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A Project Study of a Nuclear Reactor vs a Cyclotron Proposal in the Eastern Province of the Arabian Peninsula: A Feasibility Study

Abdulwahab F Alahmari*

Radiology Specialist, Department of Radiology, Al-Namas General Hospital, Ministry of Health, Al-Namas City, Saudi Arabia

***Corresponding author:** Abdulwahab Alahmari, Radiology Specialist, Department of Radiology, Al-Namas General Hospital, Ministry of Health, Al-Namas City, Saudi Arabia.

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Abstract

Purpose: *The aim of this paper is to study the benefits of building a nuclear reactor vs. a cyclotron to generate radioactive materials for medical uses. This reactor or cyclotron will be placed in the eastern province of the Arab peninsula near all the other Gulf Cooperation Council (GCC) countries. The radioactive materials can be generated and sold to the targeted market in the GCC countries to compete with the radioactive materials that are brought from Europe or Turkey and to have full independence and control over the health care systems in the GCC states.*

Method: *Data will be collected about recent developments in the GCC market and the number of hospitals in the targeted area. The amount of money that it will be invested will be compared with generated amount of money. Other international competitors' strength and weakness will be analysed and compared to this domestic project. The result will be studied and provided.*

Results: *This project can bring $16 million dollar in profit in ten years which means 137.16% as a profit margin. This project can hire from 30 up to 50 Saudis citizens in a profitable business that can provide a huge income to the Ministry of Health. The business can expand to the middle east to become the regional dominant supplier of radiopharmaceuticals.*

Conclusion: *This study shows that a cyclotron might be a very beneficial project that can bring millions of dollars in area where radiopharmaceuticals are very rare and expensive. A reactor is only good when there is a full nuclear program that has military, electrical, research, and medical applications. Then it is worth spending a billion dollars.*

Keywords: Nuclear Reactor, Nuclear Medicine, Radioactive Material, Radiopharmaceutical, Accelerator, Radioisotopes

Introduction

The aim of this paper is to study the ability to start medical radioisotopes generating and distribution business in the GCC. This project will be assessed and estimated based on the available numbers and data online to determine the average cost. The average number is always taken as a reference number in this paper. If there is a range (i.e., from 0 to 10, then in this paper it will pick the number 5 as a reference number or the mean).

Project Idea

Radioisotopes generation and distribution in areas where there are no major nuclear programs that can supply the area. For political reasons, Israeli nuclear program radioisotopes cannot be sold in Muslim countries such as the GCC (even though some GCC states now have relations with Israel). The Iranian nuclear program is under development and the Muslim countries will not be able to buy from Iran, especially the GCC states, for political reasons too.

Objectives

Cyclotrons can generate some radioisotopes that are different from radioisotopes that are generated by a nuclear reactor. Building a nuclear reactor or a cyclotron in one facility will help in generating radioisotopes for medical uses, provide a good pro-

fessional service, decrease the unemployment numbers, ensure patient safety by keeping high standards according to the GCC regulations, and support local hospitals in the GCC states. This business is expected to bring in a high income as a regular source of revenue for the ministry of health or the public sector running this project. Here is a list of the project objectives;

1. Provide an income to the country or public sector running this business.
2. Hire many Saudis and reduce unemployment numbers.
3. Increase the practice of nuclear medicine by providing the radioisotopes.
4. Provide research and training opportunities.
5. Help the patients by providing these radioisotopes in the region which will help in performing advanced scans.
6. Stop relying on other countries for medical radioisotopes.
7. Make high quality radioisotopes with the highest standards.
8. Provide cheap radiopharmaceuticals to the country.
9. Provide medical and logistical support to the neighbouring GCC states and gain more political influence in those countries.
10. Cut all international computation by producing an affordable radiopharmaceuticals service with high standards.

Literature Review

The Requirements

5 helicopters, 5 cars, 5 pilots, 5 car drivers, a team of radiopharmacists, nuclear medicine technologists, radiation safety officers (RSOs), physicists, and nuclear engineers, a reactor or a cyclotron, a security team, a land, a shielded building, a laboratory, and radionuclide generators.

The First Year's Cost

The land is taken from the government for this government business, so it cost nothing with all permissions, the planning of the building can be done by the government city regulators, and the shielding can be planned by the government experts in the ministry of health and public universities for free.

The building will cost half a million dollars. Another half a million will be spent on the shielding of this building. The reactor's or medical cyclotron's total annual cost for medical use is $584,500. The cyclotron price is over $7 million. Radionuclide generators cost $1,900 per one generator and the cost of $117,800 is for 62 generators. A nuclear reactor costs one billion dollars which is really expensive, except, if it is a part of a nuclear program for the whole country, then it will be a side benefit [1].

The helicopters each one costs $250,000 which makes 1,250,000 for five helicopters. The running cost is $500 per hour and the maintenance cost vary based on the use it could be between $5,000-$20,000 per year. The helicopters pilots cost $250,000 per year for their salaries all five together, each one costs $50,000 per year.

Car cost is $15,000 for diesel cars with very low maintenance of < $1,000 per year. The total cars cost is $75,000 with $1,000 maintenance every year for 5 cars which cost $5,000. The renewal of the cars papers cost zero because they are governmental cars. The cars drivers cost $48,000 altogether per year and each single one cost $9,600 per year.

The team consists of three radiopharmacists whose salaries per year cost $107,520 for all the three. Each one will cost $35,840 annually. The nuclear medicine techs are three and they cost per year all together $86,400 and $28,000 per person annually. The RSOs cost $140,000 per year for all of the five RSOs together and $28,000 per each RSO each year. The physicists are three and they cost per year all together $86,400 and $28,000 per person annually. The nuclear engineers are three and they cost per year all together $80,000 and $26,666 per person annually. The security team (5 people) cost $48,000 altogether per year and each single one cost $9,600 per year [2].

Kerosene's cost in Saudi Arabia is $0.048 per gallon. A 20 gallon which run the helicopter for one hour cost $0.96 us dollar per hour. Let say three hours is required to reach each country back and forth. So, six hours multiplied by five countries which will make 30 hours which multiplied by $0.96 which will cost $28.8 per week. Which is really cheap! Each week costs $28.8. So, in one month (i.e. four weeks) it will cost $115.2 per month. The amount of $115.2 is multiplied by 12 months which will cost $1,382.4 per year [3].

Diesel's cost in Saudi Arabia is $0.2 per gallon. 20 gallons can be used to drive the diesel car for 500 kilometers. 20 gallons cost $4 dollars which can cover two months cost of diesel for the cars. A $24 can cover one car diesel cost for one year to do the deliveries. 24 dollars for five cars will cost $120 as diesel costs for the whole year.

Market Study

The Total Cost

The total cost for the first year is $11,305,822 which is divided into two things; the fixed capital is $9,867,500 and the transference capital is $1,438,322 which is divided into two parts; maintenance and salaries. The second year cost will reduce to $1,438,322 per year which includes mainly maintenance and salaries only [4].

The Customers

The customers are the hospitals in the eastern part of the Arabian peninsula which are targeted market for distributing radioisotopes see (Table 1). The total number in the eastern region of the Arabian peninsula is 315 outside Saudi Arabia. The targeted percent of these hospitals will be 10% only as a minimum which means around 31 hospitals. The 10% is proposed because that all hospitals do not have a nuclear medicine department. Some hospitals might be private clinics which do not do nuclear medicine scans. If the 315 hospitals sign contracts to provide radioisotopes to their hospitals then the profit will exceed the minimal numbers estimated in this paper. Notice that the Saudi hospitals are not included in this study in order to provide an income from outside the country only which is a main target of this project [5].

Table 1: The targeted countries by distributing radioisotopes.

Country	The Last Count of Total Number of Hospitals	Expected clients 10%
United Arab Emirates [1]	170	17 hospitals
Oman [2]	84	8.5 hospitals
Qatar [3]	15	1.5 hospitals
Bahrain [4]	20	2 hospitals
Kuwait [5]	26	2.6 hospitals
Saudi Arabia [6]	494	N/A
Total	809	31.6 hospitals outside Saudi Arabia

Note: Saudi Arabia hospitals are next stage, so they are not included in the study. Instead, the focus is on outside the country hospitals to show how much profit can be made from such an investment to bring money from outside the country which is a primary objective then bring the money from inside the country which is a secondary objective and provide radioisotopes to hospitals inside the kingdom.

Each hospital will order $3,000-4,000 worth of radiopharmaceuticals per week. A year has 52 weeks and each week one generator is provided which on average will cost $3,500. The total charge per year is $182,000. Expected hospitals are 31.6 and they pay each week $3,500. This will generate $5,751,200 per year. In four years, every single dollar spent on this project in the first year will be covered. The maintenance and salaries will be covered and if more clients are needed then an addition of a 30% of clients will be added by allowing the Saudi market to get the services. With generating more and having more clients, it will cover the costs very quickly [6].

Saudi Arabia has more than 494 hospitals in 2018. It could be more than 5,000 hospitals now. The most top three radioisotopes distributors in the GCC states are; South Africa, Netherlands, and Russia which all of these countries are far away from the GCC states geographically [7]. Turkey is the only country challenging this project since they are the biggest distributors to the region in 2020, where they distributed 108 kilograms, to Pakistan, Libya, the United Arab Emirates, Iraq, Kuwait, etc [8]. Turkey is far away compared to the eastern provenance of the kingdom which is 2 hours away compared to 6 hours at least from Turkey to any GCC state. The Emirati nuclear program focuses more on covering 25% of the United Arab Emirates' electricity, not on generating radioisotopes [9].

Technical Feasibility Study

Geographic Coverage Areas

This study did not even include the private hospitals in the eastern province of Saudi Arabia, where there are many private hospitals ready to buy radioisotopes. The coverage of the geographic area can be extended to southern Iraq and central Saudi Arabia for more profits. Only the eastern part of Oman must be covered, but the western part of Oman lacks hospitals see Figure 1 and 2.

Reactors are very expensive, so they will cost more than one billion dollars and the revenue from medical radioisotopes will be less by a zero (millions) than the billion that will be spent building the reactor. But, if electricity were generated too from the reactor and research and training opportunities will be offered too by having the reactor then it might be useful, but it will not be a realistic assumption in many countries around the world for many reasons that will take too long to explain each reason of them.

Figure 1: A Google map of the Arabian Peninsula showing the area to which the project will be supplying radioactive materials to. It is the area highlighted in yellow on the eastern side of the Arabian Peninsula.

Figure 2: A Google map of the major GCC cities on the Arabian Gulf (Dammam, Kuwait, Manamah, Doha, Abu Dhabi, and Muscat) with a total distance of 2,438 km between them.

Types of Radioisotopes

A nuclear facility must be built in Dammam city in the eastern region of Saudi Arabia. This nuclear facility contains cyclotron and (might build a neutron particle emission reactor when funding is available) see (Table 2 and 3) for the comparison. The radioactive materials that will be generated is not include any radioisotope with a half-life less than 4 hours (i.e., Nitrogen-13, Oxygen-15, Flurine-18 which all have a half-life less than 3 hours). The radioisotopes that will be generated and supplied include the following:

Table 2: Reactor vs. Cyclotron radioisotopes list.

Reactor-produced radioisotopes (half-life)	Cyclotron-produced radioisotopes (half-life)
Phosphorus-32 (14 days)	Copper-64 (12.7 hours)
Chromium-51 (27.70 days)	Gallium-67 (78.28 hours)
Yttrium-90 (64 hours)	Iodine-123 (13.22 hours)
Molybdenum-99 (65.94 hours)	Thallium-201 (73.01 hours)
Technetium-99m (6.01 hours)	Technetium-99m (6 hours)
Iodine-131 (8.03 days)	
Samarium-153 (46.28 hours)	
Lutetium-177 (6.65 days)	
Iridium-192 (73.83 days)	

Note: Any very short half-life radioisotopes (i.e., half-life less than two hours) generated by the cyclotron are not included in the table because the company will not be able to generate and transport the radioisotopes to the targeted hospitals in the area because their activities will be finished by the time the radioisotopes arrive at the hospitals.

Due to the law that has been approved by all GCC countries, all citizens from any GCC country can enter any other GCC country by using their national IDs. All workers for the transportation must be GCC citizens which will facilitate the transportation and reduce unemployment numbers. The transporters must have a bachelor's degree in medical physics or nuclear medicine technology program, have passed the Radiation Safety Officer (RSO) course, examination, and must be registered with King Abdullah City for Atomic & Renewable Energy.

Table 3: A comparison table between reactors and cyclotrons according to different characteristics.

Items	Reactor	Cyclotron
Cost	$ 1 billion	$7 million
Life-time	40 years	Non applicable* Many old cyclotron still work until today
Radioisotopes	Many isotopes	Few isotopes, but sufficient
Shielding	More shielding and more cost.	Less shielding and less cost.
Radioisotopes half-life	Long	Short

Cooling system	Complicated	Simple
Radioactivity [9]	More neutrons.	Less neutrons.
	β– emission	Electron capture decay
	Suitable for therapy	Suitable for diagnostic imaging
Energy	High	Low
Production of low energy radioisotopes	Contaminated with other radioisotopes	High quality
The invested capital returned within 10 years	Never	Yes
Location	Nuclear station	Hospitals
Radionuclide type	A mixture of radionuclides	Pure
Machines dependency [9]	Only SPECT and radiotherapy radioisotopes.	PET scan radioisotopes which only can be made on a cyclotron which are; 11C, 13N, 15O and 18F. In addition, radiotherapy and SPECT radioisotopes.
Radionuclide cost	Low	High
Safety from military attack	Not safe A target	Not safe A target

Note: SPECT; single photon emission computed tomography, PET; positron emission tomography.

Profitability Test

According to the following numbers, the project estimated to make $27 million in the first ten years based on an investment of $ 11,305,822 as capital. The net profit margin is 57.83%, the net profit is $33,261,280.00, and the profit percentage is 137.16% see (Table 4).

Table 4: The profit over the course of ten years. The spending is fixed after the first year and the incomes is fixed from year one. This table shows a huge profitability based on a fixed income depending on a few hospitals.

Time/Profit	Spending	Income	Accumulative Profit
First year	$11,305,822	$5,751,200	0.0
Second year	$1,438,322	$5,751,200	0.0
Third year	$1,438,322	$5,751,200	0.0
Fourth year	$1,438,322	$5,751,200	$1,632,812
Fifth year	$1,438,322	$5,751,200	$5,945,690
Sith year	$1,438,322	$5,751,200	$10,258,568
Seventh year	$1,438,322	$5,751,200	$14,571,446
Eight year	$1,438,322	$5,751,200	$18,884,324
Ninth year	$1,438,322	$5,751,200	$23,197,202
Tenth year	$1,438,322	$5,751,200	$27,510,080
Total	$24,250,720	$57,512,000	27,510,080

Conclusion

This study shows that a cyclotron might be a very beneficial project that can bring millions of dollars in area where radiopharmaceuticals are very rare and expensive. A reactor is only good when there is a full nuclear program that has military, electrical, research, and medical applications. Then it is worth spending a billion dollars.

Recommendations

This study led to the following recommendations in order to achieve a successful nuclear radioisotopes generation and distribution program/business;

1. Must be supervised by the government in order to get contracts from neighboring countries through official offers among the GCC states.
2. All employees are Saudis in order to access neighboring countries without paperwork.
3. Increase the geographic area of the distribution to make more profit.
4. Take advantage of the lack of competition.
5. Take advantage of the closeness to all customers compared to faraway countries.
6. In cases of extremely high demands from one region, a new branch with a cyclotron and everything can start there, and after analyzing the profits of opening a new branch to supply the high demand.

Conflict of Interests

The Author declares no conflict of interests.

Acknowledgment
N/A

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