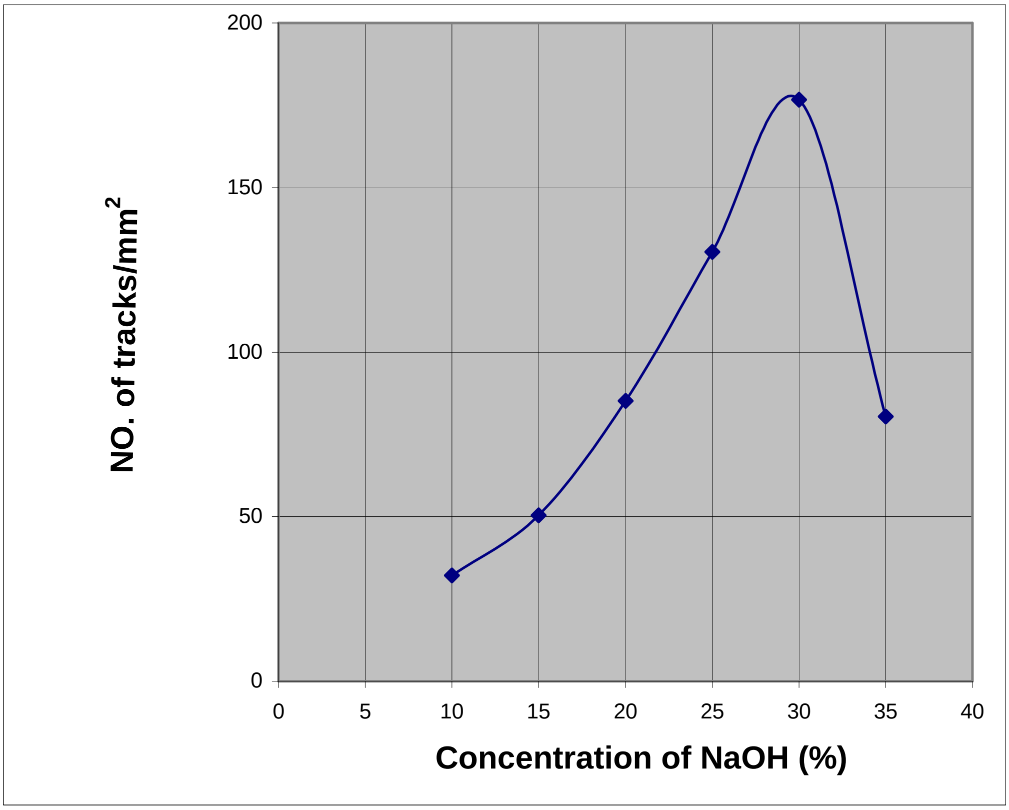


Figure 4.5: Relatioship between track density and the concetration percentage of NaOH

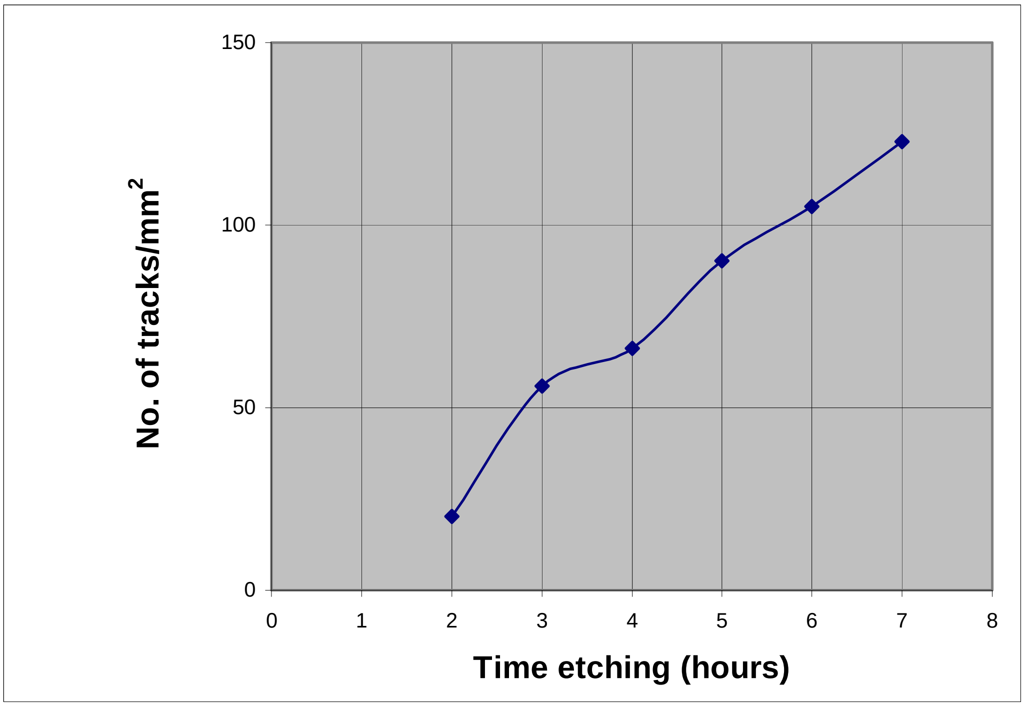


Figure 4.6: Relationship between track density and etching time

Figure (4.6) shows that the number of tracks increases when the time etching increases. However, the etching time increased greater than 7 hours, the detectors were found not valid for track counting and dissolved. The calibration is also carried out to determine the etching temperature, when a suitable etching temperature at 70^{o} is obtained. These parameters were used for control of the etching process of the detectors throughout the present work.

One hundred detectors were exposed to twenty five samples of concern. These samples were collected from the regions of the area study that represent Rafah and Khanyonis governorates of the southern part of Gaza Strip. At the end of exposure, the detectors were collected and chemically treated in solutions of caustic alkalis such as sodium hydroxide, often at elevated temperatures for several hours.Then the numbers of tracks over area counted by a microscope and Radon concentration is determined.

The detectors were collected at present work and chemically etched using solution of NaOH, at a temperature of 70 c^{o,} for 7 hours (standard condition). The CR- 39 detectors were mounted and immersed in the etching solution inside a water bath, to let the tracks appears. At the end of the etching process, the detectors were washed with distilled water and then left detectors to dry. Each detector was counted visually using an optical microscope with a power of (40 x 10). Then consistently ignore any smaller etch pits and any scratches that are easily discounted. The genuine track etch pit may be identified by slowly moving the fine focus of microscope up and down and looking for a bright point of internally reflected light at bottom tip of the etch-pit. Then we counted the average number of tracks in 1 mm^2 by moving microscope stage from left to right about 10 times to insure that no tacks are missed but counted twice, as shown in figure (4.7).

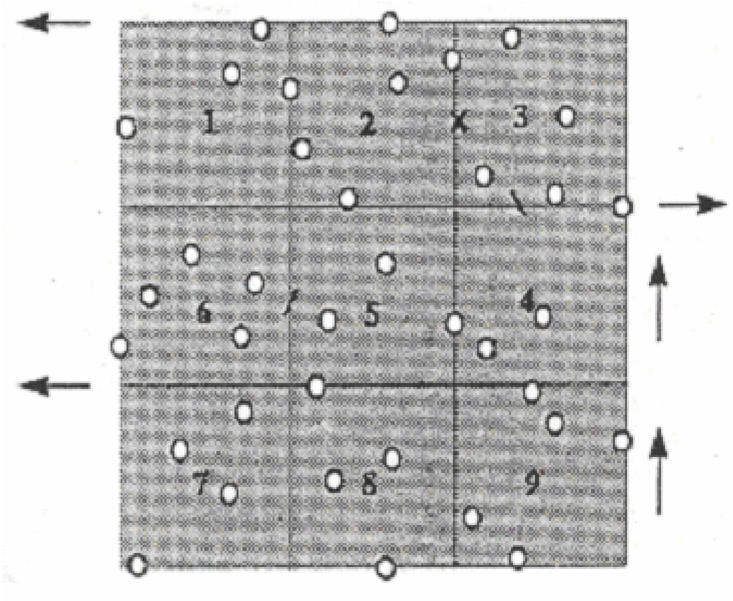


Figure 4.7: Tracks formation on CR - 39 detectors after chemical etching

4.4 Determination of Radon concentration

The solid state nuclear track detector technique is one of the most often used techniques for the measurement of Radon. Radon concentration (C) in surrounding air is measured in terms of Bq/m^3, since the most regulatory reference levels are specified in this unit. Determination of Radon concentrations (C) in groundwater at south part of Gaza Strip are carried out by the following equation [7]:

The standard deviation (S.D) in groundwater at south part of Gaza Strip is carried out by the following equation [7]:

$$C(Bq/m^3) = \frac{C_O\left(Bq.d/m^3\right)}{\rho_0}\left\{\frac{\rho}{t}\right\}_{\text{det.}} \qquad (4.1)$$

$$\sigma_n \text{ (S.D.) } = \sqrt{\frac{\sum_k^n (X_k - X)^2}{n-1}} \qquad (4.2)$$

where, C0=the total exposure of ^{226}Ra (Radon source) in term Bq.d/m^3,

ρ_0=track density (number of tracks/mm^2) of detectors exposed to ^{226}Ra,

ρ=track density (number of tracks/mm^2) of distributed detectors in water sample,

t= exposure time (days) of distributed detectors in water sample.

σn (S. D.)= Standard Deviation.

Simply, a number of dosimeters were exposed to a known dose of ^{226}Ra (Radon source) for a period of time. Then those dosimeters were collected and treated chemically etching. The average numbers of tracks/m^2 were observed. These detectors were considered as a calibration standard [8].

Similar method is also obtained for track detectors techniques to determine the calibration constant (factor). This is derived by dividing the track density by the total exposure of Radon source. Then the equation (4.1) for Radon exposure becomes as follows [7].

$$C(Bq/m^3) = \frac{1}{k}\left\{\frac{\rho}{t}\right\}_{\text{det.}} \qquad (4.3)$$

where k is called the calibration factor in terms of (track.mm^2/Bq.d.m^{-3}) or a calibration coefficient and it was determined experimentally.

4.5 Calibration factor (k)

The calibration process for dosimeters used in this survey was prepared and carried out at the laboratory of physics department to determine the calibration factor (K). Six dosimeter were exposed for 120 days to ^{226}Ra as a source of alpha particles of activity 800 Bq/m^3 with (2.12x10^4 Bq.d/m^3) concentration for total exposure.

Numbers of tracks were found in calibrated detector equal 16 tracks/mm^2 and the concentration was obtained to be 13.25 x10^{-4} Bq.d /m^{-3}. The overall uncertainty of this calibration was estimated to be ±10%**.**

The above equation (4.3) is used to determine the Radon concentration (C) throughout the present work.

For Example, if we have 14 tracks for the first water sample from Rafah city, the Radon concentration calculated as below:

$C\ (Bq/m^3) = 13.25x10^{-4}\ \{\rho/t\}_{det}$ ……………………………………….....   (4.4)

$C\ (Bq/m^3) = 13.25x10^{-4}\ \{14x10^6/120\}$

$C\ (Bq/m^3) = 13.25x10^{-4}\ x10^6\ x14/120$

$C\ (Bq/m^3\ ) = 11.04x$ No. Of tracks

$C\ (Bq/m^3) = 154\ Bq/m^3$.

1 pCi/L = 37Bq/m^3.

So, Radon Concentration = 4.2 pCi/L and so on.

The same way was done for rest of detectors.

The standard Deviation (S.D) = 32.7 for Rafah Governorate, and for Khanyonis, S.D = 31.9 .

CHAPTER (5)

RESULTS AND DISCUSSIONS

5.1 Introduction

This chapter aims to evaluate the overall significant results that obtained throughout the present work.

5.2 General Results

We have analysed the collected detectors CR-39 and No. of tracks are determined. The Radon level concentration in Rafah and Khanyonis governorates is measured in Bq/m^3. The results obtained are listed below and expained.

Table (5.1) Shows Radon Concentration for each water sample in Rafah governorate. The results indicate that the difference between the minimum 58 Bq/m^3 and maximum value 154 Bq/m^3.of the Radon concentrations for each well in the governorate is very high. This large variation in Radon concentrations may be mainly due to the difference in the soil type, rock type and the depth of these wells, this clear in wells No.

(P/138, P/152, P/148, P/153) which have high clay. Some locations in rafah governorate that have low level Radon are considered to be rural and farms territories. This is probably due to the little content of clay rocks which contain the main source of Radon in surveyed area.

Table 5.1: Radon concentration for each sample of different wells in Rafah Governorate

Well No.	**C (Bq/m^3)**	**Well No.**	**C (Bq/m^3**
P/138	154	P/153	132
P/152	132	Shoka	99
P/148	143	P/139	77
P/145	110	P/15	110
P/124	70	Fakhari	58
P/144A	66	P/10	78

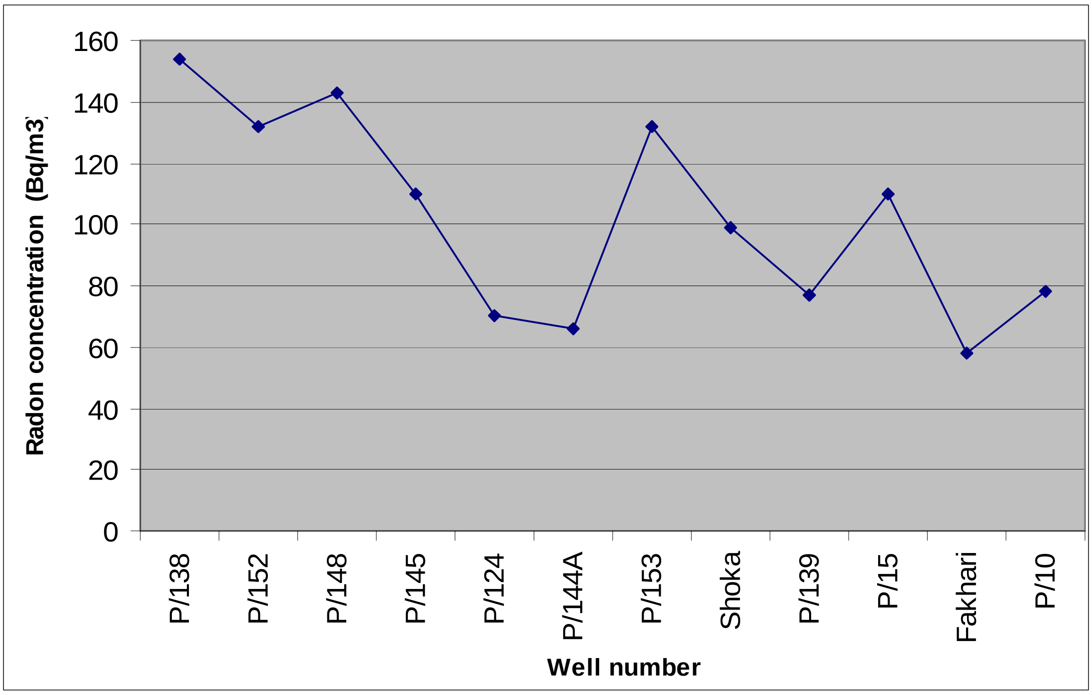


Figure 5.1: Radon concentration for each water sample in Rafah Governortae

The Radon concentration in each water sample in Khanyonis Governorate for different locations measured in Bq/m^3 are given in table (5.2). The arithmetic mean of measurements was 47.8 Bq/m^3 with a range of values between 22 and 132 Bq/m^3 and with average standard deviation of 31.9. The results indicate that the difference between the minimum and maximum Radon concentrations in the governorate is also very high and even higher than in Rafah. This large variation in Radon concentrations may be also, due mainly to the difference in the soil type, rock type and the depth of these wells.

Table 5.2: Radon concentration for each sample of different wells in Khanyonis Governorate

Well No.	C (Bq/m^3)	Well No.	C (Bq/m^3)
L/179A	35	L/190	40
L/173	40	L/87	132
L/86A	35	L/127	77
L/187	25	L/189A	33
L/159	33	L/41	88
L/43	65	L/176	37
L/181	22		

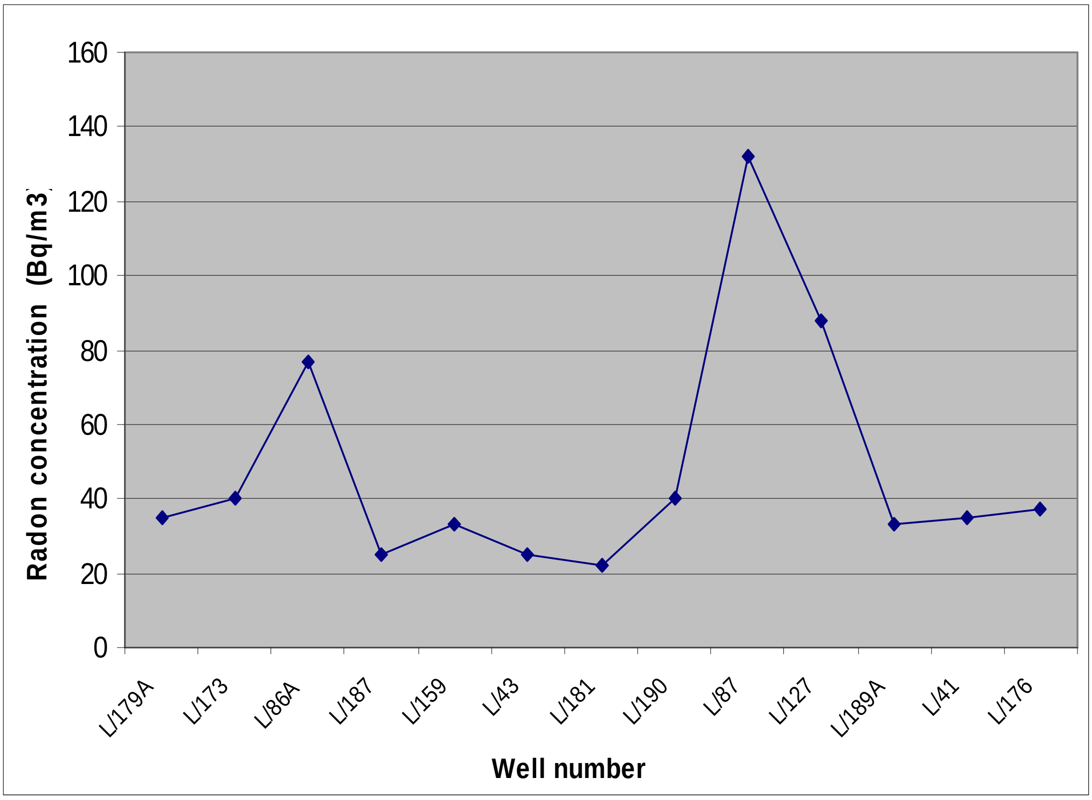


Figure 5.2: Radon concentration for each water sample in Khanyonis Governorate

Most of wells show low level of Radon concentration in Khanyonis governorate, that because of little clay, meanwhile other wells gives high level of Radon and these trends may be due to the soil types, lithology (high clay) and the depth of the wells. The table (5.3) illustrates the numbers of collected detectors from water samples, the minimum and maximum concentrations of Radon in the southern Governorate.

The average Radon concentrations (C) and the standard deviation (S.D.) for each governorate in the location of the survey are also shown in the table (5.3).

Table 5.3: Radon concentrations in each Governorate and S. D.

The Region	No.of detectors	Ave. C(Bq/m^3)	Max. C(Bq/m^3)	Min. C(Bq/m^3)	S.D
Rafah	48	102.4	154	58	32.7
Khanyonis	52	47.8	132	22	31.9
Average	-	75.1	143	40	32.3

The minimum and maximum concentration values of Radon, as well as its average concentration(c) and standard deviations (S.D) for each location are depicted in figure (5.3) for both Rafah and Khanyonis Governorates. It can be noticed that Radon levels in Rafah area is much higher than other region.

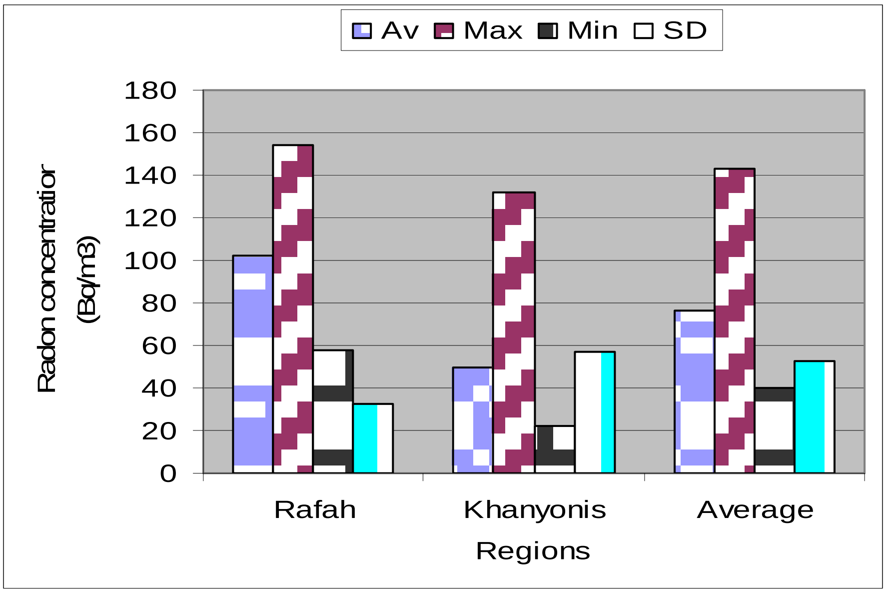


Figure 5.3: Average Radon concentration and S D in the studied area

The Radon levels ranges of values between 58 and 154 Bq/m^3 with average value of 102.4 Bq/m^3 are also obtained and the average standard deviation is 32.7 Bq/m^3.We believe that this variation of levels is mainly due to the difference in rock type, soil type and the geology of the area. This according to soil description which illustrate in an appendix II for some wells of Rafah and Khanyonis Governorate. However, the layers in wells No. (P/152), (P/148), (P153), (P/138) in Rafah Governorate is silty clay and pure clay. These layers considered source as natural radioactive, and in well No L/43 which has low concentration level in Khanyonis governorate, has small layer of clay as shown in table (5.4) and figure (5.4). This estimation is relatively close to that of the international commission on radiological protection (ICRP). However, this study should be followed by additional works covering other wells in the study region in order to get comprehensive information about Radon concentration in Gaza Strip.

Table (5.4): Relation between Radon concentration and Thicknesses of sand and clay layers.

Well No.	Well Depth (m)	Radon Concentration (Bq/m^3)	Thicknessof Sand layer (m)	Thickness of sandy and silty clay layer (m)
P/152	102	132	37	46
P/153	66	132	33	33
P/145	81	110	27	29
P/148	78	143	37	41
P/138	85	154	36	31
L/43	60	65	20	3

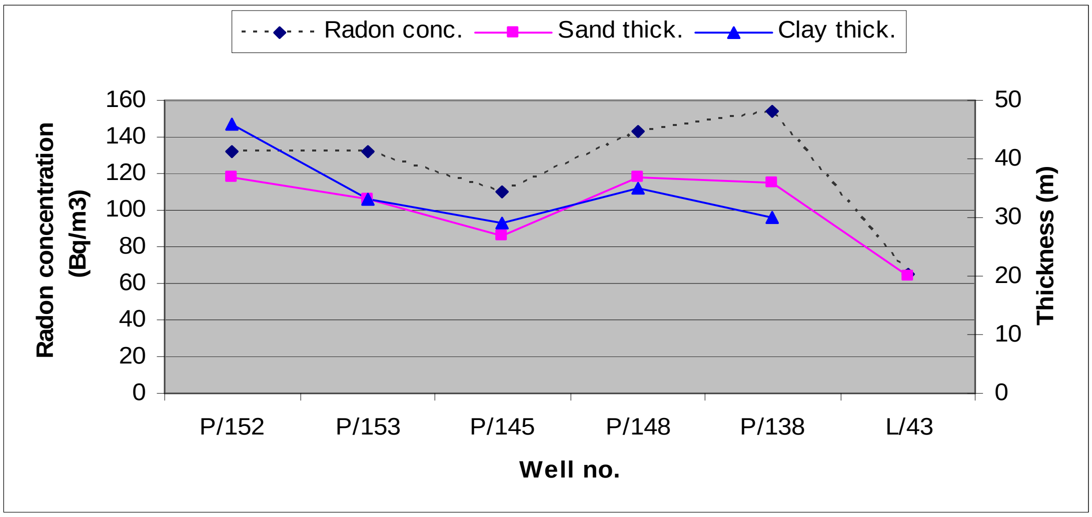


Figure 5.4: Relation between Radon concentration and Layers thicknesses in the study area.

The relation between Radon concentration and both sand and clay thicknesses are illustrated in the figure (5.4). It is well shown that a good relations could be achieved. The figure show both sand and clay thicknesses are in a good correlation with Radon concentration. Radon concentration increases as sand and clay increase.

5.3 Interpretation of contouring map of Radon concentrations

In order to understand the spatial variation of Radon concentration for 25 water well samples, the geographic location (X and Y) of each well and the corresponding measured Radon concentration for well is listed in table (5.5), that used to draw a contour map of the study area. The SURFER Software program is used to draw the contour map of the data that obtained from the study area, and the results are illustrated in figure (5.5)

The figure (5.5) shows that Radon concentrations increase in two directions; the first one is from North to South – and the other from west to east. The map also shows that three large anomalies were well observed. The first one is located in the north east of Khanyonis city, where the two others are in the south west of Rafah. However, more and extensive survey is needed to insure and to explain these anomalies, so that we can identify the factors that effect of Radon concentrations in the study area.

Table 5.5: The geographical location (X and Y) of the wells, depth and Radon concentration for water well samples

Well No.	X	Y	Radon Conc.	Depth
P/138	78773	79765	154	85
P/152	82293	79325	132	102
P/148	78600	80100	143	78
P/145	79369	79856	110	81
P/124	77598	79414	70	60
P/144A	78320	80350	66	73
P/153	77736	80521	132	66
shoka	80450	80400	99	87
P/139	77167	82011	77	60
P/15	77970	78840	110	80
Fakhari	80400	80000	58	56
P/10	78660	77050	78	82
L/179A	85570	87460	35	29
L/173	86635	87475	40	-
L/86A	82235	84663	35	47
L/187	84366	86334	25	23
L/159	82605	85047	33	45
L/43	83063	83461	65	60
L/181	81361	82373	22	42
L/190	85830	87250	40	27
L/87	83040	84200	132	52
L/127	82851	83935	77	52
L/189A	81700	82700	33	50
L/41	84345	83160	88	61
L/176	82187	83277	37	38

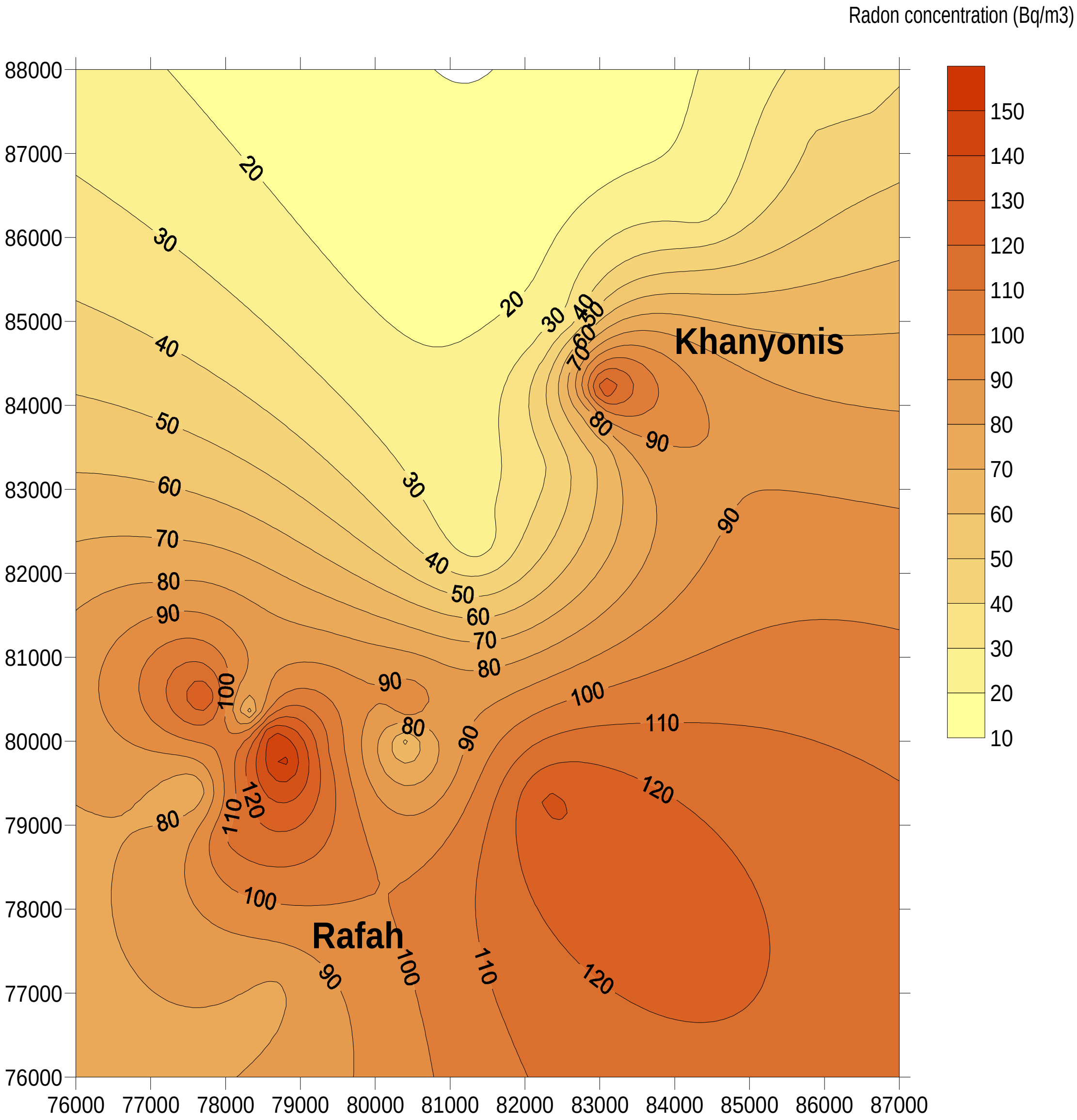


Figure 5.5: Contour map of Radon concentration for the study area

It is believed that the increasing of Radon concentrations in the above mentioned direction are related to soil types, the lithology and the depth of the well which shown in appendix II. In general, we found that the concentration of Radon ranges from (22 – up 154 Bq/m^3) in Khanyonis and Rafah governorates as shown in map (5.5). There is also a remarkable increase in Radon concentration in the wells that lie on the western south of Rafah, in addition to the well L/87 in Khanyonis area. This increase in concentration is due to soil type (sandy clay soil and silty clay or pure clay) where the characteristics of this soil are pointed in table (3.1). In addition, the lithology, soil types and depth of the well that consists of clay layer of heavy thickness, where the clay is known as radiation source.

Despite the safety measures that taken into consideration of nuclear reactor and nuclear institutions that found in adjacent countries, we believe that there is always a leakage of radiation comes from cross boarder. Particularly, the effect of Israel Nuclear reactor (Demona reactor) in Naqab area. So far there is no clear cut evidence to point out of this leakage of radiation. This is due to the lack of nuclear equipment and detectors that available in the country. However, most of the previous studies [43] indicated that there is an increase in the lung cancer diseases and infant fatal in Gaza Strip.

Although the work in this field is not initially meant for a national project, but yet these pits and lots constitute together:

1) A basis for a nation wide characterization of the Palestine in terms of Radon concentration.
2) An acceptable data base for risk estimations from such radiation of water pollutants.

To remedy radiation harmful effects of water pollutants many factors should be taken into consideration. These include the nature of the source of exposure, the type of radiation released from those sources, the nature of the well and soil type in addition to social and economical consideration. As this type of work depends mostly on the developing data base of the environmental radioactivity and radiation dosimetry. Thus, efforts need to be concentrated not only on specified sites of interest, but also to be directed towards other potential situations and factors. To give a rather comprehensive vision, contribution from man – made radiation sources is also required so as to give the annual effective dose values. The contribution of Radon (^{222}Rn) in domestic water supplies has been investigated and found to be significant for concentration over a few hundred Becquerel per cubic meter in water supply.

5.4 Relationship between Radon and depth of the wells

Measurements are also revealed a relationship between the Radon levels and depth (elevations) of wells.

Table (5.6) displays the Radon concentrations with the elevation of wells that measured in Rafah city. These values give the relationship between elevation of wells that ranges (56-102m) and Radon levels of (58-154 Bq/m^3).

The data pertaining to the location of the drilled well, site specific well and well information such as, well discharge rate and well depth. All these data of the wells can be found in the water Palestinian authority [35].

Figure (5.6) illustrates the Radon concentration with the elevation of wells. As can be deduced, the wells with high Radon values seen to be located on high elevations and wells with lower Radon values is comparatively on low elevation. Although, the conclusion is not that obvious for the relative attitude with the depth of wells, however the Radon concentration can be observed at different levels of elevations.

The measured values for Khanyonis city for well elevations are also obtained and give similar trends of significant relationship. This estimate is relatively close to that described by demsar skeppstorm, 2005 [44], who found a relationship between Radon concentrations in water with elevation of wells. The study was carried out in the central part of Stockholm country, where a total of 293 drill wells located in that area have been subject of investigation. However, this study can also be deduced that higher values of Radon correspond to areas with either sand or clay.

Table 5.6: The relationship between the depth of wells and Radon concentration in Rafah Governorate

Well No.	**Well Depth (m)**	**Radon Concentration (Bq/m^3)**
P/138	85	154
P/152	102	132
P/148	78	143
P/145	81	110
P/124	60	70
P/144A	73	66
P/153	66	132
Shoka	87	99
P/139	60	77
P/15	80	110
Fakhari	56	58
P/10	82	78

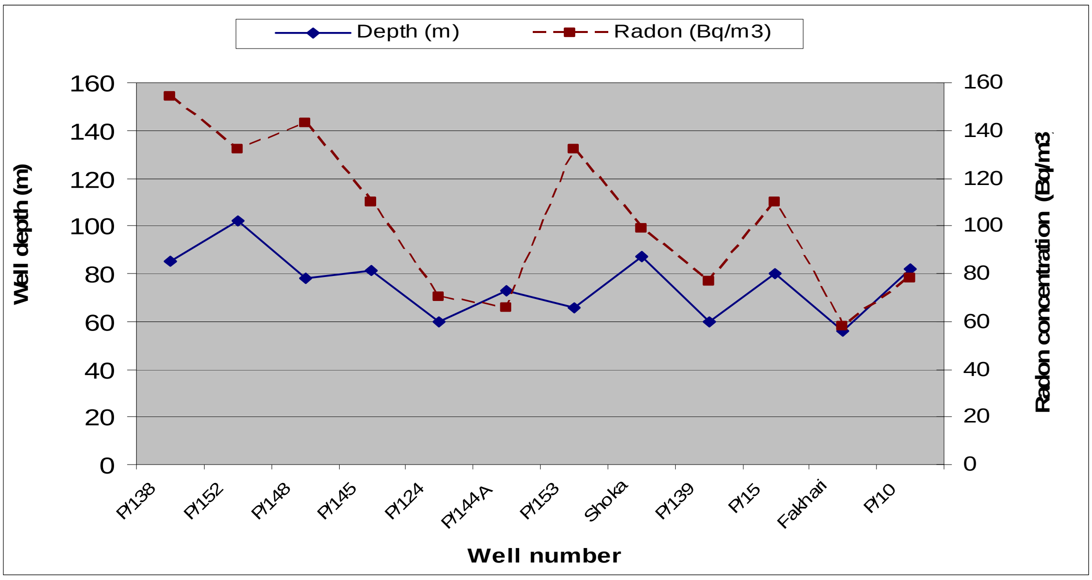


Figure 5.6: The relationship between Radon concentration and wells depth in Rafah Governorate

Table (5.7) displays the Radon concentrations with the elevation of wells that measured in Khanyonis governorate. These Values give the relationship between elevation of wells that ranges (23-61m) and Radon levels of (22-132 Bq/m^3).

Figure (5.7) illustrates the Radon concentration with the elevation of wells. As can be deduced, the wells with high Radon values seen to be located on high elevations and wells with lower Radon values is comparatively on low elevation.

Table 5.7: The relationship between the depth of wells and Radon concentration in Khanyonis Govenorate

Well No.	**Depth of the well (m)**	**Radon Concentration (Bq/m^3)**
L/179A	29	35
L/173	-	40
L/86A	47	35
L/187	23	25
L/159	45	33
L/43	60	65
L/181	42	22
L/190	27	40
L/87	52	132
L/127	52	77
L/189A	50	33
L/41	61	88
L/176	38	37

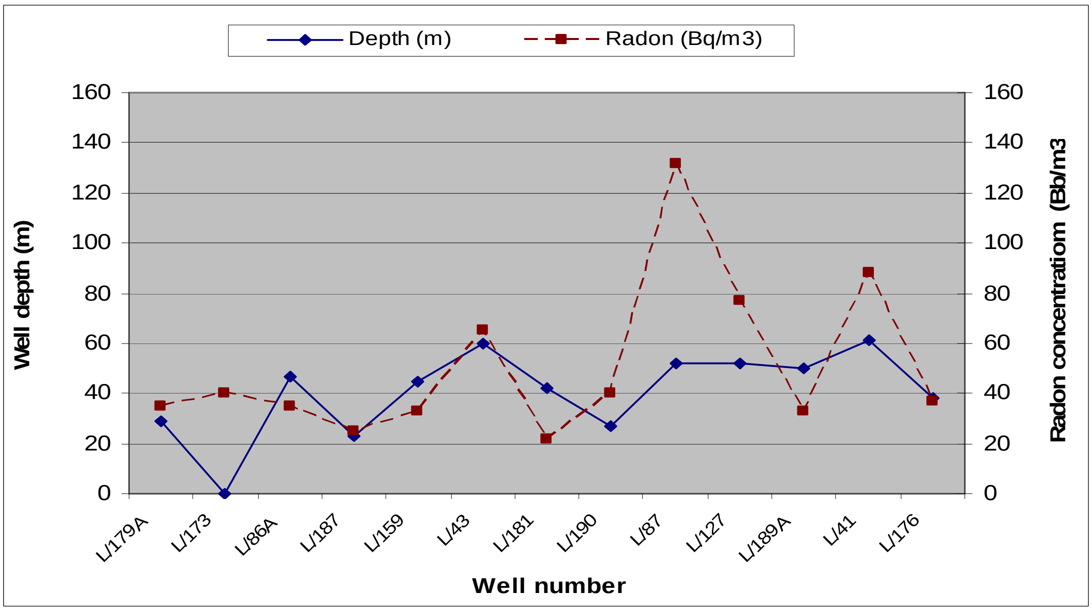


Figure 5.7: The relationship between Radon concentration and wells depth in Khanyonis Governorate.

CHAPTER (6)

CONCLUSIONS AND RECOMMENDATIONS

6.1- Conclusions

Air, soil and water pollution are believed to be responsible for many diseases that spread in the country of Gaza Strip. Natural radiation, Radon gas, present universally in different concentrations in air, soil and water has its harmful impacts on public health and causes lung cancer. This study focus on measuring the Radon levels in groundwater in the southern region of Gaza Strip. Different factors that affected Radon concentration were also investigated.

Radon produced in the soil matrix can easily diffuse to the water trapped in the pore spaces and migrate to groundwater. Radon and its short-lived daughter products represent the main source of exposure to natural radiation. Radon is now believed to be the most important source of ionizing radiation in our environment.

The purpose of our study was to find out an approximate mean and range of Radon concentrations in groundwater. This information can be used to estimate the possible health hazards from Radon in the southern region of Gaza Strip in the future from environmental point view, to promote public awareness related to risk of Radon exposure.

Groundwater samples were collected from twenty five wells and Radon concentration were measured as part of a water-quality. The samples represent the southern region of Gaza Strip, Rafah and Khanyonis. The samples collected from different location covering most of the study area.

CR-39 solid state nuclear track detectors of good quality were used in this survey. Two Detectors were placed inside each water sample as previously described. One is immersed in the water and the other is in the lid of the container facing the water sample. The detectors were left for a period of time of 120 days (for a period during mid of April to mid of August) to allow Radon gas to come to an equilibrium level. The detectors were then collected and chemically etched. Each detector was counted visually using an Optical microscope with a power of (40 x 10), and number of tracks determined.

Results obtained show that the Radon levels in Rafah area range of values between 58 and 154 Bq/m^3 with average value of 102.4 Bq/m^3, and standard deviation (S.D) is

32.7. Also, in Khanyonis area Radon levels range of values between 22 and 132 Bq/m^3 with average value of 47.8 Bq/m^3, and standard deviation (S.D) of 31.9. The variation of levels could be mainly due to the difference in rock type, soil type, depth of the well and the geology of the area.

The relation of Radon concentration with other factors is also investigated in the present work with respect to depth of wells. The results show that the wells with high Radon values noticed to be located on high depth and wells with lower Radon values is comparatively on low depth.

The results normally provide preliminary reconnaissance coverage of Radon concentration in groundwater. However a radiometric survey under certain conditions can be used for geologic mapping. The area surveyed was selected on basis of geological, topographical consideration and other preliminarily studies. This fact is related to the soil (sand and clay) being the primary source of Radon, where we suspect that an industrial nuclear waste are buried in that area.

6.2 Recommendations

The present work suggests the following:

- Set up strategies, methods and save tools for measuring Radon levels, and for taking remedial actions should be taken into account.
- Drawing maps for the radiation pollution in groundwater and the other type of water in Gaza Strip.
- It is important to starting with making epidemiological studies of the general population to determine lung cancer incidence due to high level of radiation, although there is hope for future. This would give a good motivation to remedial the area of radiation pollution and to protect people of radiation risks.
- We recommend upgrading the existing equipments to get better quality and higher resolution.
- The lack of correlation between Radon concentrations in groundwater with respect to elevation of wells indicated that the number of samples collected per geological and geographical factors needed to be increased, performed and analyzed as a function of geological and geographical location.

- We suggest that more research should be followed by additional investigation covering other wells in the region of study.
- Government should decide to issue grants for equipment for reducing the Radon concentration in drinking water used by residents on a daily basis.
- We suggest that more studying to Radon before and after winter because Radon concentrations in ground water vary with time because of dilution by recharge of rainfall.
- It is necessary to involve radiation guidelines within Palestinian standards for groundwater quality.
- More investigation about the radioisotopes in different places in south region of Gaza Strip and the part of the Gaza Strip is required.

REFERENCES

[1] Hem, J.D., Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 2254, 263 p, (1985).

[2] K.A.Narayana,C.Schleebergerb,P.BCharleswortha and K.L.bristowa Effects Of Groundwater On Saltwater Intrusion In The Lower Burdekin Delta, North Queensland [on line] Accessed on May 12,2006 at www.clw.csiro.au/Ibi/publications/Effects%of %groundwater%pumping.pdf.

[3] Almahallawi,k Modeling Interaction of land Use, Urbanization and Hydrological Factors for the analysis of Groundwater Quality in Mediterranean Zone (Example the Gaza Strip, Palestine) Ph.D.Thesis. University of Lille, France, (2004).

[4] Otton, J.K., The geology of Radon: U.S. Geological Survey, General Interest Publications of the U.S. Geological Survey, 28 p, (1992).

[5] Radiation all around us, from www.Physics.isu.edu/radinf/natural.html.

[6] United Nation Scientific Committee on Atomic Radiation,UNSCEAR: sources and Effects of ionizing radiation, A/AC-82/r, 441:113-120, (1986).

[7] Mahmoud Rasas, “Measurement of Radon and Its daughter’s Concentrations Indoor and outdoor Throughout Gaza Strip", Islamic University of Gaza, (2003).

[8] Saeed A. Durrani and Radomir Ilic, “Radon measurements by etched track detectors,” Applications in radiation protection, earth science and the environment, printed in Singapore, (1997).

[9] The Radon Information Center, “The Radon facts sheet”, from www.Radon.com/Radon/Radon_facts.html, (1999).

[10] Mose, D.G., Mushrush, G.W, and Chrosinak, C., 1990, Radioactive hazard of potable water in Virginia and Maryland: Bulletin of Environmental Contamination and Toxicology, v. 44, no. 4, p. 508-513.

[11] U. S. Environmental Protection Agency and Centers for Disease Control, A citizen's guide to Radon - The guide to protecting yourself and your family from Radon (2d ed.): EPA 402-K92-001, 15 p, (1992).

[12] Palestinian Water Authority PWA, Agricultural and Municipal Water Demand in Gaza Governorate, Strategic Planning Department, Water Resource and Planning Directorate, Gaza, Palestine, (2005).

[13] Virk, H.S. and Singh, B. Radon Anomalies in soil-gas and groundwater as earthquake precursor phenomena. Tectonophysics, Vol. 27: 215-224, (1993).

[14] Wayne M. Lowder: "Natural Environmental Radioactivity And Radon Gas", (1989).

[15] David Bodansky, Maurice, A. Robkin and David R. Stadler, “Indoor Radon and Its Hazards,” Univ. of Washington Press Seattle and London, second edition, printed in the U. S. A, (1989).

[16] United States Environmental Protection Agency office of Air and Radiation, “A Citizen’s guide to Radon,” Indoor Environments Division 6609 J, EPA Document 402-k92-001, third edition, (2001), from www.epa.gov/iaq/iaqxline.html.

[17] Faure, G., Principles of isotope geology: New York, John Wiley and Sons, Inc., 589 p, (1986).

[18] Senior, L.A., Radon-222 in the ground water of Chester County, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 98-4169, 79p, (1998).

[19] R. Ilic: "Damage Track Detectors for Alpha Particle Registration - Track Formation and Detector Processing", (1989).

[20] Michel J Relationship of radium and Radon with geological formations. In C.R. Cothern and P. Rebers (Editors) Radon, Radium and Uranium in Drinking Water. Lewis Publishers, Chelsea, (1990).

[21] Ball TK, Cameron DG, Colman TB and Roberts PD. Behavior of Radon in the geological environment: a review. Quarterly Journal of Engineering Geology (London), 24: 16,(1991).

[22] Norwegian Radiation Protection Authority, Anbefalte tiltaksnivەer for Radon. (In Norwegian). Recommended action levels for Radon in the home and work-place. Statens strolevern, Norway Brochure no. 5, (1995).

[23] Crawford-Brown, D.J., Analysis of the health risk from ingested Radon, chap. 2 of Cothern, C.R., and Rebers, P.A., Radon, radium and uranium in drinking water: Chelsea, Michigan, Lewis Publishers, Inc., p. 17-26,(1990).

[24] Cothern, C.R., Estimating the health risks of Radon in drinking water: Journal of the American Water Works Association, v. 79, no. 4, p. 153-158, (1987).

[25] U. Kafri, Radon in groundwater as a tracer to assess flow velocities: two test cases from Israel, Journal of Environmental Geology, Earth and Environmental Science, v.40, no.3, p. 247-398, (2001).
http://www.springerlink.com/content/59np11huwyw9yda3/?
http://www.springerlink.com/content/4hw318bet8nk/

[26] John F. DeWild and James t. Krohelski, “Radon Concentration in Groundwater and Soil Gas on Indian Reservation in Wisconsin."

[27] Skeppström, Kirlna Radon in Groundwater- Influencing Factors and Prediction Methodology for a Swedish Environment,(2007-01-10), (2005).
http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-491

[28] Nabil Hamed, “Measurement of Radon Concentration in Soil at North Gaza", Islamic University of Gaza, 2005.

[29] Abu Mayla, Y. and Aish, A. Water Resources Program in Gaza Strip. Submitted in Regional Meeting of IHP 8-12 September, 1997 Rabat, Marocco, (1997).

[30] Abu Mayla, Y.; Abu-Jabbal, M.; and El-Baba, M. Water Resources Management and Development in Gaza Strip – Palestine. Paper Presented at Conference of Water and Food Security in the Middle East 20-23 April 1998. Nicosia, Cyprus, (1998).

[31] Al-Agha, M.R. Environmental contamination of Groundwater in Gaza Strip. Environmental Geology, col.75:pp.109-113, (1995).

[32] Bruins, H.J. Tuinhof, A. and Keller, R. Water in the Gaza Strip Hydrology Study Final Report. Government of the Netherlands Ministry of Forejen Affairs Directorate General International Cooperation,(1991).

[33] Environmental planning Directorate, Policy Direction in Groundwater Protection and Pollution Control. The Palestinian Authority Ministry of Planning and International Cooperation. Gaza, (1996),

[34] Mogheir, Y. Salt Water Intrusion Modeling and Monitring in the Gaza Strip Aquifer. MSc Thesis. IHE, Delft, The Netherlands, (1997).

[35] (PWA) USAID, Coastal Aquifer Management Program (CAMP), Integrated Aquifer Management Plan (task -3) Appendix A, Palestinian Water Authority, Gaza, Palestine, (2000).

[36] Palestinian Central Bureau of Statistics (PCBS), Population and Housing and Establishment Census, 1997. Palestinian National Authority, (2003).

[37] Al-Yaqubi, A.S. Water resources and Management Issue
(Gaza Strip). Water resources and Planning Dept., PWA/PNA. July 2001, pp 24, (2001).

[38] Abu Heen, Z.H. and Lubbad, S. H. Assessment of Groundwater Quality in Gaza city (south of Palestine) during the period (1994-2004). Proceeding of the 9th international water technology conference, sharm al- Sheekh, Egypt, 1: 431-443, (2005).

[39] World Health Organization (WHO). Guidelines for Drinking- Water Quality – 2nd ed. Vol. 2. Health criteria and other supporting information. Geneva, pp. 201-206, (1998).

[40] Palestinian Water Authority (PWA) and Coastal Aquifer Management Program (CAMP). Basis of Design Report and Design Criteria For Gaza Regional Water Carries. (Task-26). PWA, CAMP. Vol. 2. Gaza. January 2003, pp, (2003).

[43] Ministry of Health (MOH), Annual report, the status of health in Palestine, (2002).

[44] Ministry of Planning and International Corporation (MOPIC).Techincal Maps for Gaza Governorate, First Version. Gaza, Palestinian National Authority, (1997).

[45] Riyad Awad, Omar Abu Arquob, The Status in Health in Palestine, "Palestine annual report," (2002).

[46] Albu M, Banks D and Nash H 1997. Mineral and Thermal Groundwater Resources. Chapman and Hall, London, 447 pp.

GLOSSARY

Aquifer: An underground geological formation able to store and yield water.

Alpha particle: The nucleus of the helium isotope of mass 4 u; emitted in the decay of some heavy radioactive nuclei.

Becquerel (Bq): The S. I. Unit of rate of radioactive decay; 1 Bq equals 1 disintegration per second.

Beta particle: An electron (with either negative or positive charge); emitted in the decay of some radioactive nuclei.

Confined aquifer: (also known as artesian or pressure aquifers) exist where the groundwater is bounded between layers of impermeable substances like clay or dense rock. When tapped by a well, water in confined aquifers is forced up, sometimes above the soil surface. This is how a flowing artesian well is formed.

Contaminant: Any substance that when added to water (or another substance) makes it impure and unfit for consumption or an intended use.

Cosmic rays: High-energy radiations arriving at the earth from space. These radiations originate both from the sun and from beyond the solar system.

Curie (Ci): A unit of rates radioactive decays; Curie is measure of the number of atoms disintegrating per second in radioactive material. One Ci is equal to 3.7×10^{10} disintegrations per second.

Daughter: The atom produced by the decay of a radioactive parent atom.

Decay chain: A radioactive isotope and the series of radioactive daughter, which are generated from it through a succession of radioactive decays. The chain ends when one of the daughters is non-radioactive..

Emanation: The gas emitted from a solid or liquid. Radon was originally called (emanation) since it was emitted by radium.

Gamma ray: Radiation, similar to x-ray and light, emitted the decay of some radioactive nuclei.

Gray: The S. I. unit of physical dose, i.e., the unit of deposition of energy in material due to the passage radiation; 1 Gray equals 1 joule per kilogram.

Groundwater: Water found in the spaces between soil particles and cracks in rocks underground (located in the saturation zone). Groundwater is a natural resource that is used for drinking, recreation, industry, and growing crops.

Groundwater Contamination: the word "contamination" implies that human activities have increased the concentration a constituent, through not necessarily harmful.

Groundwater Pollution: contaminant levels that exceed acceptable limits result in pollution. Groundwater pollution is any physical chemical or biological change in groundwater quality that has a harmful effect on living organisms or makes water unsuitable for desired uses.

Hydrogeology: The study of the interrelationships of geologic materials and processes with water, especially groundwater.

Hydrologic cycle: (also known as the water cycle) The paths water takes through its various states--vapor, liquid, solid--as it moves throughout the oceans, atmosphere, groundwater, streams, etc.

Hydrology: The study of the occurrence, distribution, and chemistry of all waters of the earth.

Half-life time ($t_{1/2}$): The time required for the number of radioactive nuclei present at any instant of time to be reduced by a factor of two, due to radioactive decay.

Fresh water: Water with less than 0.5 parts per thousand dissolved salts are generally drilled into aquifers that are not used as a drinking water source, unused aquifers, or below freshwater levels.

Leachate: Liquids that have percolated through a soil and that carry substances in solution or suspension.

Leaching: The process by which soluble materials in the soil, such as salts, nutrients, pesticide chemicals, or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water.

Impermeable layer: A layer of material (such as clay) in an aquifer through which water does not pass.

Infiltration: Flow of water from the land surface into the subsurface.

Infiltration rate: The quantity of water that enters the soil surface in a specified time interval. Often expressed in volume of water per unit of soil surface area per unit of time.

Injection well: A well constructed for the purpose of injecting treated water, often wastewater, directly into the ground. Water is generally forced (pumped) into the well for dispersal or storage into a designated aquifer. Injection wells.

Interflow: Water that travels laterally or horizontally through the aeration zone during or immediately after a precipitation event and discharges into a stream or other body of water.

ICRP: The International Commission on Radiological Protection; international group of experts who recommend limits for exposure to ionizing radiation to the international community.

Ionization radiation: Radiation with the ability to interact with and remove electrons from the atoms of material, leaving the atom ionized.

Maximum contaminant level (MCL): Designation given by the U.S. Environmental Protection Agency (EPA) to drinking water standards promulgated under the Safe Drinking Water Act. A MCL is the greatest amount of a contaminant allowed in drinking water without causing a risk to human health.

Municipal water system: A network of pipes, pumps, and storage and treatment facilities designed to deliver potable water to homes, schools, businesses, and other users in a city or Permeable/Permeability: Capable of transmitting water (porous rock, sediment, or soil); the rate at which water moves through rocks or soil.

NCRP: The National Council on Radiation Protection and Measurements; a congressionally chartered group of experts who are charged with studying the effects of exposure to ionizing radiation and recommending protective measures.

Noble gas: A noble gas is gaseous element with negligible chemical reactivity. Helium, neon, argon, krypton, xenon and Radon are noble gases. Radon is the only radioactive noble gas.

NRC: Nuclear Regulatory Commission; also National Research Council.

Potential alpha energy: The amount of alpha-particle kinetic energy that can be dissipated within an atmosphere containing some particular mixture of short-lived daughters of Radon, if they all decay there.

Rad (rad): A traditional unit of physical radiation dose, i.e., the unit of deposition of energy in material due to the passage of ionizing radiation; 1 rad equals 100 ergs per gram.

Radioactivity: The process by which an atom changes spontaneously into a different atom by the emission of an energetic particle from its nucleus.

Permeable layer: A layer of porous material (rock, soil, unconsolidated sediment); in an aquifer, the layer through which water freely passes as it moves through the ground.

Pollution: An alteration in the character or quality of the environment, or any of its components, that renders it less suited for certain uses. The alteration of the physical, chemical, or biological properties of water by the introduction of any substance that renders the water harmful to use.

Pore space: Openings between geologic material found underground. Also referred to as void space or interstices.

Porosity: The ratio of the volume of void or air spaces in a rock or sediment to the total volume of the rock or sediment. The capacity of rock or soil to hold water varies with the material. For example, saturated small grain sand contains less water than coarse gravel.

Potable water: Water of a quality suitable for drinking.

Precipitation: The part of the hydrologic cycle when water falls, in a liquid or solid state, from the atmosphere to Earth (rain, snow, sleet).

Recharge: Water added to an aquifer. For example, when rainwater seeps into the ground. Recharge may occur artificially through injection wells or by spreading water over groundwater reservoirs.

Recharge rate: The quantity of water per unit of time that replenishes or refills an aquifer.

Runoff: Precipitation that flows over land to surface streams, rivers, and lakes.
Radium: A naturally occurring radioactive element whose decay produces Radon. Radium is a number of the decay chain of uranium.

Radon daughters: The term (Radon daughters) usually refers to the short-lived radioisotopes in the decay chain of Radon down to Lead-210. These are Polonium-218, Lead-214, Bismuth-214 and Polonium-214.

Radon: Radon-222, radioactive noble gas generated by the decay of radium.

Relative risk: A risk of an adverse health effect due to some injury which is proportional both to the magnitude of the injury and to the usual rate of occurrence of the adverse health effect in the population at risk.

Rem (rem): A traditional unit of dose equivalent used to express on a common basis the health hazard from different kinds of radiation; the dose equivalent in rem is equals to the product of quality factor (other modifying factors, if used) and the physical dose in rad. (1 rem = 10^{-2} sieverts).

Sievert (Sv): The S. I. Unit of dose equivalent is used to express on a common basis the health hazard from different kinds of radiation; the dose equivalent in sieverts is equals to the product of quality factor and the physical dose in grays. (1 Sv = 100 rem).

Salinization: The condition in which the salt content of soil accumulates over time to above normal levels; occurs in some parts of the world where water containing high salt concentration evaporates from fields irrigated with standing water.

Soil: The top layer of the Earth's surface, containing unconsolidated rock and mineral particles mixed with organic material.

Soil moisture: Water contained in the aeration or unsaturated zone.

Specific activity: The amount of activity in a unit amount of material. Usually specified as amount of activity per unit mass, e.g., pCi/g.

Wastewater: Water that contains unwanted materials from homes, businesses, and industries; a mixture of water and dissolved or suspended substances.

Water quality: The chemical, physical, and biological characteristics of water with respect to its suitability for a particular use.

Water quality standards: Recommended or enforceable maximum contaminant levels of chemicals or materials (such as nitrate, iron, and arsenic) in water. These levels are established for water used by municipalities, industries, agriculture, and recreations.

Water table: The top of an unconfined aquifer; indicates the level below which soil and rock are saturated with water. The upper surface of the saturation zone

Well: A bored, drilled or driven shaft, or a dug hole whose depth is greater than the largest surface dimension and whose purpose is to reach underground water supplies to inject, extract or monitor water.

Working level (WL): One working level is that amount of potential alpha-particle energy dissipated in air by the short-lived daughters in equilibrium with 101.3 pCi/l of Radon. One WL is equal to 130000 MeV of alpha-particle energy deposited per liter of air.

Unconfined aquifers: An aquifer in which the water table is at or near atmosphere pressure and is the upper boundary of the aquifer. Because the aquifer is not under pressure the water level in a well is the same as the water table outside the well.

X-ray: Radiation similar to gamma rays and light emitted during rearrangements of the inner electrons surrounding an atom.

APPENDIX (I)

Sample collection form

Area Name: Rafah……………………, Khanyonis…………………….………………..
Sample No:……………………………………………………………………….………
Well Name: …………………………………………………………………………
Well No : …………………………………………………………………………
Water Type: Groundwater (***Domestic Water***) from Rafah and Khanyonis municipality..
Sample Date:………………………………………………………………………
Well Depth:…………………………………………………………………………….
Water Volume:…One Liter………………………………………………………..
Number of detectors……One Hundred Detectors……………………..................
Detectors type :……CR-39……………………………………………….…...............

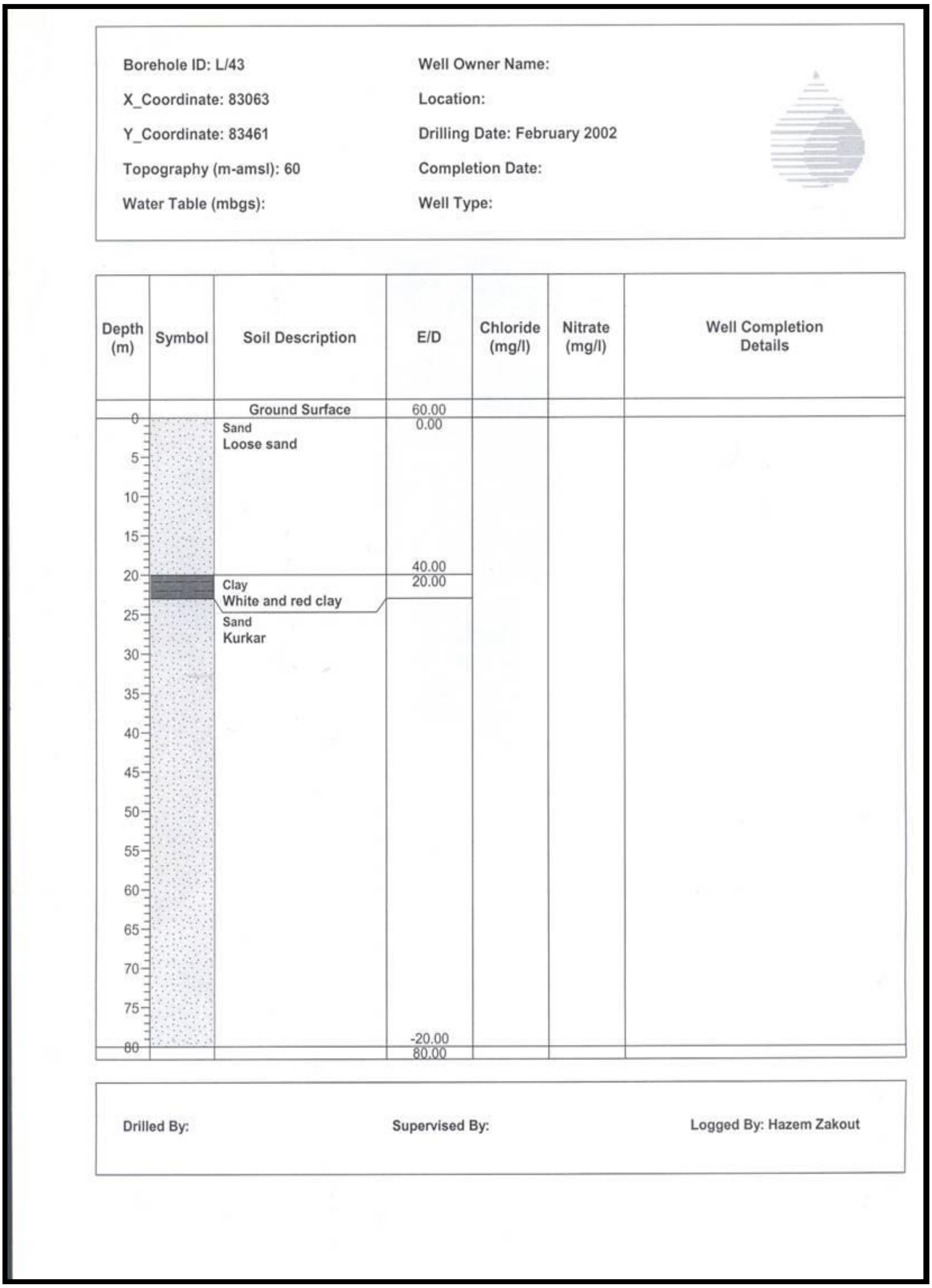
Exposure Period:
Date of Detectors Distribution: 15/4/2006
Date of Detectors Collective The: 15/8/2006

Sample No.	**Detector serial No.**	**Number of Track**	**Radon Concentration in the samples (Bq/m^3)**	**Standard Deviation**

Comments:…………………………………………………………………………..

APPENDIX II

Borehole geologic description



Borehole ID: L/43

X_Coordinate: 83063

Y_Coordinate: 83461

Topography (m-amsl): 60

Water Table (mbgs):

Well Owner Name:

Location:

Drilling Date: February 2002

Completion Date:

Well Type:

Depth (m)	Symbol	Soil Description	E/D	Chloride (mg/l)	Nitrate (mg/l)	Well Completion Details
		Ground Surface	60.00 0.00			
0		Sand Loose sand				
20		Clay White and red clay	40.00 20.00			
		Sand Kurkar				
80			-20.00 80.00			

Drilled By:

Supervised By:

Logged By: Hazem Zakout

Borehole ID: P/152

X_Coordinate: 82293.49

Y_Coordinate: 79324.88

Topography (m-amsl): 68

Water Table (mbgs): 67.85

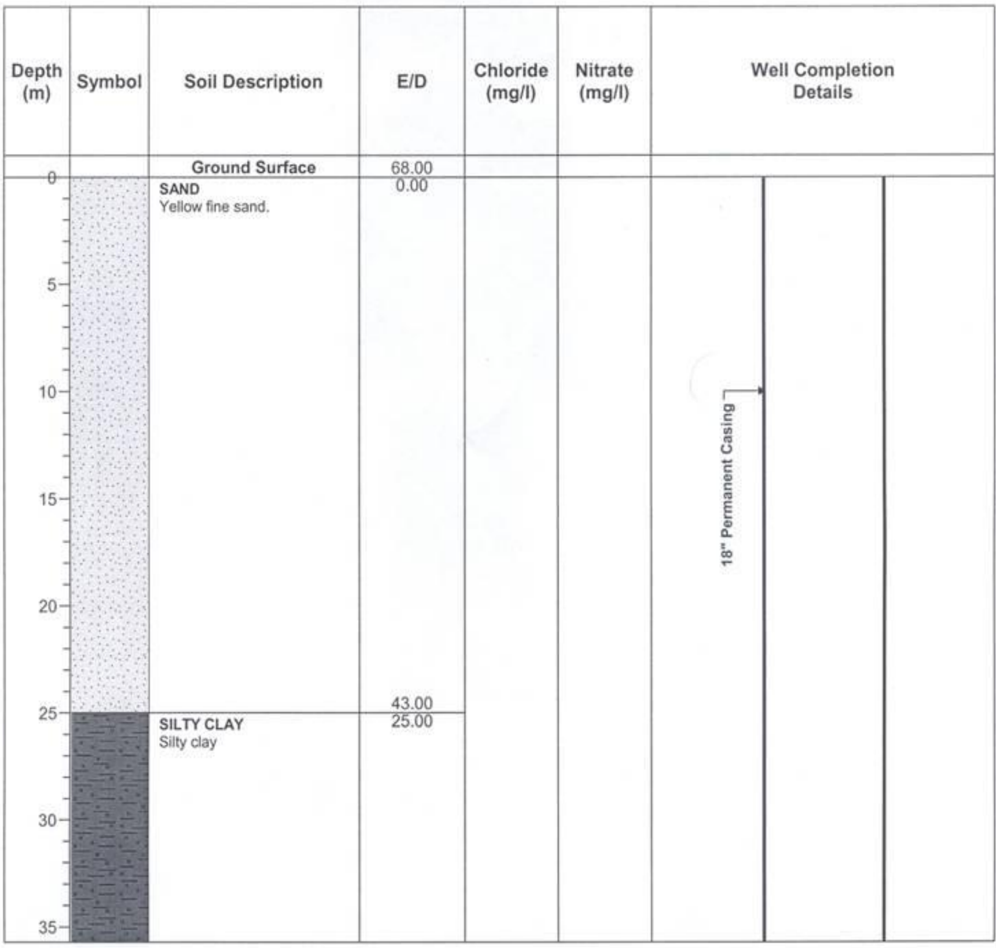
Well Owner Name: El-Fukhari & El-Shokha Municipality

Location: Rafah

Drilling Date: March 2000

Completion Date: April 2000

Well Type: Municipal



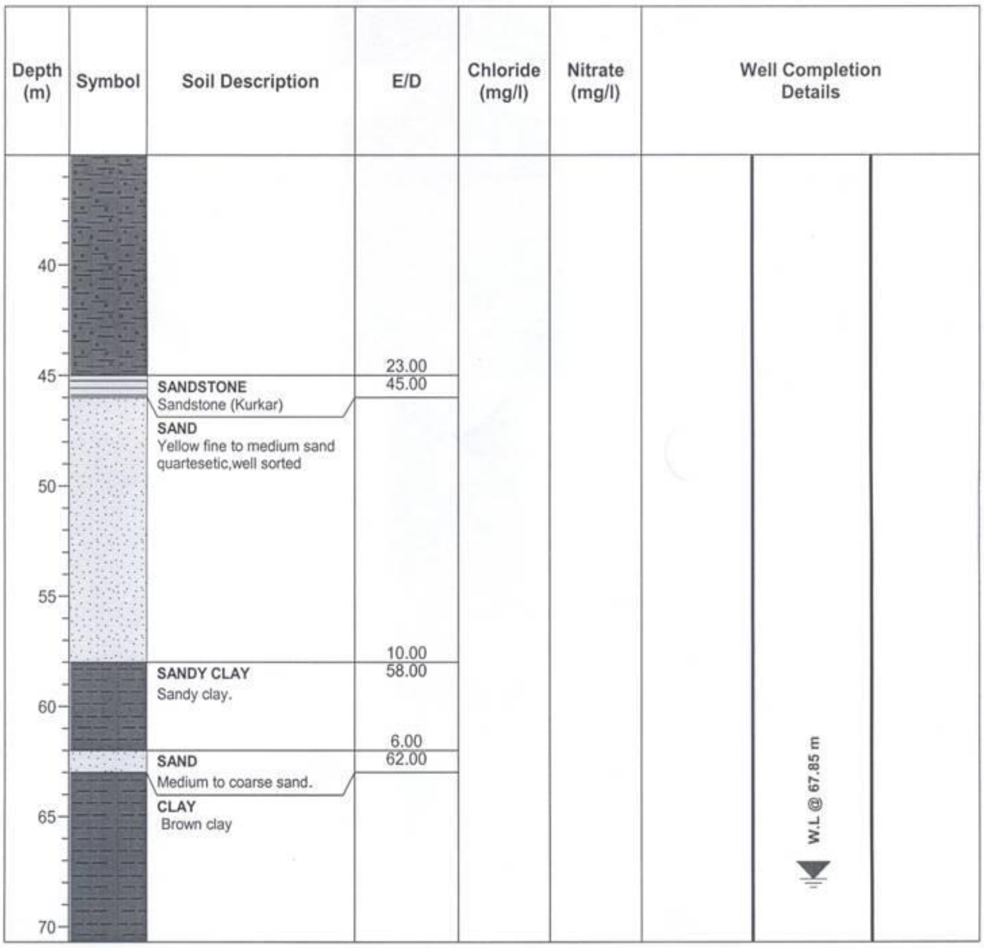
Drilled By:

Supervised By: PWA

Logged By: Hazem Zakout

Borehole ID: P/152
X_Coordinate: 82293.49
Y_Coordinate: 79324.88
Topography (m-amsl): 68
Water Table (mbgs): 67.85

Well Owner Name: El-Fukhari & El-Shokha Municipality
Location: Rafah
Drilling Date: March 2000
Completion Date: April 2000
Well Type: Municipal



Depth (m)	Symbol	Soil Description	E/D	Chloride (mg/l)	Nitrate (mg/l)	Well Completion Details
		SANDSTONE Sandstone (Kurkar)	23.00 45.00			
		SAND Yellow fine to medium sand quartesetic,well sorted				
		SANDY CLAY Sandy clay.	10.00 58.00			
		SAND Medium to coarse sand.	6.00 62.00			
		CLAY Brown clay				

Drilled By:

Supervised By: PWA

Logged By: Hazem Zakout

Borehole ID: P/152

X_Coordinate: 82293.49

Y_Coordinate: 79324.88

Topography (m-amsl): 68

Water Table (mbgs): 67.85

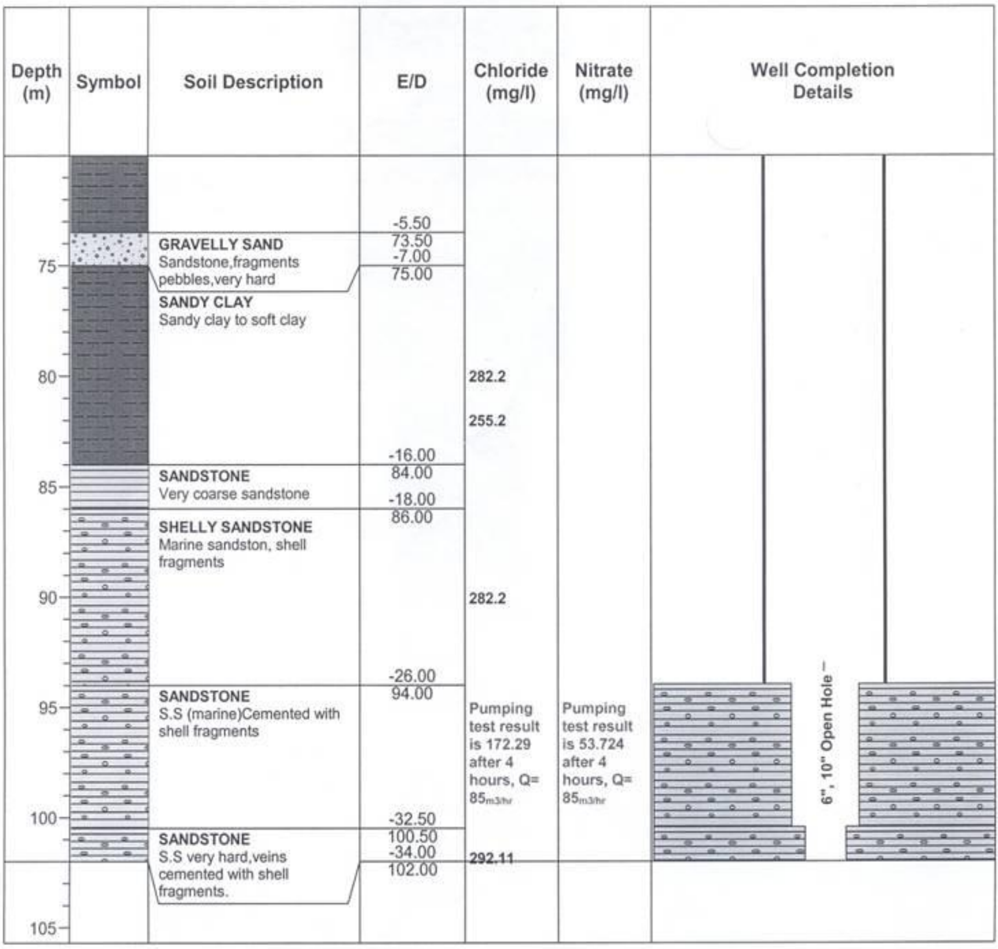
Well Owner Name: El-Fukhari & El-Shokha Municipality

Location: Rafah

Drilling Date: March 2000

Completion Date: April 2000

Well Type: Municipal

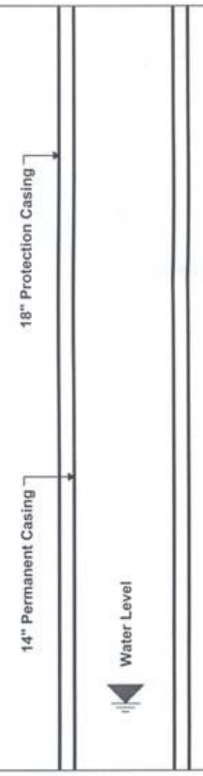


Drilled By:

Supervised By: PWA

Logged By: Hazem Zakout

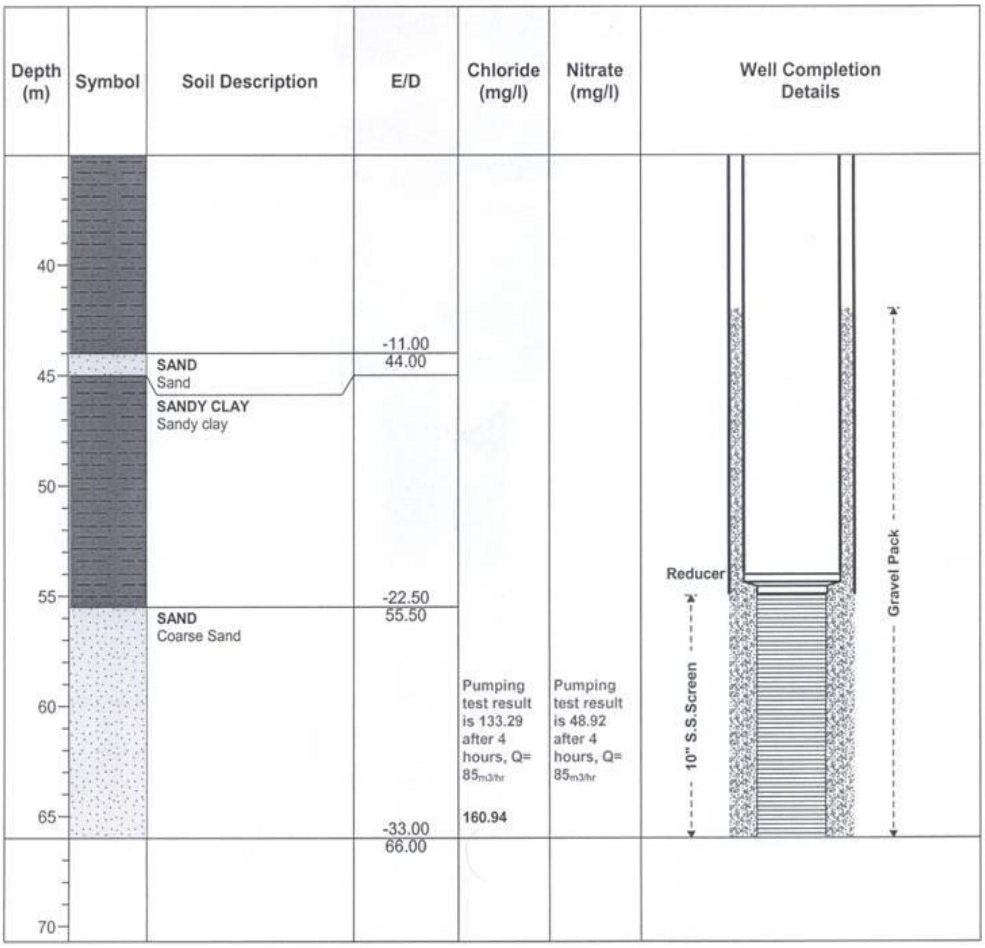
Borehole ID: P/153	**Well Owner Name:** Rafah Municipality
X_Coordinate: 77736.61	**Location:** Rafah
Y_Coordinate: 80521.123	**Drilling Date:** March 2000
Topography (m-amsl): 33	**Completion Date:** April 2000
Water Table (mbgs): 32.60	**Well Type:** Municipal_ Al-Eskan

Depth (m)	Symbol	Soil Description	E/D	Chloride (mg/l)	Nitrate (mg/l)	Well Completion Details
		Ground Surface	33.00			
0 5 10 15	░	**SAND** Fine yellow sand	0.00 15.00			
20 25	▓	**SILTY CLAY** Brown silty clay	18.00 5.00			
30	░	**SAND** Fine to medium sand	28.00 1.00			
35	▓	**SANDY CLAY** Sandyclay	32.00			

Drilled By: **Supervised By:** PWA **Logged By:** Yasir & Rena

Borehole ID: P/153
X_Coordinate: 77736.61
Y_Coordinate: 80521.123
Topography (m-amsl): 33
Water Table (mbgs): 32.60

Well Owner Name: Rafah Municipality
Location: Rafah
Drilling Date: March 2000
Completion Date: April 2000
Well Type: Municipal_ Al-Eskan



Pumping test result is 133.29 after 4 hours, Q= $85_{m3/hr}$

Pumping test result is 48.92 after 4 hours, Q= $85_{m3/hr}$

Drilled By:

Supervised By: PWA

Logged By: Yasir & Rena

Borehole ID: P/145

X_Coordinate: 79368.62

Y_Coordinate: 79856.37

Topography (m-amsl): 48.21

Water Table (mbgs): 51.68

Well Owner Name: Rafah Municipality

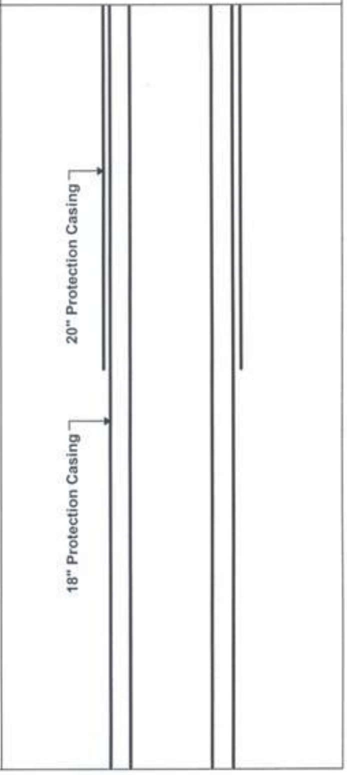
Location: Rafah

Drilling Date: October 1997

Completion Date:

Well Type: Municipal _ El-Hashash

Depth (m)	Symbol	Soil Description	E/D	Chloride (mg/l)	Nitrate (mg/l)	Well Completion Details
		Ground Surface	48.21			
0	░	**SAND** sand and clayey sand	0.00 32.21			
16	▦	**SANDY CLAY** sandy clay	16.00 18.21			
30	≡	**SANDSTONE** sandstone	30.00 13.21			
35	░	**SAND** sand	35.00 8.21			
40	▦	**SANDY CLAY** sandy clay	40.00 3.21			
45			45.00			



Drilled By:

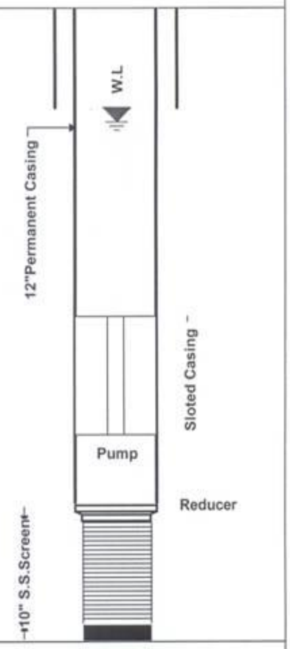
Supervised By: PWA

Logged By: Yasir & Rena

Borehole ID: P/145
X_Coordinate: 79368.62
Y_Coordinate: 79856.37
Topography (m-amsl): 48.21
Water Table (mbgs): 51.68

Well Owner Name: Rafah Municipality
Location: Rafah
Drilling Date: October 1997
Completion Date:
Well Type: Municipal _ El-Hashash

Depth (m)	Symbol	Soil Description	E/D	Chloride (mg/l)	Nitrate (mg/l)	Well Completion Details
		SAND sand	-1.79 50.00			
50		**SANDSTONE** sandstone	-10.79 59.00			
60		**CLAY** clay	-15.79 64.00			
65		**SANDSTONE** sandstone	-21.79 70.00			
70		**CLAY** clay	-26.79 75.00			
75		**SANDSTONE** sandstone	-32.79 81.00			
80		**SAND** sand				
85				77		
90				154		



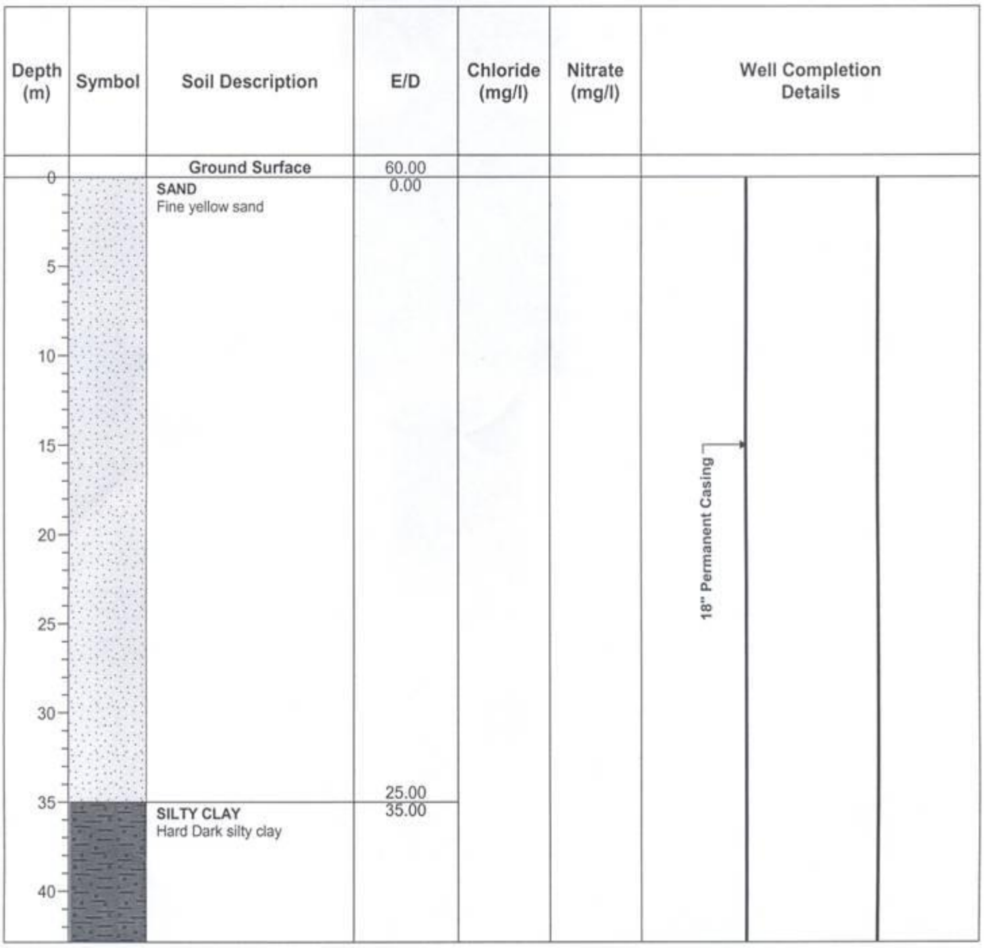
Drilled By:

Supervised By: PWA

Logged By: Yasir & Rena

Borehole ID: P/148
X_Coordinate: 78600
Y_Coordinate: 80100
Topography (m-amsl): 49
Water Table (mbgs): 52.30

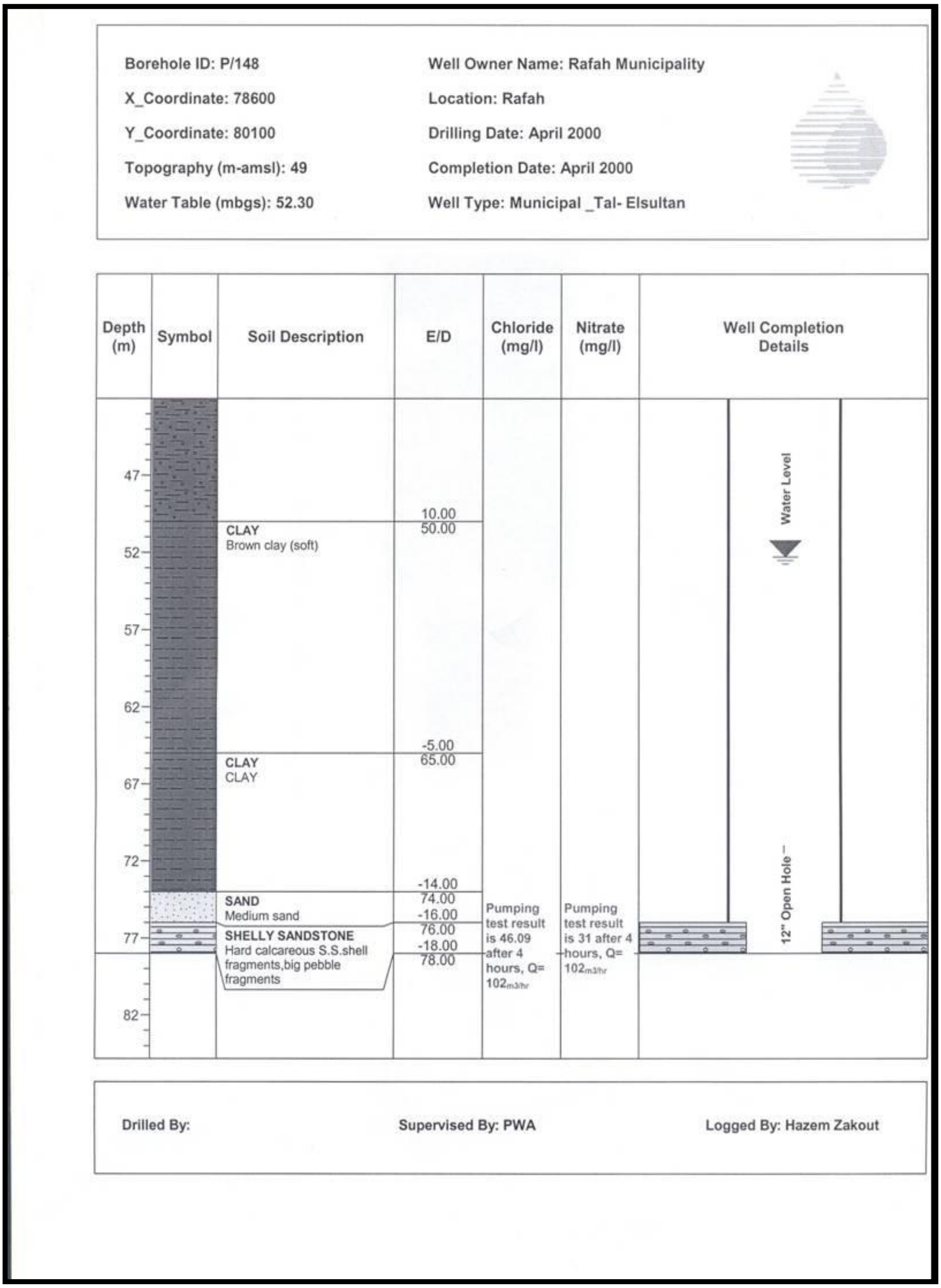
Well Owner Name: Rafah Municipality
Location: Rafah
Drilling Date: April 2000
Completion Date: April 2000
Well Type: Municipal _Tal- Elsultan



Drilled By:

Supervised By: PWA

Logged By: Hazem Zakout



Borehole ID: P/148

X_Coordinate: 78600

Y_Coordinate: 80100

Topography (m-amsl): 49

Water Table (mbgs): 52.30

Well Owner Name: Rafah Municipality

Location: Rafah

Drilling Date: April 2000

Completion Date: April 2000

Well Type: Municipal _Tal- Elsultan

Depth (m)	Symbol	Soil Description	E/D	Chloride (mg/l)	Nitrate (mg/l)	Well Completion Details
47 52 57 62		**CLAY** Brown clay (soft)	10.00 50.00			Water Level
67 72		**CLAY** CLAY	-5.00 65.00			
		SAND Medium sand	-14.00 74.00			
77		**SHELLY SANDSTONE** Hard calcareous S.S.shell fragments,big pebble fragments	-16.00 76.00 -18.00 78.00	Pumping test result is 46.09 after 4 hours, Q= 102m3/hr	Pumping test result is 31 after 4 hours, Q= 102m3/hr	12" Open Hole
82						

Drilled By:

Supervised By: PWA

Logged By: Hazem Zakout

Borehole ID: P/138

X_Coordinate: 78772.697

Y_Coordinate: 79764.797

Topography (m-amsl): 47.72

Water Table (mbgs): 52.35

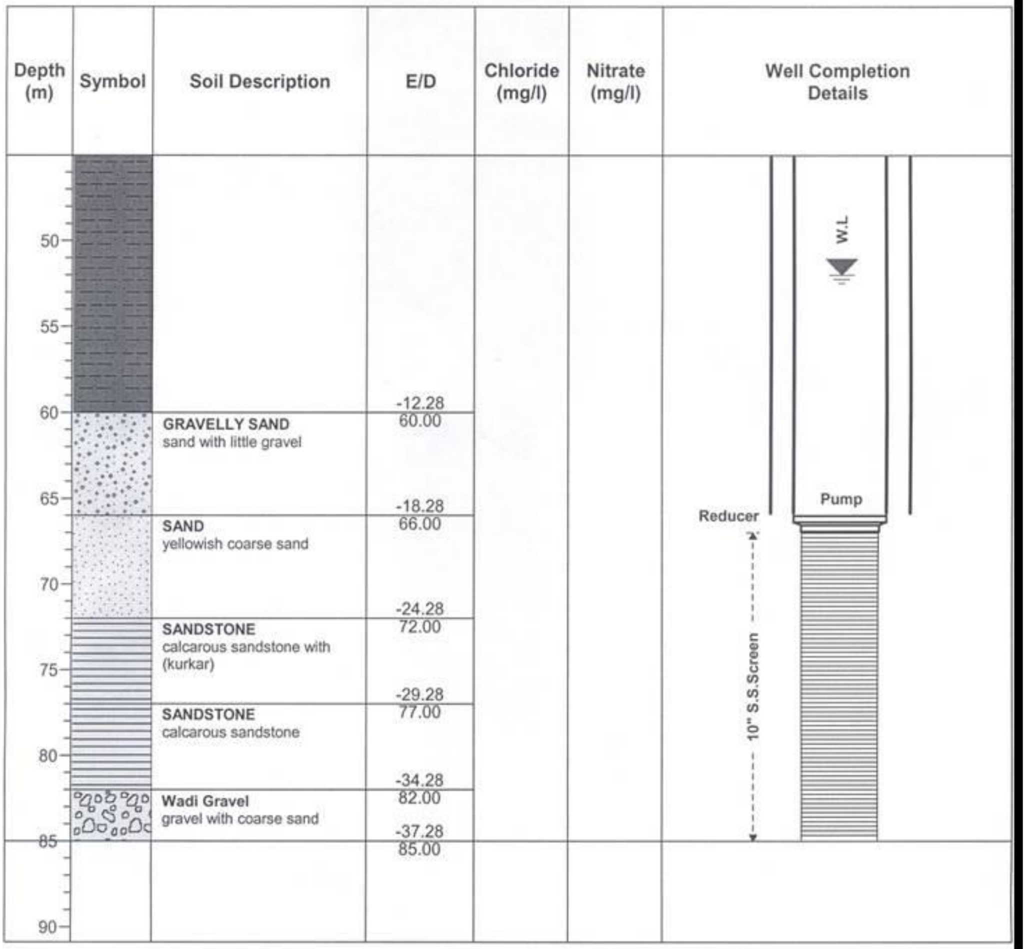
Well Owner Name: Rafah Municipality

Location: Rafah

Drilling Date: August 1998

Completion Date:

Well Type: Municipal - Abu Zohree



Drilled By:

Supervised By: PWA

Logged By: Hazem Zakout