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Radioactive Waste from a Nuclear Medicine Department

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الفضلات الإشعاعية في الطب النووي

هادية بريرحي و أنتوني كونستبل

خلاصة : تقدم هذه الدراسة فرصة فريدة لقياس النشاط الإشعاعي في نظام تصريف مياه مجاري محدودة ، كما تحدد الخطوط الأساسية لقرارات الإدارات اللاحقة . تم أخذ عينات من مياه السقي وفضلات المجاري الناتجة عن محطة معالجة المياه الثقيلة التابعة لمستشفى جامعة السلطان قابوس لغرض تحديد مستوى النشاط الإشعاعي الناتج عن استخدامات النظائر المشعة في قسم الطب النووي . و تم تشخيص النظير المشع وتحديد نشاطه باستخدام كاشف الجرمانتيوم عالي النقاوة ، كما رُكز الاهتمام على نظير اليود المشع – 131 ذو متوسط العمر البالغ ثمانية أيام في محاولة للمحافظة على تركيزه في مياه السقي كي يتماشى مع مواصفات منظمة الصحة الدولية (WHO) الخاصة بمياه الشرب التي تنص على أن لا تتجاوز الجرعة الإشعاعية السنوية المستلمة نتيجة استهلاك مياه الشرب على 0.1 mSv. لقد كانت المهمة صعبة وذلك لوجوب التماشي مع السياسة المحلية التي تفرض إبقاء مرضى سرطان الغدة الدرقية في المستشفى بعد علاجهم باليود – 131 وبنشاط قـــــدرة 10 GBq .

ABSTRACT: Sampling of irrigation water and sludge from the sewage treatment plant at Sultan Qaboos University Hospital was undertaken to assess the level of radioactivity due to radionuclides used in the Nuclear Medicine Department. Radionuclide identification and corresponding activity were determined with a high purity germanium detector. The radionuclide, Iodine-131 with its eight day half-life, was of major concern while attempting to maintain its concentration in the irrigation water at a level commensurate with World Health Organization Guidelines for Drinking Water Quality which specifies that the annual radiation dose from drinking water should not exceed 0.1 mSv. This was difficult to achieve while adhering to a strict local policy of keeping thyroid cancer patients in hospital following treatment with up to 10 GBq of I-131. The study provided a unique opportunity to measure radioactive sewage in a well contained system and provided baseline data for subsequent management decisions.

The rapid removal of radioactive waste from a Nuclear Medicine Department into the sewage system is a subject which does not generally lend itself to extensive investigation. Sewage systems usually handle waste from many sites and any radioactivity discharged into them is rapidly diluted into a complicated network of interconnected pathways, sewage treatment plants (STP) and discharge channels.

The Sultan Qaboos University Hospital (SQUH) is not typical of those found in Europe. It is well removed from large populations and is situated on a university campus with its own STP. All liquid waste from the hospital passes directly to the treatment plants. The STP is designed for a population of 10,300 but the existing population (in 1997) is about 6200. The treated water is stored in holding tanks and used for irrigation purposes throughout the university campus, an area extending over 1.96 km^2 including the hospital, the university, a farm, student residential accommodation and staff housing. As the amount of water needed for irrigation is variable and usually greater than the amount produced by the STP, potable water (rarely exceeding 5% of the total volume) is added to the holding tanks and constitutes the only source of dilution into this well contained system. Any radioactivity discharged from the hospital passes into the system and is periodically monitored.

There are no radioactive allowances for any sites in Oman which means that, at the time of disposal, the sludge from the STP must have a radioactive concentration lower than 100 $kBq \cdot kg^{-1}$ which the UK regulations judge to be the minimum activity concentration for any material to be considered radioactive (Ionizing Radiation Regulations 1985, UK).

The present paper discusses the levels of radioactivity found in the irrigation water and sludge in relation to the quantities of the various radionuclides discharged from the nuclear medicine department.

Methods

A preliminary study was carried out shortly after commencement of nuclear medicine services and continued for a period of 6 months (July to December 1991). During this time daily water samples were collected and analyzed. The sampling point was immediately before the point of use as irrigation water. The activities found in these samples were compared on a monthly basis with the activity administered to patients during the same period. Irrigation water has been sampled continuously on a weekly basis up to the present time (1997).

The sludge sampling has also been carried out continuously since 1992 from sites in the STP where it is held for drying. Samples were taken from the dried sludge at times ranging from a few days to a few weeks after sludge production and their activities were corrected to the time of production and compared with the activities administered to patients. As most of the radionuclides used in the nuclear medicine department have short half lives or are of very low activity, the only radionuclide looked for in the sludge samples was Iodine-131(I-131) which has a half-life of 8 days.

In this hospital, I-131 is regularly used for the treatment of patients with thyrotoxicosis and thyroid cancer. Furthermore, in order to avoid unnecessary family exposure, these patients are normally kept in hospital for up to two weeks. The cancer patients have doses which normally fall in the range 4-10 GBq and, to avoid the obvious problems of introducing excessive amounts of I-131 into the sewer during the first 48 hours after administration, all urine during this period was stored in specially constructed containers housed on the roof of the hospital. All the remaining waste from cancer patients and all the waste from thyrotoxic patients (who have doses ranging from 400 to 600 MBq) was discharged into the sewage system.

The identification of radionuclides and the measurement of activity was carried out with an EG&G Ortec multichannel analyzer and a high purity germanium detector calibrated against a standard package of radionuclides in Marinelli beaker format. A library of radionuclides was compiled and included all those in normal use in the Nuclear Medicine department. Background activities for irrigation water and sludge were determined by counting one litre of distilled water and one kilogram of surface soil from a non-irrigated site in the same counting geometry as the samples.

Acceptable Levels of Radioactivity in Sludge and Drinking Water

Because of the well contained working environment at SQU, the permissible levels of radioactivity in sludge and irrigation water had obviously to be chosen to be as low as possible within the constraints of providing a full patient service, one in which all patients undergoing thyroid treatment are kept in hospital for up to two weeks.
No official regulations for the control
radiations have been in use in Oman up to r
has been the practice since starting the nucle
service in 1990, to adopt UK Regulatio
Recommendations of the International Com
Radiation Protection (ICRP) (1990) in the p
control of radioactive waste disposal.

The irrigation water is distributed thro
campus to maintain a very considerable displa
plants and trees, and it was thought advisable
level of I-131 activity satisfying the Wo
Organization (WHO: 1993) guidelines which s
the annual radiation dose for drinking water
exceed 0.1 mSv. Assuming an adult drinks tw
water daily this gives a calculated maximum p
concentration of I-131 to be 5.5 Bq·litre^{-1}. Th
radioactivity is far more stringent than leve
from the ICRP recommendations.

The sludge is deposited at sites designa
municipality. Preliminary calculations, bas
expected patient throughput, showed that it
possible to limit the sludge concentration of
maximum of 4 kBq·kg^{-1}. This limit is considera
the level of 100 kBq·kg^{-1} referred to abo
compatible with UK guidelines for radioactiv
waste. The design of SQUH provides the rare o
of working with a well contained sewage sys
exceptionally clean environment. We consider
we have chosen to be most appropriate and
wish to exceed them until and unless it
absolutely necessary.

It might be considered unnecessary to kee
being treated for thyrotoxicosis in hospital for
weeks. To send them home, as is the practice i
and USA, would relieve the problem of was
university site by the simple expedient of dis
throughout the towns and villages of Oman. Th
local conditions and customs do not allow us to
practice at the present time. Most of our pa
young mothers with large families. The social
are very strong in Oman and it is the normal tr
practice for Omani mothers to be in very clos
with their younger children day and night.
practical way to prevent this is to keep patients in
for two weeks following the administration of I-1
after patients return home the radiation doses rec
children living and sleeping in close contact w
mothers is not inconsiderable and they are curren
investigated.

Results

Table 1. shows the activities in GBq of th
nuclides administered to patients during the s
period of 6 months, from July to December 1991

TABLE 1

Activities administered to patients in the initial 6 months period of sampling in 1991.

Activities administered GBq (1991).

	Tc-99m	I-131	Tl-201	Ga-67
July	4.041	1.063	0.204	0.064
August	10.304	0.328	0.229	0.069
September	9.398	4.504	0.242	0.245
October	8.795	1.371	0.238	0.179
November	9.408	5.516	0.178	0.103
December	11.098	0.403	0	0.264

The activities, measured in Bq·litre^{-1}, of the processed water for irrigation, from July to December 1991, are shown in Table 2. The correlation of the administered activity with the irrigation water levels was seen to be poor and this should be expected because of the diversity of the pathways.

The local water radioactivity intake limits are based on the values in Table 3. These have been developed using the ALI (Annual Limit of Intake) for radiation workers and applied to the general public for a total annual effective dose of 1mSv (1990 ICRP recommendations), assuming an adult drinks two litres of water daily. It can be seen that the radioactivity in the irrigation water (Table 2) is small by comparison.

Table 4. shows the average I-131 concentrations in sludge (in Bq·kg^{-1}) and irrigation water (in Bq·litre^{-1}) calculated from the monthly measured activity over the years 1992 to 1996. The activity from the irrigation water varied from 2 to 20 Bq·litre^{-1}. The table also shows the sludge average activity (in kBq·kg^{-1}) corrected to the date of its deposition in the sludge beds and the average activity (in GBq) administered to patients during the corresponding periods. The averages were calculated over periods of 4 months. As might be expected there was no simple correlation between the sludge or water activities and the corresponding administered activities. The diversity of pathways and accumulative effect of radioactivity on the growing deposit of sludge and the probable non-compliance of admitted patients to urinate in a container during the first 48 hours post I-131 administration does not allow straightforward determination of any relationship between administered dose and sludge or water activity concentration.

TABLE 2

Activity concentrations in irrigation water in the initial 6 months period of sampling in 1991.

Activity concentrations Bq-litre^{-1} (1991).

	Tc-99m	I-131	Tl-201	Ga-67
July	0.02	0.24	0.14	0.07
August	0.02	0.02	0.05	< 0.07
September	0.11	0.31	< 2.10	< 0.84
October	0.10	0.08	< 2.01	< 0.51
November	0.06	0.29	< 2.01	< 0.70
December	0.03	0.28	< 2.78	< 1.09

TABLE 3

Limit of intake activity concentrations in drinking water to give an annual radiation dose of 1 mSv.

Maximum activity concentrations Bq-litre^{-1}

	Tc-99m	I-131	Tl-201	Ga-67
Permitted level	7.10^{4}	55	2.10^{4}	5.10^{3}

Discussion

This study demonstrated that the nuclear medicine procedures in practice during the period of investigation resulted in the presence of measurable quantities of radioactive waste in the water output of the sewage treatment plant and the thyroid treatment programme resulted in the presence of I-131 in the sludge. The level of activity in the water during the period of investigation when the patient throughput was low did not exceed the limits. Although there is no direct relationship between administered dose and the quantities of radioactivity in sludge and irrigation water, it cannot be doubted that big increases in administered dose coupled with inattention to good practice in the nuclear medicine department will result in higher output levels. During the latter half of 1991, the irrigation water levels of I-131 reached a maximum of 0.31 Bq·litre^{-1}, well below the WHO recommended value for drinking water of 5.5 Bq·litre^{-1}. This low level of I-131 became difficult to maintain as the number of thyroid patients increased but there remains some reluctance to abandon the practice of keeping them in hospital for 2 weeks. In 1996 the activity levels in the

TABLE 4

Averaged I-131 concentrations in sludge and irrigation water and average doses administered to patients obtained monthly data from 1994 to 1996. The averages were calculated over periods of 4 months.

I-131					
Sludge Activity kBq/Kg (at time of collection)	Sludge Activity Averaged over 4 months after correction for decay to date of output			Activity administered GBq	Activity in irri water Bq/litre
	Months	Year	Activity kBq/Kg		
0.15	7-8-9-10	1992	56	9.2	2
0.36	3-4-5-6	1993	12	5.6	2
0.88	7-8-9-11	1993	58	13	2
5.0	2-3-4-5	1994	134	9.8	19
1.7	6-7-11-12	1994	58	10	12
2.3	1-2-9-10	1995	72	9.7	20
0.77	1-2-3-4	1996	121	17	16
1.2	5-6-7-8	1996	548	64	2

irrigation water reached 29.1 Bq·litre^{-1} on one occasion. The WHO recommendations for I-131 in drinking water is ten times less than the limits based on IRCP recommendations because it is based on a total annual effective dose of 0.1 mSv. As the irrigation water is never used for drinking we believe we could tolerate an I-131 level of 55 Bq·litre^{-1}. The WHO level has been exceeded but not the tolerated level of 55 Bq·litre $^{-1}$.

In order to avoid further increases, delay tanks have now been installed. This will allow increases in the patient throughput without discontinuing the practice of keeping them in hospital for two weeks and will also avoid the distribution of irrigation water throughout the campus with I-131 levels higher than is permitted for drinking water.

Although the activity of the sludge at discharge is high compared to the acceptable level for non radioactive material (100 kBq·kg^{-1}), it is usually left to decay to the level of 4 kBq·kg^{-1} before its disposal at designated sites.

Conclusion

The aim of the present study was to investigate the environmental distribution of radionuclides originating in a nuclear medicine department before and during its implementation of a busy program of clinical procedures. The local conditions were especially suited to the investigation particularly as all waste is co in a nearly closed system.

The results obtained have provided us with guideline figures from which the consequen increasing the number of patient procedures c judged. This has provided invaluable baseline d addition to that derived from normal calc estimates.

The practice of keeping patients confin hospital is a necessity imposed by the local cu environment, but the future possibility of discha patients after receiving suitable instructions is continuous review.

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