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MONITORING AND QUALITY CONTROL TESTS OF NIGERIAN NATIONAL PETROLEUM CORPORATION (NNPC) DIAGONSTIC FACILITIES: PART OF QUALITY ASSURANCE PROGRAMME OF RADIOLOGY IN NIGERIA

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ABSTRACT

This paper presents a monitoring and Quality Control (QC) tests carried out in the Nigeria National Petroleum Corporation (NNPC) Diagnostic centres in Kaduna, North Western Nigeria. The results of these investigations revealed that both radiation protection and Medical/Health Physicist were visibly missing. Monitoring of the facilities showed that in X-ray suites (room1 and room2), the dose rate found near the cubicle and changing room were in the range of factors of 2.0 - 6.7 and 3.3 - 16.7 higher than the background dose rate respectively. However, in the plant clinic, there were radiation leakages. The quality control test of the rooms showed reproducibility of kilovolt peak (kVp) in room1, while QC tests in room2 were acceptable (fall within the range of the required standard). It was recommended that the plant clinic be shut down because of radiation leakages found there.

Keywords: *Quality control, quality assurance, diagnostic facilities, radiology*

INTRODUCTION

Quality assurance (QA) is a management technique that is used to moderate any system that results in a product [1]. However, in setting up a QA programme, both the final product and the system that produces it are defined. The quality control (QC) comprises the regular testing that must be carried out on each major component of the system to ensure its optimum performance within the system as a whole [2]. In context of diagnostic radiology, quality assurance is carried out to ensure the production of a high quality diagnostic image for the minimum radiation dose to the patient [3]. The technique of quality assurance in diagnostic radiology involves a quality control programme that will involve the selective testing of each major system component on regular basis to ensure optimum performance within the system [4].

The major system in diagnostic radiology to which major quality control can be applied include; X-ray production, detection, image processing, and image viewing. These tests must be coupled with the routine monitoring of final image quality and the environment. The most efficient QA programme is those in which the patient dose reduction is balanced against the cost of staff time, material and equipment [2].

In the X-ray production, some of the variables investigated during quality control include the following; peak tube voltage (kVp), product of tube current and exposure time (mAs), beam filtration, automatic exposure devices (AEDs), machine output, X-ray beam/alignment and focal spot. These variables are initially checked to establish a baseline for QA programme. Thereafter, regular testing is contrived to AEDs machine output and beam alignment. Certain test is expected to be carried out on weekly basis on certain devices such as AED since it has the tendency to lose calibration over a period of time and this will affect both image quality and patient dose. Other variable that requires weekly measurement is the radiographic output. However, it is rather unfortunate that in Nigeria, these measurements are not regularly carried out if done at all, hence, it affects the quality of patient dose and image quality

REGULATORY PROGRAMMES IN NIGERIA

Since radiation does not respect local or international boundaries once released into human environment, it is necessary to monitor its

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presence in the environment. It is also a necessity to set up a regulatory body that will regulate the activities of the user of radiation. This requirement prompted the federal government of Nigeria to inaugurate a nuclear safety committee to draft a law on nuclear safety and radiation protection as well as to do an inventory of all radiation source users in Nigeria. The law was passed in January, 1995 but not functional as there was no incorporation of sufficiently competent and independent nuclear regulatory organization for ensuring protection and safety. However a few years ago, a competent body known as Nigerian Nuclear Regulatory Agency (NNRA) was created; other regulatory bodies such as Federal Radiation Protection Service (FRPS) also evolved. In 2005, an institute called National Institute of Radiation Protection and Research (NIRPR) was established by Act 19 of 1995, this body besides the regulatory responsibilities is also a training institute and it's in conjunction with the Physics department, University of Ibadan, Nigeria. The memorandum of understanding between the two resulted in the commencement of two radiation protection courses namely; Masters in Radiation Protection and Postgraduate Diploma in Radiation Protection using the International Atomic Energy Agency designed syllabus.

The need for regulatory bodies stems from the fact that diagnostic X-ray procedures are significantly sources of radiation exposure to both patients and medical personnel [5]. The Nigerian Nuclear Regulatory Authority is saddled with the responsibility of ensuring that radiological practices conform to recommendations of the International Commission on Radiological Protection (ICRP).

In this study we present the results of the monitoring of immediate environment of the facilities and tested the X-ray facilities in the X-ray unit of the hospital of the subsidiary of Nigerian National Petroleum Corporation located in Kaduna, North Western Nigeria.

MATERIALS AND METHODS

In this study both questionnaire and measuring devices were used in the collection of data. Information that bothered on the availability and the number of personnel, types and model of X-ray machines monitoring procedures used in the past, appropriateness of main and auxiliary equipment, preventive maintenance repairs, facilities shielding and log book for documentation of information were obtained with questionnaires. The questionnaires were completed by the most senior personnel in the X-ray unit. The devices used for the test of the X-ray facility was a calibrated non-invasive X-ray test device, Victoreen model 4000M+. This was employed to determine the accuracy and timer setting as well as X-ray machine output. However for the monitoring of the facility, immediate environment calibrated survey monitor 4 minirad 1000+ was used. These devices were obtained from the National Institute of Radiation Protection and Research (NIRPR), Physics department, University of Ibadan.

RESULTS AND DISCUSSIONS

Personnel and general observations

Table1 shows the clinics investigated model of machine and year of manufacture. This table shows that one of the machines located in X-ray room1 was manufactured thirty years ago while that of room2 (industrial clinic) was also manufactured about seventeen years ago. The third machine in the plant clinic was manufactured about twenty years ago. Table2 shows the distribution of personnel in the three diagnostic centres; this distribution confirms the earlier report in Nigeria [5]. The table shows visibly missing positions of Radiation Protection Officer (RPO) and Medical Physicist (MP) while the radiologist is non-residential. Apparently only one Radiographer is responsible for the exposure of every patient in the three clinics; this implies that the work load is in excess of what is expected. This probably may not create room for vacation for the Radiographer. In addition, since there was no Radiation Protection Officer and Medical Physicist present, and then it will not be unlikely that the radiation dose has never been measured nor the output of the X-ray machines, these are the responsibilities of the radiation Protection Officer and Medical Physicist.

Table3 is a general observation about the facilities provided for the patients and personnel safety, it is evident from the table that there was no efficient cubicle and cubicle window in both room1 and plant clinic. There was no provision made for door interlock; and the door could not close automatically, as a result any one could enter into the X-ray room even while the exposure was going on. In plant clinic, hazard was not provided while in all the three diagnostic centres, there were no personnel monitoring badges provided and moreover, no log book was available for record keeping. All these observations made here show that the three clinics fall short of the expected standards required by the international regulatory bodies.

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Background Monitoring

Table4, 5 and 6 indicates the dose rate measured at different locations within the clinic; the table revealed that in room1, the dose rate was higher than the background by as high as a factor of 6.7 at the edge of the cubicle while at the changing corner, the dose rate was higher than the background by a factor of 16.7. In room2, the dose rate near the cubicle was higher than the background by a factor 2 and a factor of 3.3 within the changing room. It is worthy noting here that the dose rate at the waiting seat was higher than the background by a factor of 5; there were leakages at the plant clinic. The condition of leakages poses danger to both patient and the personnel.

Quality control test

Quality control (QC) test was performed on the equipment in the three rooms of the clinic. The results of QC test are shown in tables 7, 8 and 9; in all rooms where the QC test were carried out. Figure 7 shows that only reproducibility of kVp in room1 was acceptable, while in room 2 (figure 8) all the tests carried out were acceptable. However, in the plant clinic, leakages prevented the QC test from being carried out. The layouts of the X-ray suites indicate that dark room and sorting room are sandwiched between room1 and 2. There were also line of sight from focus out of room 1 and 2; in plant clinic where leakages were recorded, the dark room lies adjacent to the X-ray suite and there is a line of sight from focus also exists.

Due to the negative effects associated with the unwanted X-ray radiation doses, it is necessary to protect both personnel and patients from radiation. Therefore, the guiding principle stipulates that radiation doses must be kept low as reasonably achievable (ALARA principle). Besides, quality assurance of the equipment must be ensured; all the equipment used must be subjected to quality control test periodically. In this study, we found out that there were no adequate personnel to man the three X-ray rooms. The only Radiographer available will have a great deal of work load per week; this could be at the expense of his health. In addition, the officers and personnel responsible for the quality control, radiation monitoring and regular measurement of dose to the patient were not available. We also found that adequate safety measures were not in place; one of the machines (in plant clinic) was leaking. Also, the X-ray suite was not designed to meet the standards required by the International regulatory body. The occupancy factor of the operator area was exceeded in room 1 and plant clinic while the occupancy factor of patient's waiting area was also exceeded in room 2 and plant clinic.

As a result of the foregoing findings from the QC test, the following recommendations were made;

1.) A quality management program should be urgently put in place and must have radiation safety policies and procedures.
2.) Radiation safety officer (at least) and perhaps medical physicist should be engaged.
3.) Beam alignment must be carried out (the film exposed over 50% off target in x-ray room 1) and the machine should be over hauled.
4.) Since determination of exposure ionizing radiation is an important function of radiation protection in general and is particularly necessary for radiation workers, it is necessary to carry out the measurement regularly. Periodical monitoring recommended using direct and indirect methods, the result of the measurement should be forwarded or made available to the National Institute of Radiation Protection and Research (NIRPR), Ibadan which keeps the National dose register.
5.) New X-ray machines are recommended for X-ray room 1 and plant clinic because of their poor quality test reports.
6.) To enhance adequate documentation of all activities, log book should be provided for recording and references. A record keeping system to be handled by record officer, to document quality control procedures and compliance with the accepted norms. The items to be included are room log books, incident reports, control chart, equipment checklist, and examination requisition, film badge report of every personnel and image interpretation reports. All inadequacy of equipment and personnel and corrective measures should be documented in the log book.
7.) Warning lights and signs at the entrance to the X-ray rooms to indicate a "controlled area" due to X-ray should be provided and put in place.
8.) Finally, efficient lead apron should be provided by the management of the clinic especially in plant clinic which was expected to be sealed off because of leakages found.

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As regard the Nigerian Nuclear Regulatory Authority, it is expected that this body be adequately funded by the government to perform its functions adequately.

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Table 1: Data of X-ray machines in different Clinics

	Clinic and location	Machine manufacturer	Name of machine	Year of manufacture	Model
1	X-ray room 1 (Industrial clinic)	Philips Medical Systems, Holland	Rotapractix 980210503001	1975	NR645070
2	X-ray room 2 (Industrial clinic 2)	Philips Medical System, Holland	Medio 50 CP-H Fluorount	1991	885245
3	Plant Clinic X-ray room	Pilipia Medical System, Japan	MCD 100 (Mobile unit) Rotalix	1981	76108

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Table 2: Distribution of Personnel in the centre (clinics)

No. of Radiologist	No. of Medical Medical Physicist	No. of Radiographer	No. of Technician	Radiation Protection Officer	Number of X-ray machines
1(visiting)	0	1	2	0	3

Table 3 : General facilities Observations

	General observations	**X-ray room 1**		**X-ray room 2**		**Plant clinic**	
		Y	**N**	**Y**	**N**	**Y**	**N**
1	Main door to X-ray room (lead lined)	**X**	**-**	**X**	**-**	**X**	**-**
2	Main door to X-ray room (lead efficient	X	-	X	-	X	-
3	Cubicle(lead wood type)	X	-	-	-	X	-
4	Cubicle (lead concrete type)	-	-	X	-	-	-
5	Cubicle efficient	-	X	X	-	-	X
6	Cubicle window (efficient)	-	X	X	-	-	X
7	Door interlock provided	-	X	-	X	-	X
8	Door (close automatically)	-	X	-	X	-	X
9	Provision of lead apron	X	-	X	-	-	X
10	Lead apron efficient	-	X	-	X	-	-
11	Hazard warning light provided	X	-	X	-	-	X
12	Hazard warning light functional	X	-	X	-	-	X
13	Hazard warning sign (displayed)	X	-	X	-	-	X
14	Functional air-conditional provided	X	-	X	-	X	-
15	Personnel monitoring TLD badge available	-	X	-	X	-	X
16	Qualified Radiographer available	X	-	X	-	X	-
17	Dark room X-ray room interconnected	X	-	X	-	X	-
18	Darkroom temperature controlled	X	-	X	-	X	-
19	Thoroughfare(prohibited) not available	X	-	X	-	X	-
20	Log book available	-	X	-	X	-	X
21	X-ray machine over 15 years	X	-	X	-	-	X
22	Space of X-ray room adequate	X	-	X	-	X	-
23	Collimator light functional	X	-	X	-	-	-
24	X-ray beam in alignment and within limits	-	X	X	-	-	-

Y (X) =yes N (X) =no

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Table 4: Dose rate level of X-ray room 1

	Description	Dose rate µSv/hr
1	Left edge of cubicle	1.5
2	Right edge of cubicle	2.0
3	Patient changing corner	5.0
4	Entrance door outside (door closed)	BK
5	Entrance door outside (door opened)	2.5
6	Room (left) beside X-ray room ½ metre from the wall	0.5
7	Room (left) beside X-ray room 1 metre from the wall	BK
8	Sorting room on the right of X-ray room	BK
9	Darkroom	BK

Background reading (BK) within the X-ray room: 0.1-0.3 µSv/hr
Background reading outside the X-ray room: 0.0 -0.3 µSv/hr

Table 5: Dose rate level of X-ray room 2

	Description	Dose rate µSv/hr
1	Within the cubicle	BK
2	Within changing room (door closed)	BK
3	Within changing room (door opened)	1.0
4	Edge of cubicle	0.6
5	Entrance door outside (door closed)	BK
6	Entrance door1/2 metre from door(opened)	2.0
7	Patient waiting seats	1.5
8	Sorting room on the left of X-ray room	BK
9	Darkroom	BK

Table 6: Dose rate level of Plant clinic (third room)

	Description	Dose rate µSv/hr
1	Mobile machine (at the control panel) while setting Parameters tube emits X- ray	8.0

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Table 7: Quality Control Test on X-ray tube and Generator (Room 1)

Types of Test	Variations %	Settings		Measured Quantities			Test Results (A=Acceptable NA=Not Acceptable)
		kVp	mAs	Efficient kVp	Exposure Time(s)	Output (mR)	
Accuracy (kVp)	±5%	61	10	-	-	-	NA
		75	10	77.89	0.13	40.85	
		80	10	83.76	0.14	47.24	
		108	10	100.10	0.22	77.48	
		100	10	113.40	0.16	51.56	
Accuracy (Time)	±5%	80	5	80.85	0.06	21.10	NA
		80	20	83.08	0.27	88.19	
		80	32	83.60	0.45	151.40	
		80	50	84.20	0.69	232.00	
Consistency (kVp)	±10%	80	05	80.85	0.06	21.10	NA
		80	20	83.08	0.27	88.19	
		80	32	83.60	0.45	151.40	
		80	50	84.20	0.69	232.00	
Linearity (mA)	±10%	80	10	82.51	0.13	44.38	NA
		80	20	83.12	0.26	86.69	
		80	32	83.85	0.43	142.90	
		80	40	83.88	0.49	158.30	
Reproducibility (kVp)	±5%	80	10	82.02	0.12	41.58	A
		80	10	82.20	0.12	41.15	
		80	10	82.10	0.13	40.71	
Reproducibility (Timer)	±5%	80	10	82.02	0.12	41.58	NA
		80	10	82.20	0.12	41.15	
		80	10	82.10	0.13	40.71	
Consistency of Output	±5%	80	32	96.30	0.44	139.40	NA
		80	32	76.80	0.40	129.50	

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Table 8: Quality Control Test on X-ray tube and Generator (Room 2)

Types of Test	Variations %	Settings		Measured Quantities			Test Results (A=Acceptable NA=Not Acceptable)
		kVp	mAs	Efficient kVp	Exposure Time(s)	Output (mR)	
Accuracy (kVp)	±5%	60	10	57.78	0.02	42.24	A
		70	10	67.85	0.01	59.99	
		81	10	78.51	0.02	81.88	
		102	10	98.61	0.03	126.50	
		125	10	121.90	0.03	188.10	
Accuracy (Time)	±5%	81	05	78.40	0.01	42.28	A
		81	20	79.10	0.04	158.70	
		81	32	78.90	0.06	252.30	
		81	50	79.30	0.10	395.60	
Consistency (kVp)	±10%	81	5	78.40	0.01	42.28	A
		81	20	79.10	0.04	158.70	
		81	32	78.90	0.06	252.30	
		81	50	79.30	0.10	395.60	
Linearity (mA)	±10%	81	10	79.30	0.02	181.44	A
		81	20	79.80	0.04	159.90	
		81	32	80.80	0.06	253.80	
		81	40	80.80	0.08	317.80	
Reproducibility (kVp)	±5%	81	10	77.20	0.02	81.38	A
		81	10	77.30	0.02	81.32	
		81	10	78.00	0.02	81.38	
Reproducibility (Timer)	±5%	81	10	77.20	0.02	81.38	A
		81	10	77.30	0.02	81.32	
		81	10	78.00	0.02	81.38	
Consistency of Output	±5%	81	32	78.10	0.06	255.60	A
		81	32	78.10	0.06	255.30	

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Table 9: Quality Control Test on X-ray tube and Generator (Plant Clinic)

Types of Test	Variations %	Settings		Measured Quantities			Test Results (A=Acceptable NA=Not Acceptable)
		kVp	mAs	Efficient kVp	Exposure Time(s)	Output (mR)	
Accuracy (kVp)	±5%	61	10	No measurement was recorded From this machine due to radiation leakages from the tube when knob was adjusted for parameter setting.			NA
		75	10				
		80	10				
		108	10				
		100	10				
Accuracy (Time)	±5%	80	05				NA
		80	05				
		80	05				
		80	05				
Consistency (kVp)	±10%	80	05				NA
		80	05				
		80	05				
		80	05				
Linearity (mA)	±10%	80	10				NA
		80	20				
		80	30				
		80	10				
Reproducibility (kVp)	±5%	80	10				NA
		80	10				
		80	10				
Reproducibility (Timer)	±5%	80	10				NA
		80	10				
		80	10				
Consistency of Output	±5%	80	32				NA
		80	32				