

## ASSESSMENT OF USING $^{99}\text{MO}$ AND $^{99\text{m}}\text{Tc}$ ISOTOPES IN KUWAIT MEDICAL SECTOR

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**Abstract**—The Ministry of Health (MOH) in the state of Kuwait currently depends on importing the radioisotope molybdenum (Mo) in its isotopic form ( $^{99}\text{Mo}$ ) to fulfill its demands. The present study was conducted on all nuclear medicine departments in the state of Kuwait. Daily, weekly, and monthly data were analyzed to statistically determine the current and future demands for the isotope  $^{99\text{m}}\text{Tc}$ . This analysis was performed by collecting and analyzing data on MOH consumption of  $^{99\text{m}}\text{Tc}$  for different diagnostic applications. The overall results indicate a partial decrease of 1.012% in the overall total demand for  $^{99\text{m}}\text{Tc}$  up to the year 2018 for the state of Kuwait.

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**Key words:** Ministry of Health; molybdenum; technetium; dose assessment; emergencies; radiological

### INTRODUCTION

MOLYBDENUM (Mo) was discovered by Swedish chemist Peter Jacob Hjelm in 1781, and its radioactive isotopes are made using light-particle reactions, fusion-evaporation reactions, neutron- and charged particle-induced fission, and projectile fragmentation or fission (Advameg 2014; Parker and Thoennessen 2012). Mo is used to generate other radioactive isotopes that are medically important. Typically generated radioactive isotopes include technetium (Tc) in the isotopes of  $^{99\text{m}}\text{Tc}$ ,  $^{99\text{m}}\text{Tc}$  (m + g), and  $^{94\text{m}}\text{Tc}$ , with  $^{99\text{m}}\text{Tc}$  being one of the most important. The letter “m” means that the isotope is metastable, indicating the short half-life of this

isotope (e.g.,  $^{99\text{m}}\text{Tc}$  has a half-life of approximately 6 h) (Parker and Thoennessen 2012). The short half-life prevents the isotope from being stored for a long period of time; therefore, continued production is necessary. Any difficulties in the supply due to the limited number of facilities would result in an unplanned interruption of patient care.

Some research has been conducted on the production of  $^{99\text{m}}\text{Tc}$  without the use of  $^{99}\text{Mo}$  (Stolarz et al. 2014). These processes use uranium, and the amount of radioactive waste produced is greatly reduced (Barci et al. 1993; Pagdon et al. 2011). However, because this technique is under development, it is unlikely to occupy a significant share of the market in the short or medium term. The advantages of  $^{99\text{m}}\text{Tc}$  are the short biological and physical half-life that enables very fast clearance from the patient’s body and the emission of a single gamma that is not accompanied by any beta emissions. These properties allow a precise alignment of the imaging detectors (WNA 2015).

Today,  $^{99\text{m}}\text{Tc}$  is considered one of the most required medical isotopes; 30 million patients per year use it worldwide. The approximate worldwide demand for Mo used to produce  $^{99\text{m}}\text{Tc}$  is approximately 450 TBq weekly (AIPES 2008). Technetium-99 m ( $^{99\text{m}}\text{Tc}$ ) is vital for certain diagnostic tests for cancers and heart diseases; it is used in greater than 80% of nuclear medicine’s diagnostic procedures across the world (WNA 2015). Examples of the types of diagnoses for which  $^{99\text{m}}\text{Tc}$  is used include the diagnoses of metabolic bone disease (Fogelman et al. 1978), renal tubular acidosis (Cağlar and Topaloğlu 2002), and methoxy isobutyl isonitrite (MIBI) imaging in patients with malignant tumors (Aktolun et al. 1992).

The Ministry of Health (MOH) in the state of Kuwait currently imports this radioisotope (i.e., Mo) to fulfill its demands and faces the risk of the shortage or even the stoppage of supply due to different scenarios; i.e., the sources are shut down or an accident occurs with the cargo transferring the supply. The Kuwait Institute for Scientific Research (KISR) is currently supporting its national commitment to the International Atomic Energy Agency (IAEA) through a Technical Cooperation (TC) project with the IAEA titled

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“Supporting the Establishment of a Nuclear Research Center,” IAEA-TC (KUW/1/006). As part of these collaborative efforts, it would be practical to assess the possibility of producing  $^{99}\text{Mo}$  via different methods using a neutron-generating facility (NGF) and determining the best route of production that can meet the MOH’s demands in Kuwait by considering future demands. The current research assists decision makers in Kuwait’s MOH in predicting the future demands for  $^{99\text{m}}\text{Tc}$  by collecting and analyzing the consumption data of  $^{99\text{m}}\text{Tc}$  for different diagnostic applications from the MOH’s nuclear departments.

## METHODS

Current and future change in  $^{99\text{m}}\text{Tc}$  demands is evaluated by collecting  $^{99\text{m}}\text{Tc}$  consumption data from all nuclear medicine departments in Kuwait from 2012 to 2014; forecasting missing data using various methods, such as moving average and a linear trendline for backwards, midpoint, and forward data; and forecasting Kuwait’s future total  $^{99\text{m}}\text{Tc}$  consumption using a logarithmic trendline with a seasonal index.

The average percentage of error for the forecast data is calculated to determine the level of acceptance of the predicted results.

## RESULTS

### Data collection

The data were collected from 2012 to 2014 from nine MOH nuclear medicine departments: Al-Amiri Hospital, Ibn Sina Hospital, Kuwait Cancer Control Center (KCCC), Al-Farwaniya Hospital, Mubarak Al-Kabeer Hospital, Yiacco Medical Company, Al-Jahra Hospital, Jaber Al-Ahmad Hospital, and Chest Diseases Hospital. The consumption dosages from Al-Amiri Hospital and Mubarak Al-Kabeer Hospital were provided as the total  $^{99\text{m}}\text{Tc}$  consumption of different imaging tests per day only. The imaging tests performed at these departments include tin colloid, thyroid, MIBI, methylene-diphosphonate (MDP), microaggregated albumin (MAA), testicular, dimercaptosuccinic acid (DMSA), MYO view, hepatobiliary iminodiacetic acid (HIDA), mercaptoacetyltriglycine (MAG-3), HMPO, LEUKOSCAN, and diethylenetriamine-pentaacetic acid (DTPA). In addition to the two previous nuclear medicine departments, all data provided from the MOH were in terms of the daily and weekly consumption dosage of  $^{99\text{m}}\text{Tc}$ .

### Missing data prediction

The collected data from Al-Amiri Hospital contained many missing values for the year 2012; therefore, the year 2012 dosage was instead predicted using a linear backward trendline for all four quarters of the year. The data of the first quarter of 2013 for Ibn Sina Hospital exhibited

an outlier; therefore, an average of the weekly consumption dose of the first quarter was used instead. For the same hospital, data from the fourth quarter were missing at the time the project was executed. Thus, these data were forecast using the moving average method with two periods. The dosage for the fourth quarter of 2014 for KCCC was not available at the time of data collection; therefore, this information was predicted using the moving average method with four periods. The dosage for the last two months from the fourth quarter of 2014 for Al-Farwaniya Hospital was not available; therefore, this information was predicted using an exponential trendline with a seasonal index. The dosage for the last month of 2014 was not available for the Mubarak Al-Kabeer Hospital; therefore, these data were forecast using the moving average method with two periods.

Due to unavailable data, the data for the third and fourth quarters of 2014 were forecast for the Yiacco Medical Company using a linear trendline with a seasonal index with a 10% safety factor to reduce the error. Al-Jahra Hospital had missing data for January and June 2014; these values were assumed to be the average of the summation of the previous and following months. The missing data for February and November 2013 were predicted using the moving average method with two periods. The data for the fourth quarter of 2014 were not available at the time, so they were forecast using the moving average method with four periods. The Jaber Al-Ahmad Hospital data for the first two quarters of 2012 were predicted using a backward linear trendline with a seasonal index to fill in the missing values. For the last two quarters of 2014, a linear trendline with a seasonal index was used to provide the missing values. Finally, year 2014 data for the Chest Diseases Hospital were forecast using a logarithmic trendline with a seasonal index because they were not available at the time. Table 1 presents Kuwait’s overall  $^{99\text{m}}\text{Tc}$  consumption for the period from 2012 to 2014 based on the information mentioned previously and the data gathered from all stated nuclear medicine departments. The values represented in bold are the predicted values, and the remaining values represent the real data collected from MOH.

### Future demands

To further evaluate the consumption of  $^{99\text{m}}\text{Tc}$  in Kuwait and predict future changes in consumption, the data obtained in Table 1 were plotted and then forecast logarithmically with a seasonal index (Fig. 1). The average percentage of error for the forecast data is 2.4%, providing a good indication that the result obtained is acceptable.

It can be inferred from Fig. 1 that the consumption rate is decreasing slightly every year. Because  $^{99\text{m}}\text{Tc}$  is used for patients, a 5% safety percentage was added to the forecast values to prevent a shortage of  $^{99\text{m}}\text{Tc}$  in the MOH. Table 2

**Table 1.** Kuwait's nuclear departments' total  $^{99m}\text{Tc}$  consumption.

Year	Quarter	Al-Amiri	Ibin Sina	KCCC	Al-Farwaniya	Mubarak Al-Kabeer	Yiaco	Al-Jahra	Jaber Al-Ahmad	Chest diseases	Total (MBq)
2012	1	<b>473,784.14</b>	463,573	1148,347.92	1,769,045	555,845.41	459,281	533,403.1	<b>959,249.60</b>	1,367,705	7,730,233.93
	2	<b>475,559.29</b>	468,383	1360,231.66	2,042,611	606,196.27	476,782	415,939.2	<b>1,143,848.70</b>	1,410,292	8,399,843.04
	3	<b>477,334.44</b>	391,016	860,446.54	1,757,012	401,519.15	303,326	327,461.1	792,832.30	1,021,644	6,332,591.14
	4	<b>479,109.59</b>	406,445	981,392.29	1,938,604	511,737.82	416,583	370,880.6	1,362,171.65	1,426,831	7,893,754.49
2013	1	401,920.64	<b>425,315</b>	741,867.02	1,627,316	573,618.03	339,734	379,203.19	1,055,254.80	1,282,346	6,826,574.19
	2	480,244.09	387,182.8	852,331.88	1,913,666	754,771.14	361,379	348,880.4	1,418,202.60	1,420,541	7,937,198.82
	3	517,036.52	429,681	893,874.82	1,734,155	476,007.96	354,534	348,773.47	1,022,428.40	914,455	6,690,946.39
	4	584,988.13	463,832	883,184.08	1,847,158	613,511.43	428,719	324,810.60	1,414,824.50	1,107,780	7,668,808.14
2014	1	458,553.13	387,057	705,027.97	2,125,578	441,116.51	419,025	311,939.78	1,109,474.60	<b>1,156,987.70</b>	7,114,759.56
	2	577,653.99	390,572	894,854.99	2,458,254	633,148.18	477,744	423,963.26	1,144,365.60	<b>1,273,674.75</b>	8,274,230.88
	3	412,701.70	380,064	674,115.21	2,129,587	451,277.16	<b>368,969.27</b>	310,283.96	<b>1,011,872.36</b>	<b>883,010.25</b>	6,621,880.71
	4	463,550.43	<b>385,318</b>	<b>789,295.56</b>	<b>2,139,298.19</b>	<b>620,529.34</b>	<b>474,270.07</b>	<b>342,749.40</b>	<b>1,551,315.83</b>	<b>1,166,456.06</b>	7,932,782.91

presents the future predicted doses that are recommended for use by the MOH.

## DISCUSSION

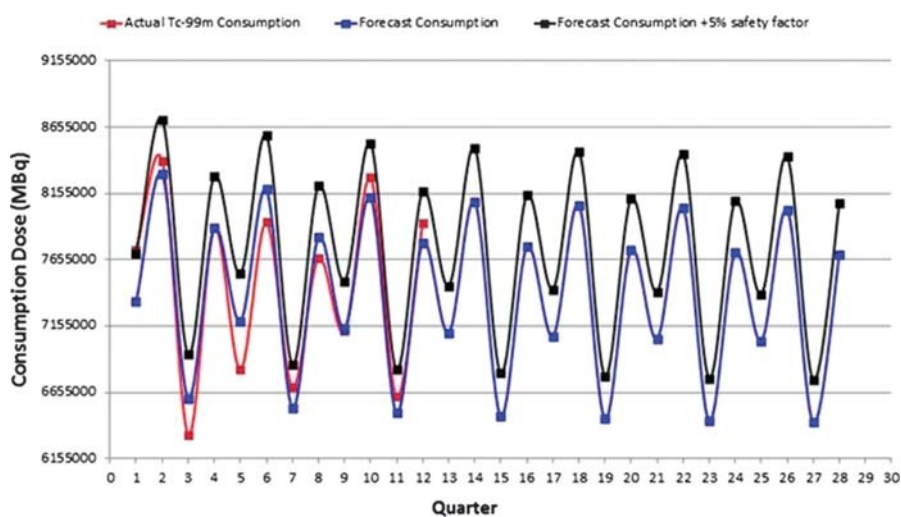
The MOH in Kuwait has recently enforced the recording of all dosages of  $^{99m}\text{Tc}$  used at its nuclear medicine departments. Because this practice is new, data are available only from the year 2012 and beyond in the form of handwritten documents, which has led in some cases to missing data and lost documents. Thus, to conduct this study, the missing data had to be predicted using different forecasting methods. Although the overall result showed an error of only 2.4%, more data are required to obtain more realistic and reliable results. The overall result indicates that there will be a partial decrease of 1.012% in the overall total demand for  $^{99m}\text{Tc}$  from 2015 to 2018. This result therefore indicates that the consumption rate in Kuwait is roughly

constant or that the assumed values for the missing data and the high consumption rate in 2012 affected the results.

## CONCLUSION

The radioactive isotope  $^{99m}\text{Tc}$  is a radioactive isotope produced from the decay of  $^{99}\text{Mo}$ , with a short half-life of 6 h. As such, it is useful for medical imaging for the diagnoses of various ailments. Its emission can be detected by imaging equipment used by hospitals to produce clear and accurate images of defects within a human body. It is used in more than 80% of nuclear medicine's diagnostic procedures across the world, as it is vital for diagnostic tests for several cancers and heart diseases.

The Ministry of Health in the state of Kuwait currently depends on importing  $^{99}\text{Mo}$  to meet its needs. As such, it is important to evaluate Kuwait's current and future demands for  $^{99m}\text{Tc}$ . This is done by gathering the consumption data



**Fig. 1.** Kuwait's actual and forecast  $^{99m}\text{Tc}$  consumption from 2012 to 2018.

**Table 2.** Kuwait's total predicted  $^{99m}\text{Tc}$  consumption from 2015 to 2018.

Year	Quarter	Total forecast $^{99m}\text{Tc}$ (GBq)	Total forecast $^{99m}\text{Tc}$ With 5% safety (GBq)
2015	1	7,067.777	7,421.164
	2	8,063.114	8,466.266
	3	6,453.577	6,776.254
	4	7,730.003	8,116.505
2016	1	7,036.105	7,387.938
	2	8,029.222	8,430.709
	3	6,428.047	6,749.466
	4	7,701.069	8,086.128
2017	1	7,011.167	7,361.742
	2	8,002.175	8,402.293
	3	6,407.401	6,727.784
	4	7,677.463	8,061.338
2018	1	6,990.595	7,340.134
	2	7,979.642	8,378.650
	3	6,390.085	6,709.580
	4	7,657.483	8,040.359

of  $^{99m}\text{Tc}$  from all nuclear medicine departments in Kuwait, predicting missing data using different statistical approaches, and predicting the future total consumption of  $^{99m}\text{Tc}$ .

The predicted total  $^{99m}\text{Tc}$  consumption in Kuwait has shown a reduction of 1.012% for the upcoming years with an average error of only 2.4%. This can be due to many reasons, mainly missing data, high consumption during the 2012 period, and human error. The suggested future consumption had a 5% increase on the forecast data. This is to ensure the availability of  $^{99m}\text{Tc}$  at all times.

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