THE RADIOLOGICAL AND SAFETY CONSIDERATIONS FOR NUCLEAR POWER PLANT SITING IN IRAQ

ISMAEL MOHAMMED MOHAMMED SAEED

UNIVERSITI TEKNOLOGI MALAYSIA

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ISMAEL MOHAMMED MOHAMMED SAEED

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Dedicated to:

My dearest father, my mother soul (be blessed), my dear wife for her patience and support, my Asma & Asia, the most dear daughters ever, for their never-ending love, and my dear friends who never stop supporting me during hard times of my study.

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ABSTRACT

The consecutive shortages in electricity supply during the last 25 years in Iraq makes the review of the energy capabilities and policies extremely important. Long-range Energy Alternative and Planning (LEAP) model was used to estimate the demand for electricity and its corresponding environmental impact by 2040 setting 2011 as the base year. The demand for electricity is expected to increase more than twice that of the base year. Introducing 1 GW of electricity from nuclear power plant (NPP) starting from 2020 will reduce 8.1% of CO_2 emissions due to the demand on electricity. Atmospheric dispersion models of Hybrid Single Particle Lagrangian Integrated Trajectory model (HYSPLIT), Consequences of Releases to the Environment: Assessment Methodology (PC-CREAM) and Environmental Radiation Dosimetry Software System (GENII) were used to study the dispersion profile and its corresponding radiological impact for radioactive releases from NPP at four nominated sites; Abbasiyah, Abu Dalaf, Baii and Mahzam during the normal and accidental operation. The air concentration and the ground deposition of radionuclides at Baiji and Mahzam nominated sites were lower than other sites. The annual effective dose equivalent (AEDE) in Baiji site was lower than other sites during normal operation, but this does not pose any significant radiological impact for all sites. The air concentrations and their corresponding AEDE due to the accidental operation of the NPP at Baiji and Abu Dalaf sites based on source term (ST); ST1 and ST4 accident scenarios were lower at Baiji site. Based on time series of spatial distribution of the radionuclide releases, the emergency planning zones were determined. Baiji and Samarra cities were categorized as plume zone as the AEDE exceeded 100 mSv and instant evacuation is required, while Tikrit and Balad cities were categorized as ingestion zones and north areas from the NPP as support zone. Predetermined protective action plans were proposed to avoid and mitigate potential exposure to the radioactive releases.

ABSTRAK

Kekurangan bekalan elektrik selama 25 tahun berturut-turut di Iraq menjadikan kajian semula keupayaan dan dasar tenaga sangat mustahak. Model Tenaga Alternatif dan Perancangan Jangka Panjang (LEAP) digunakan untuk menganggarkan permintaan tenaga elektrik dan kesannya terhadap alam sekitar menjelang tahun 2040 dengan tahun 2011 ditetapkan sebagai tahun asas. Permintaan untuk tenaga elektrik dijangka meningkat lebih daripada dua kali ganda daripada tahun asas. Dengan penjanaan 1 GW tenaga elektrik daripada loji tenaga nuklear (NPP) bermula dari tahun 2020, didapati 8.1% pengeluaran CO_2 dapat dikurangkan kerana permintaan elektrik. Model penyebaran atmosfera seperti Model Trajektori Bersepadu Lagrangian Hibrid Zarah Tunggal (HYSPLIT), Kesan Pelepasan terhadap Alam Sekitar: Metodologi Penilaian: (PC-CREAM) dan Sistem Perisian Dosimetri Sinaran Alam Sekitar (GENII) digunakan untuk mengkaji profil penyebaran dan kesan radiologi melalui pelepasan bahan radioaktif daripada NPP semasa operasi biasa dan semasa kemalangan di empat tapak yang dicalonkan iaitu; Abbasiyah, Abu Dalaf, Baiji dan Mahzam. Kepekatan udara dan pemendapan tanah radionuklid di tapak yang dicalonkan di Baiji dan Mahzam adalah lebih rendah berbanding tapak yang lain. Dos setara berkesan tahunan (AEDE) ditapak Baiji adalah lebih rendah dari tapak yang lain semasa operasi biasa, tetapi tidak mempunyai impak ketara untuk kesemua tapak. Kepekatan udara dan dos setara berkesan tahunan (AEDE) yang sepadan semasa kemalangan di NPP Baiji dan Abu Dalaf berdasarkan senario kemalangan terma sumber (ST); ST1 dan ST4 adalah lebih rendah di Baiji. Berdasarkan siri masa pengagihan ruang pelepasan radionuklid, zon perancangan kecemasan telah ditentukan. Bandar Baiji dan Samarra dikategorikan sebagai zon plum dengan AEDE melebihi 100 mSv dan pemindahan segera perlu dilakukan, manakala bandar Tikrit dan Balad dikategorikan sebagai zon pengingesan dan kawasan utara dari NPP sebagai zon sokongan. Pelan tindakan perlindungan telah dicadangkan untuk mengelakkan dan mengurangkan kemungkinan pendedahan berlebihan akibat pelepasan bahan radioaktif.

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σ	-	Diffusion coefficients
Q	-	Source emission rate (Bq h^{-1})
λ	-	Weighting coefficient
$C_{c,s}\{x_r, y_r, z_r\}$	-	Concentration contribution from the terrain-following plume state-convective and stable (g m^{-3})
$C_T\{x_r, y_r, z_r\}$	-	Total concentration (g m^{-3})
σ_y	-	Dispersion coefficient in crosswind direction
σ_z	-	Dispersion coefficient in vertical direction
u	-	Wind speed (m s^{-1})
f	-	Plume state weighting function
z_r	-	Height relative to elevation of stack base
z_p	-	Receptor height above local ground
z_t	-	Height of terrain at a receptor location
P_w	-	Probability density function of the instantaneous vertical velocities
P_y	-	Lateral probability density function
P_z	-	Vertical probability density function
σ_w	-	Vertical turbulence (m s^{-1})
d_a	-	Distance from the puff center to the receptor along-wind direction (m)
d_c	-	Distance from the puff center to the receptor in the cross-wind direction (m)
g	-	Vertical term of Gaussian equation
H	-	Effective height above the ground of the puff center (m)

x_{pi}	-	Particle position
u_{pi}	-	Lagrangian turbulent velocity fluctuation
$\overline{u_i}$	-	Eulerian mean velocity
d_W	-	Incremental Wiener process
m	-	Mass of the pollutant
$D_{wet+dry}$	-	Total deposition (wet and dry)
β	-	Deposition constant
V_d	-	Deposition velocity
Z_p	-	Depth of pollutant layer
P	-	Precipitation rate
F_b	-	The fraction of the pollutant layer that is above the cloud bottom
F_t	-	The fraction of the pollutant layer that is below the cloud bottom
$\hat{H}$	-	Henrys Law constant
$\hat{R}$	-	Universal gas constant
T	-	Absolute temperature
$\hat{S}$	-	Average scavenging ratio
E_c	-	Energy consumption
E_a	-	Energy activity
E_e	-	Energy intensity
$D_{b,s,t}$	-	Energy demand
$TA_{b,s,t}$	-	Total activity
$Emission_f\{t,v\}$	-	An environment measure of the energy technology
Sc	-	Scenario
l/l	-	Scavenging ratio
l/s	-	Explicit scavenging coefficient
$EI_D\{t,y-v\}$	-	A factor which represents the change in energy intensity as a technology ages

LIST OF ABBREVIATIONS

ADM	-	Atmospheric Dispersion Modelings
AEDE	-	Annual Effective Dose Equivalent
AMS	-	American Meteorological Society
amu	-	Atomic Mass Units
BMI	-	Business Monitor International
BP	-	British Petrolium
CEA	-	Atomic Energy Commission
DoE	-	Department of Energy USA
DRNS	-	Directorate of Radiological and Nuclear Safety
EIA	-	Energy Information Administration
FRAMES	-	Framework for Risk Analysis in Multimedia Environmental Systems
FSU	-	Former Soviet Union
GCR	-	Gas Cooled Reactor
GDAS	-	Global Data Assimilation System
GDP	-	Gross Domestic Product
GEOSURVIRAQ	-	Ministry of Industry-Iraqi Geology Survey-Iraq
GHG	-	Greenhouse Gas
GWP	-	Global warming potential
HOMER	-	Hybrid Optimization of Multiple Energy Resources
HWR	-	Heavy Water Reactor
HYSPLIT	-	Hybrid Single-Particle Lagrangian Integrated
IAEA	-	International Atomic Energy Agency
IAEC	-	Iraqi Atomic Energy Commission

ICARDA	-	The International Center for Agricultural Research in the Dry Areas
ICRP	-	International Commission on Radiological Protection
IEA	-	International Energy Agency
IMOS	-	Iraqi Metreological Organization and Siesmology
INES	-	Integrated National Energy Strategy
INES	-	International Nuclear Events Scale
ISH	-	Integrated Surface Hourly
LEAP	-	Long-range Energy Alternative and Planning
LMCFR	-	Liquid Metal Cooled Fast Reactor
LWR	-	Light Water Reactor
MMBOE	-	Million Barrels of Oil Equivalents
$MMtCO_2$	-	Million Metric Tonnes CO_2 Equivalent
MoE	-	Ministry of Electricity - Iraq
MoO	-	Ministry of Oil - Iraq
NCAR	-	National Center for Atmospheric Research
NCEP	-	National Centers for Environmental Prediction
NCRP	-	National Council on Radiological Protection and Measurments
NESHAPS	-	National Emission Standards for Hazardous Air Pollutants Compliance Monitoring
NPP	-	Nuclear Power Plant
NWP	-	Numerical Weather Prediction
OBT	-	Organically Bound Tritium
OECD/NEA	-	Organisation for Economic Co-operation and Development/The Nuclear Energy Agency
OPEC	-	Organization of the Petroleum Exporting Countries
PBL	-	Planetary Boundary Layer
PC-CREAM	-	Consequences of Releases to the Environment:

		Assessment Methodology
pdf	-	Probability Density Function
PGSFR	-	Prototype Gen-IV Sodium Cooled Fast Reactor
PNNL	-	Pacific Northwest National Laboratory
PWR	-	Pressurized Water Reactor
REEEP	-	Renewable Energy & Efficiency Partnership
SiC_f	-	Silicon Carbide Fiber
SEI	-	Stockhol Environment Institute
SOARCA	-	State-of-the-Art Reactor Consequence Analyses
TED	-	Technology and Environmental Database
TSSD	-	Ttime Series of Spatial Distribution
USCEAR	-	United Nations Scientific Committee
		on the Effects of Atomic Radiation and Others
US EPA	-	U.S. Environmental Protection Agency
US-NRC	-	United State-Nuclear Regulatory Commission
UTM	-	Universiti Teknologi Malaysia

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CHAPTER 1

INTRODUCTION

1.1 Introduction

It is well known that energy is the source of life, and it has made great contribution to every aspect of human activity on earth. Electricity is considered to be the main engine in rotating the wheel of everyday life in all economic and social sectors. Electricity has become a measure to the welfare of people and a determinant on the lifestyle of human societies. People, represented by their governments, seriously and vigorously seek to ensure sustainable sources of energy, especially electrical energy for the sustainability of the lifestyle that governments seek to provide to the people (Hodgson, 2010).

Nuclear power technology is considered as the only energy source that provides a large scale of electricity with comparatively minimum environment impact. At the global level, there were 441 operating nuclear reactor at the end of 2002 providing 16% of global electricity generation (Lillington, 2004). However, any future expansion in nuclear power technology will acquiesce to the further innovations in reactor, fuel cycle and waste disposal technologies. Such innovations should provide and inherent the safety system, anti-proliferation characteristics and reduction of radioactive wastes (Lillington, 2004; Hodgson, 2010).

Nuclear power plant accidents were a main motivation the nuclear industry sector to improve the safety principles in nuclear reactors, especially after Chernobyl accident on 26^{th} April 1986. The nuclear industry among the world shocked and it faced a considerable recession. Nuclear safety standards, from the basic design of nuclear reactors to the emergency preparation have changed and thoroughly revised (Labib, 2014; Lillington, 2004). The independent systems of control and shutdown was the most considerable improvements that have been invented in the design of next generations of reactors (Generation III) after Chernobyl accident in terms of safety considerations. Many generic lessons have been learnt in terms of safety measures and emergency preparednesses during accidents, which lead specialists to seek for urgent improvement in all fields related to nuclear power plants (Beresford *et al.*, 2016).

1.2 Overview of electricity in Iraq

The first electricity generation machine in Iraq was commercial and it was used by the English-Persian Oil company in 1911 (Kubba, 2004). The discovery and extraction of oil in Iraq helped Iraqi government to build more service institutions and industrial facilities across the country, including electrical facilities (World Bank, 1952). Table 1.1 shows the extent of change in the growth rate of the industrial sector (including oil production industry) and national income during the last time period from 1953-1963 (Alnasrawi, 2002).

Table 1.1: The growth rate of economic sectors from 1953-1963 (Alnasrawi, 2002)

Sectors	Growth Rate (%)
Industry	11
Electricity Production	16.7
Banking and Insurance	11.3
Transport	6
Civil Administration	10.5
Defense	10.5
Wholesale and singular trade	5.7
Housing and construction	2.4
Imports	67
Non-oil funds	19
Gross Domestic Product (GDP)	6.4

Industrial sector witnessed a growth rate of 11% over ten years, while the growth rate in electricity production sector was 16.7% during the same period. This indicates that a rapid development within the industry and energy sectors were achieved during that period as a result of the government orientation towards the adoption of industry as a major income source in the structure of the Gross Domestic Product (GDP) (Alnasrawi, 2002).

Iraqi government has planned to become an industrial country by the adoption of a five-year plan in development of the industrial sectors within the country, including the industry for extraction and export of oil (Dawisha, 2009; World Bank, 1952). Accordingly, the need for electricity increased, and the need for new power plants became inevitable.

Many new power plants were built, and the process of electrification of cities and villages continued after the 1958 revolution, with a new distribution grid system joining together all the country regions. The capacity for electricity production in Iraq could match the slowly increasing demand through continuous projects being carried out around the country (Kubba, 2004).

The production capacity of electricity was twice of that required by the domestic demand since the beginning of the year 1990, when the Iraqi government was aspiring to export electricity to both Turkey and Syria through a huge distribution network. Some parts of the project have been completed before the occupation of Kuwait by Iraq, but did not become operational (Yee, 2010; Al-Khalisi, 2014). After the invasion of Kuwait and the second Gulf War, the destruction included 80% of the productive capacity in the electricity sector in Iraq, and the subsequent Iraqi governments from 1991-2013 have not been able to execute a successful plan to make electricity production capacity match the domestic demand (Al-Khalisi, 2014).

Since 1991, after the second gulf war, Iraq has suffered from the lack of electricity power supply. The military operations and the bombing of infrastructure facilities in Iraq from 1991 to 2003 resulted in the destruction of Iraq's administrative potentials for reconstruction of electricity production sector (Istepanian, 2014;

Al Qaisi, 2013). Figure 1.1 shows the increase in the gap between electricity production and demand in Iraq, especially after 2003 when the demand has increased rapidly due to the new market policy adopted by the new government and high increase in GDP per capita (Kubba, 2013).

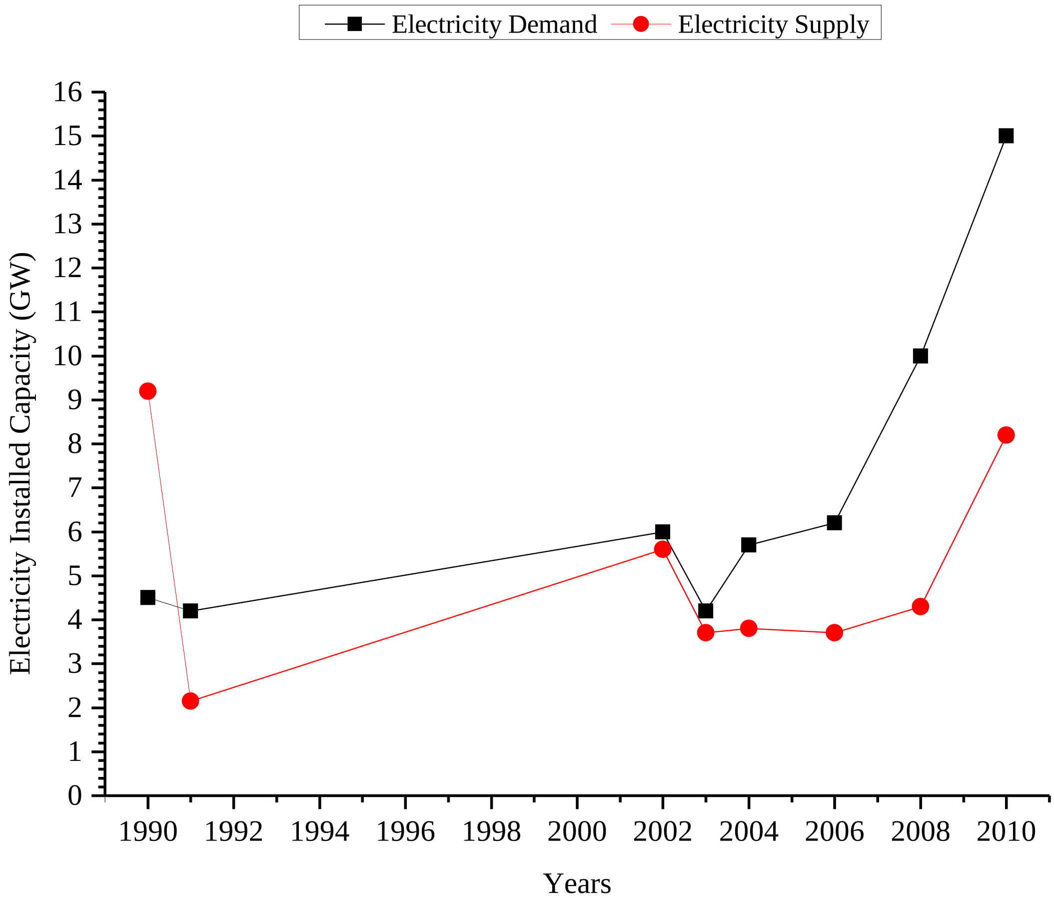

Figure 1.1: Electricity demand and production in Iraq from 1990 to 2010 (Kubba, 2013; CSO, 2014)

Beside the lack of electric power supply, high percentages of loss in electricity power is also due to the deterioration of transmission and distribution in the networks in electricity sector in Iraq. The loss rate in the electricity energy sector has continued to grow rapidly, and has been ranked number one among the surrounding countries. As shown in Figure 1.2, Iraq has the highest rate of lose in electricity power (IEA, 2012).

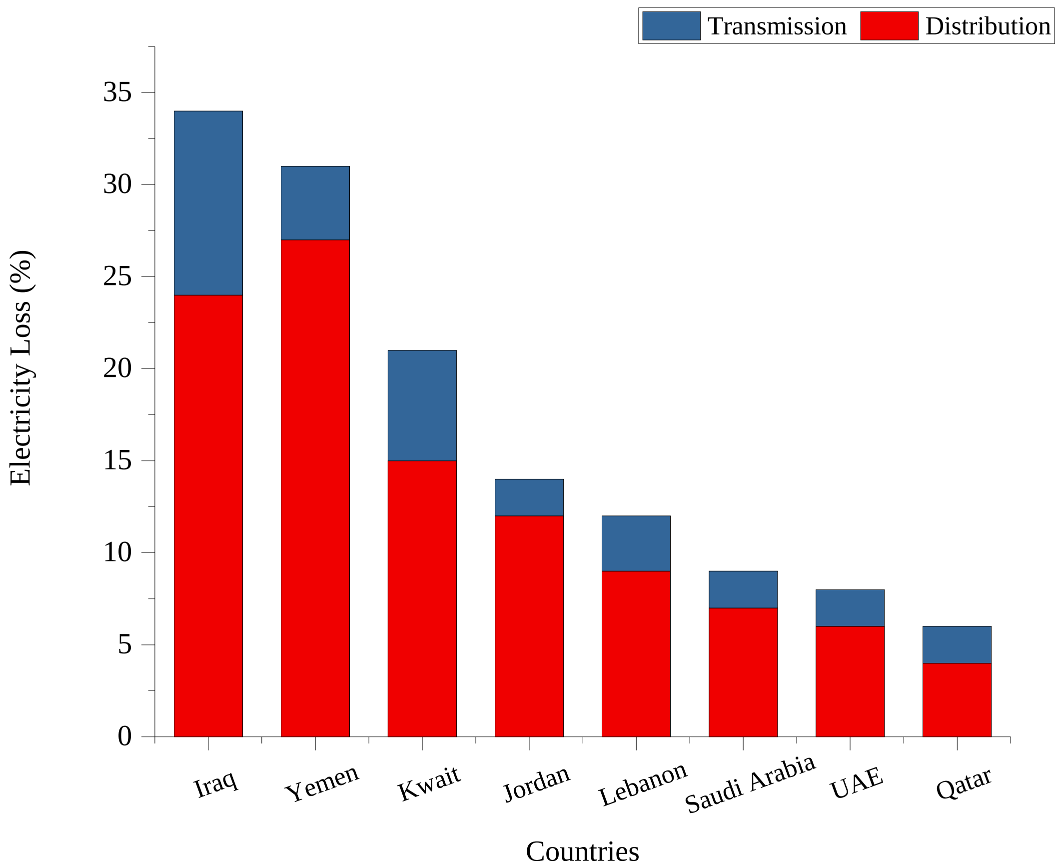

Figure 1.2: Electricity losses by type in selected countries at 2010 (IEA, 2012)

Iraq has good potential of non-renewable and renewable energy sources that could be utilized in energy production sectors, including the electricity (Hamdan, 2014; Chaichan, 2012). Iraq is ranked fourth in oil reserve. It has a proven oil reserve of 140-150 billion barrels according to latest surveys in 2013. Iraqs natural gas reserve accounts for around 1.5% of total world reserve, ranking thirteenth among global reserve countries (IEA, 2012; BMI, 2014), even though most areas of Western, North Western, North, and some areas in the South of Iraq have not been subjected to a thorough advanced geological survey (Kubba, 2004). Other potential sources of energy are available in Iraq such as nuclear, hydroelectric, wind, and solar energy. Exploitation of these energy sources should be included in current or future plans of Iraqi government for electricity generation, and they need to be adopted seriously (Hamdan, 2014). In addition, Iraqi government did not have a clear and elaborate master plan to rebuild the electricity generation infrastructure in spite of her huge investments in electricity sector from 2003 until now (Al-Majid, 2013). Hence, The electricity generation technologies restricted to the fossil fuel consumers which were more easier for Iraqi government to put more investment and development through, while other technologies of electricity generation became too far from official ambitions during last 30 years, as shown in Figure 1.3.

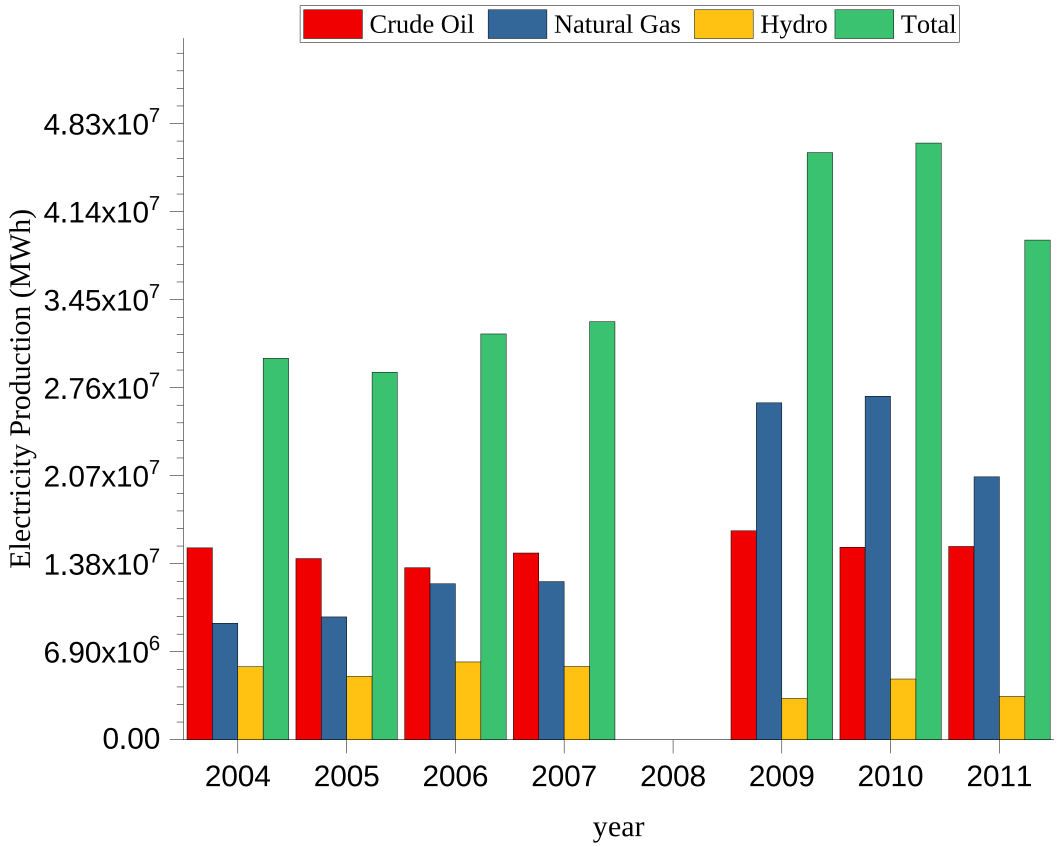

Figure 1.3: Electricity production share in Iraq from 2004 to 2011 (CSO, 2014)

1.3 Problem statement

Iraq has faced consecutive shortages in electricity supply during the last 25 years. This requires a review of the current and previous plans in energy sector, especially electricity supply system. This study aims to determine the potential energy sources available in Iraq besides fossil fuels, which can be in the form of renewable energy and nuclear facilities. The possibility of their exploitation as well as their impact on mitigation of greenhouse-gas emissions are also discussed (Kubba, 2013).

Electricity generation in Iraq relies completely on oil and gas products as the main source of fuel, due to its abundance. Hence, the security and diversity in energy supply are not assured due to the depletion of oil and gas resources. Also, the environment will continue to be affected negatively by greenhouse gas (GHG) emission from fossil energy sources. Iraq owns good potential sources of non-fossil energy such as renewable energy. Renewable energy sources are considered as desired alternative sources due to their low impact on environmental (Hodgson, 2010), but the limitation of their production capacity which is dominant by the weather conditions make them undesired based on the huge demand on energy in Iraq.

Thus, reliable sources of energy is required to provide sustain and huge amounts of energy in Iraq to ensure the required energy for country developments. Therefore, nuclear energy could be the desired alternative of reliable energy source in terms of its provision rate of energy and its low environmental impact.

Within the context of the above investigation this study will also focus on the site selection for nuclear power plants in accordance with IAEA safety requirements. This study will also concentrate on such factors as possible radioactive radiation and contamination of the environment in both normal operations and those due to accidents (IAEA, 2006b; Farmer, 1967). Preliminary radiological assessment of public health impact due to atmospheric release of radionuclides during normal operation for two selected potential sites; Al-Mahzam and Baiji, was conducted previously for the (VVER-440) reactor using (AIRDOS-EPA) computer code (Marouf *et al.*, 1991a, 1992). The assessment was interrupted by the invasion of Kuwait in 1991, and hence the estimation of radiological impact for nominated sites were not completed.

Therefore, a complete system of safety analysis, which considers the human health and the environmental impact for normal operation and accidental situation, is required for new nuclear facility. The hypothetical accident scenarios and the emergency plan are needed to mitigate the radiological impact of any accident. This research conducted extensive radiological assessment for nominated sites for normal and different nuclear accident scenarios and verified the suitable site for NPP using atmospheric dispersion analysis.

1.4 Research objectives

This research aims to achieve certain objectives, which can be summarized as follows:

1. To assess the current and future electricity demand in Iraq and their corresponding environmental impact for each electricity generation technologies using Long-range Energy Alternatives Planning (LEAP) model.
2. To measure and compare the annual air concentration and ground deposition due to the atmospheric release using Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT), Radiation Dose and Risk Calculation (GENII) and Consequences of Releases to the Environment: Assessment Methodology (PC-CREAM) models from NPP at Abbasiyah, Abu Dalaf, Baiji and Mahzam nominated sites during normal operation.
3. To estimate the annual effective dose resulting from atmospheric and aquatic releases of radionuclides at nominated sites during normal operation, using GENII model.
4. To predict the human health impact and risks for different scenarios of hypothetical nuclear accidents at nominated sites using GENII and HYSPLIT models.
5. To create an appropriate emergency plan that ensures the mitigation of radiological impact from nuclear accidents, including preparednesses based on the prediction of atmospheric dispersion of radionuclides release during the accident using atmospheric dispersion models.

1.5 Scope of the study

This research studies the energy status of Iraq, particularly the electricity sector, and performs an estimation for future increment in demand for electricity by using LEAP model, including the environmental impact of current government plan for expanding the electricity production capacity. Study of different scenarios for growth rate in both population and gross domestic product (GDP) is another scope of this study, including their impacts on the increase in the total energy demand in Iraq. Investigation and evaluation of availability and capability of other energy resources in Iraq and their potential on electricity generation are also the discussed in this research. This thesis will focus on the environmental impact of current energy technologies that are adopted by Iraqi government for electricity generation, including the future plan of Iraqi government for the extension of electricity generation capacity.

The mitigation impact of non-fossil fuel resources in electricity generation is one of the concern of this research. In order to avoid the disastrous effects of greenhouse-gas emission, which accompanies the consumption of fossil fuel, the use of nuclear power or renewable energy inclusion in any future extension plan for electricity generation sector have been examined in detail.

This research focus on the radiological and safety considerations for new power plant at four nominated sites in Iraq. Other factors and considerations that affect the site selection procedure for new nuclear power such as economic, social, political factors is excluded in the scope of this research.

Atmospheric dispersion of radioactive discharges from normal operation of potential nuclear power plants in terms of air concentration and ground deposition is another interest of this work. Different tools and models such as HYSPLIT, GENII and PC-CREAM have been utilized in order to obtain an accurate picture of atmospheric dispersion of radioactive discharges in terms of spatial distribution and quantitative values. This provides information on the health impact of these radioactive discharges to the population living around the nuclear power plants. This also provide information on the impact on atmospheric and aquatic environment.

This research is also involved in estimating the quantitative human health impact that is due to the normal operation of NPP at nominated sites. GENII model, which is certified and adopted by international institutions that are concerned with nuclear safety, has been used as a main tool to assess the health impacts of radioactive discharges to the atmosphere and aquatic environment.

Hypothetical scenarios of nuclear accident and their radiological impact are another concern of this research. Atmospheric dispersion models have been utilized to measure and indicate the spatial distribution of radioactive discharges to atmospheric environment. Assessment of radiological impact of hypothetical accident has been examined by this research, especially the region that are most susceptible to high levels of exposure doses. Emergency plan preparednesses have been proposed by this research to mitigate the radiological impacts. This was based on the atmospheric dispersion of radioactive discharges.

1.6 Significance of the research

The sharp increase in the demand for energy, especially electricity, makes the study and search for sustainable energy sources an urgent issue. This is to ensure sustainability, economic feasibility, as well as environmental sustainability. This research tries to obtain a clear picture of the energy situation, especially the electricity sector. It investigates the available potential from non-fossil and nuclear energy sources. The environmental impact of current energy policy in terms of GHG emission in ambient environment is studied. The future demand for energy has been predicted for next 30 years. The resultant impact of global warming potential was also investigated for Iraqi situation.

This research examined four nominated sites suggested by Iraqi Atomic Energy Council IAEC; Abu Daalaf, Abbasiyah, Baiji and Mahzam. Investigation were done in terms of atmospheric dispersion of radioactive discharges of NPP during normal operation. Suitable site for nuclear power plant construction has been chosen, to be more compatible with safety measures and regulations stipulated by ICRP recommendation and IAEA safety regulations.

This study also examines the impact of any hypothetical severe accident scenarios for nuclear power plant at two of the nominated sites, Abu Dalaf and Baiji. This is to figure out the expected radiological health impact upon human living around the nuclear power plant and surrounding areas. The atmospheric dispersion models were used. Based on the estimated radiological impact, an emergency plan has been proposed to mitigate the accident impact upon population. The mitigation of an accident is depending on a proper emergency plan to handle the accident. This work provides the base line information that could be used for possible implementation and to scrutinize decisions by the Iraqi Atomic Energy Commission (IAEC) and Iraq government.

1.7 Thesis's organization

Chapter 1, gives detailed presentation of the electricity sector situation in Iraq. it also represents the electricity supply situation. The main objectives of this work are addressed in brief, followed by its signification and structure.

Chapter 2 represents the enormous natural sources of energy that are available in Iraq, including the possibility of exploiting this in diversification of energy sources. It also presents background and literature review about energy, nuclear energy, site selection for NPP according to international regularities, atmospheric dispersion models and health impact estimation of radioactive releases.

Chapter 3 presents the methodologies that were used to achieve the research objectives. A brief description of the tools that have been used to perform the tasks of this research, their configuration is also given.

Chapter 4 presents the results that were obtained for energy demand estimation and its environmental implications. Results of atmospheric dispersion for normal operation of nuclear power plants releases and its health impact were presented. Relevant discussions and analysis were presented.

Chapter 5 illustrates the results of atmospheric dispersion of accidental release at nominated sites. The results of radiological impact of hypothetical accident scenarios at two of the nominated sites were been presented in terms of annual effective dose and cancer risks. Emergency planning zone has been determined based on the results of time series of spatial presentation of dispersed radioactive contaminants.

Finally, Chapter 6 draws the conclusions from the results, provides the the recommendations nd future research suggestions.

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