CHAPTER 7
CONCLUSIONS

7.1 INTRODUCTION

The purpose of this chapter is to summarise the conclusions drawn from the studies reported in the Chapters 2 to 6. The need for the development of remote afterloading systems is outlined in Chapter 1. Some of the salient features pertaining to Selectron (LDR) remote afterloading system, is also described. Before any treatment system is commissioned, it is mandatory to make physical studies in order to ensure that the system can be safely used for treatment, without causing any undue damage. Hence physical studies like calibration of (caesium-137) sources and attenuation of gamma-rays in tissue equivalent materials are done. To compute the dose (from Selectron application), a software has been developed. To check the computed values, direct measurements in wax phantom have been performed. Dose distributions are obtained on films and compared with computed distributions. Dosimetry is done using contour projector also. Some clinical aspects like complications of rectum and bladder from Selectron treatment are studied and compared with those due to manual afterloading in order to evaluate, how far the system could be relied upon from the clinical point of view. A survey of radiation dose distribution in the Selectron room has also been carried out.

7.2 CONCLUSIONS OF THE STUDIES

7.2.1 Calibration of sources

In Chapter 2, calibration of caesium-137 sources of Selectron has been reported in the first part. 36 caesium
sources are procured in 1985. The sources are got in 2 consignments, with 18 sources in each consignment. The exposure rate at 1 metre, has been quoted to be 0.33R/Ci/hr, in the "Certificate of calibration" provided by Amersham. Using this factor the minimum and the maximum exposure rate values (expected) are calculated from the minimum and the maximum activity of the sources quoted in the certificate. The calculated minimum and maximum values of exposure rate at 60 cm are 0.598 mR/min. and 0.636 mR/min. respectively. The weighted average value is 0.617 mR/min. The deviation of the minimum and maximum value from the mean value is -3.08% and +3.08%. The exposure rate (at 60 cm) measured at the hospital shows a minimum of 0.588 mR/min and a maximum of 0.627 mR/min, the mean value being 0.608 mR/min. The deviation of the minimum and maximum value from the mean value is -3.29% and +3.13%. If calculations are done assuming that the activity of each source is 40 mCi, the exposure rate at 60 cm works out to be 0.597 mR/min. The measured mean value differs from this value by +1.84%. The actual mean apparent activity, which is determined by comparing the measured exposure rate with the calculated exposure rate, works out to be 40.74 mCi.

The measured mean value is 1.46% less than the mean value stated by the manufacturer and 1.84% higher than the nominal activity of 40 mCi.

7.2.2 Attenuation of gamma-radiation in tissue equivalent materials

In the second part of Chapter 2, the attenuation of gamma-radiation from caesium-137, in tissue equivalent materials is reported. The tissue equivalent materials used for the study are water, wax, perspex, pressd-wood and tissue equivalent rubber (Indian made). Eventhough all these materials are considered to be equivalent to tissue, the
physical quantities like the effective atomic number, the electron density and the density, differ by some amount from material to material. The energy of the gamma-ray from caesium-137 is 0.662 MeV, and hence attenuation is mainly due to Compton effect, which depends on the electron density of the attenuating material. Since the electron density of the above mentioned materials differ, attenuation studies are done for all the materials. The results have been compared with the calculated values, using Meisberger's formula. It is observed from the results that, for distances from 2 cm to 6 cm the variation is within ±1%, for all the materials. For distances between 7 cm and 9 cm, the variation is above ±1%. A maximum deviation of +3.77% is observed, for a distance of 9 cm in water. Since the precision of the dosemeter is only ±0.01, more precise readings could not be obtained, which otherwise would have improved the results. The Ionex dosimeter (with a precision of ±0.01R) was out of order when the measurements were carried out. As far the dosimetry of intracavitary treatment is concerned, the points of calculation (like points A and B) lie within 5 cm from the central tandem of sources. Since at these distances, the measured correction factors vary within ±1% of the calculated values, it is concluded that for clinical dosimetry, the correction factors for tissue attenuation can be calculated employing, Meisberger's relation.

7.2.3 Dosimetry of Selectron using computer

To make the dose computation for Selectron, easy and fast a computer program has been written in Fortran. The program takes into account the correction factors for tissue attenuation and oblique filtration through the applicator wall. By feeding the data from the AP shift X-ray, the distribution in any of the three planes (coronal, transverse and sagittal) could be obtained.
Unless direct measurements are made, the computed values cannot be relied upon. Also it is not possible to make direct measurements in patient, as far the intracavitary treatment is concerned. Hence to confirm the validity of the computed values, direct measurements are carried out in a specially constructed wax phantom (with Selectron applicators). Measurements carried out at point A showed that the values deviate from the computed values, from -4.01% to 5.10%. As far the dose rate at point B, the deviation is from -7.50% to 0.19%. Hence at point A, the variation of the measured values from the computed values is within ±5%. Only four of the measured values at point B are between -5% and -7.5%. Hence it is concluded that the program can be used for clinical dosimetry. A copy of the program is given in the Appendix 2.

If tissue absorption is taken into consideration, the dose at point A is reduced by 2%, while at point B the reduction is around 5%. Similarly if tissue absorption is taken into account, the dose at 2 cm (i.e. at point A) shifts by 0.24 mm. and at 4 cm, the shift is 0.95 mm. Hence the shift is only a fraction of a millimetre. These results prove that it is enough to apply the simple inverse square law, to calculate the dose at a point, when calculations are done manually. When computers are employed, the tissue absorption and oblique filtration should be considered to enhance the precision and accuracy.

7.2.4 Film dosimetry of Selectron

There is no better way of checking the computed dose distribution around the Selectron applicators, in a phantom, except film dosimetry. Dose distribution can be obtained by direct measurements also. But the difficulty is that, multiple number of measurements have to be made with the smallest possible detector, as the dose falls off rapidly. Radiation
field analyser can be made use of but the problem is that the applicators have to be positioned properly in water, which may not be possible. Thermoluminescence dosimeters (TLD) in the form of pellets could be used. The advantage with TLD is that all of them could be irradiated, at a time. After irradiation each pellet has to be read to get the dose distribution. The facts that films (i) have high intrinsic spatial resolution (ii) are available in large areas and (iii) are thin, facilitate them to be used for film dosimetry, especially for intracavitary treatment, in which case the dose fall-off is rapid.

INDU NDT 55 films, which are locally available have been made use of for the study. These films have been shown to yield good linear response. Film calibration has been done to start with. Then films are irradiated by keeping them between the sections of a wax phantom which incorporates the Selectron applicators. Isodensity distributions are obtained from the irradiated films, using densitometer. These isodensity distributions are compared with the corresponding computed isodose distributions. It is observed that the isodensity distributions match well with the isodose distributions, but for the discrepancy around the vaginal applicators. The 100%, 90%, 80%, etc. isodensity lines around the vaginal applicators deviate inwards from the 100%, 90%, 80% etc. isodose lines of the corresponding computed distribution. Also kinks are seen at the places where the film touches the vaginal applicators. This might be due to the attenuation (inter pellet shielding) by the sources in the vaginal applicators. The source train in each of the vaginal applicators is in a plane which is perpendicular to the plane of the film. In the computer software no correction factor is included for the inter pellet shielding. This might be the reason for the deviation.
Eventhough it is mentioned that the overall accuracy of the calibration procedure is better than +4.5%, the leakage radiation received by the film, while the shutter opens and closes could not be determined and hence not taken into account. The maximum time of exposure for calibration, itself is only 10 seconds as the film is a fast one. The calculated dose at point \( A \) for the time set for the irradiation of films in the wax phantom ranges between 4.6 cGy and 5.8 cGy. If the films could be given dose of the order of 50 or 100 cGy, the percentage uncertainty in the interpretation of the dose could be minimised. Hence not much importance is given to the estimation of absolute dose, from irradiated films. The dose values at point \( A \), as evaluated from the films are always less than the computed values. Eventhough the evaluation of absolute dose is not so accurate, film dosimetry is the ideal one to have a permanent record of dose distribution. Dose distribution could be obtained on a single sheet of film. The dose distribution obtained is not only permanent, but it is a visual record, that can be expected around the applicators, inside the patient.

7.2.5 **Dosimetry with contour projector**

In small centres, which cannot afford to have a computer (or which do not have the access to a computer), contour projector can best be utilized to find out the dose from intracavitary applications. The device is simple to use with minimum effort. To confirm the validity of using this method, direct measurements have been done. By placing the lead markers in the wax phantom, an AP shift X-ray is taken. Using the shift X-ray, the sources are reconstructed in space and the dose to the marked points are read using the contour projector. Direct measurements are made in the phantom at these marked points. The deviation of the measured values from the values obtained using contour projector
ranges from -5.41% to -0.68% in one set and in the other set the deviation ranges from -0.40% to +4.32%. Only three measured values deviate more than -5% (-5.08%, -5.40% and -5.41%) in the first set of measurements.

The use of contour projector in finding the dose to certain points in the pelvis and hence in estimating the radiation midline is described in Chapter 5. By measuring the distance between the radiation midline and the anatomical midline, the shift of the radiation dose distribution from the centre of the pelvis is determined. Actually this helps in treating the parametria, avoiding over dose to tissues. Except the fact it is time consuming, the device is simple and the method is reliable (most of the measured values vary within + 5%) to be used for dosimetry.

7.2.6 Analysis of rectum and bladder complications

The analysis of the complications of rectum and bladder, reported in Chapter 6, shows that rectal complications due to Selectron treatment is slightly less than that due to cobalt-60 (manual afterloading) treatment. The rectal complication rates due to Selectron and cobalt applications are 7.1% and 7.6% respectively. The difference is not significant. 10.7% of the patients who had Selectron applications and 13.9% of the patients who had cobalt applications suffered bladder complications. Hence it is seen that patients who had cobalt application, recorded 3.2% higher bladder complication rate.

In the manual afterloading, the applicators are straight and hence the sources are in the same horizontal plane. The vagina is packed in order to bring down the dose to rectum. While doing so, the applicator set may be lifted up, giving more dose to the bladder. This may not be the case with Selectron applicators, as the vaginal sources
are angled down and hence the sources lie in a perpendicular plane.

The survey conducted shows that the exposure rate near the entrance of the Selectron room is 0.5 mR/hr. For a treatment time of 15 hours the exposure will be 7.5 mR. If manual afterloading practiced, the exposure received by the physicists and the therapists during the application of the sources has been estimated to be 10 mR (for 4 patients), whereas this exposure is completely eliminated. Similar is the case with nurses attending to the patients. But the exposure received by the nurse is not estimated. Hence it is concluded that from clinical point of view, treatment with Selectron has not produced more morbidity compared to manual afterloading. From protection point of view it is highly safe to use.

7.3 SOME SUGGESTIONS FOR FURTHER STUDY

Direct measurements are done with semiconductor probe, hence the points of measurements had to be limited to point A and point B, as the measurements are time consuming. Using thermoluminescence dosimeters, dose can be measured for a number of points by irradiating the capsules or pellets at a time. Measurements could also be done in the sagittal plane with particular reference to bladder and rectum and compared with computed values.

Similarly, the dose distributions in the transverse and sagittal planes can be obtained on films, by designing a proper wax phantom, embedding the Selectron applicators. The dose distribution in the coronal plane at different levels can be had to get a 3 dimensional distribution.

In the analysis of intracavitary applications, the recurrence free survival and the failure rates can be studied.
The complications can also be graded as mild, moderate and severe. If possible an attempt can be made to correlate the bladder and rectal complications with respective measured values so that the tolerance dose that will not produce any clinically significant damage, can be arrived at.

In the paragraph 7.2.3 it has been stated that the dose shifts (inwards), if tissue absorption is taken into consideration. Only 2 points have been taken for example, and that too along the line through point A and point B. The ICRU Report No. 38, [48] states that it is not sufficient just to specify the dose at a point. The dose should be specified for the volume (details given in the Appendix 3). Also mentioned in that, is the treatment volume, which is the one covered by the 60 Gy isodose surface. The volume covered by 60 Gy isodose can be estimated with and without tissue absorption correction and the difference in volumes can also be made out. The volumes can be evaluated using integral calculus. The volumes can also be estimated, for same uterine length but with different source configurations (linear and point sources).