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ANALYSIS OF DOSIMETRY DATA FOR SAFETY OF HOSPITAL STAFF 2018-2022 A.D

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ABSTRACT
Hospitals face various radiations from the manmade sources of radiation for the purpose of therapy and sterilization. The radiation leakage may be dangerous to health if the sources are not monitor properly. The data given by dosimeter from B.P. Koirala Institute of health science (BPKISC) is analyzed by using suitable statistical techniques. The overall absorbed dose is found to be 0.078 mSv per year. The obtained value is very much below 20 mSv (dose recommended by International Commission on Radiological Protection (ICRP)) So, the staffs are found working in the safe condition in B.P. Memorial Institute of health science. The result from the analysis of Chi-square test makes sure that the gender wise there is no such variation in absorption of dose. From the above observations of BPKIHS, it can be concluded that the staffs exposed to the radiation are safe. This data will enlighten the safety of the BPKIHS. So, for the measurement of the safety level in terms of radiation all the hospitals should made dosimeter compulsory for the medical staffs and the dosimetry data available for the analysis to the researchers.
Keywords: Radiation, Dosimeter, ICRP, Chi-square,

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List of Abbreviation

ALARA:	As l Low as Reasonably Achievable
B.P:	Bisheshwor Prasad
ICRP:	International Commission on Radiological Protection
Mev:	Mega electron volt
mSv:	Milli Sievert
UK:	United Kingdom

I. INTORDUCTION

1.1 Background

The radiation is the emission of energy as electromagnetic waves or as high- energy subatomic particles. Radiation can be natural or artificial. In nuclear physics those nuclei with neutron to proton ratio not equal to unity are considered to be unstable. These unstable nuclei are likely to emit radiations to become stable hence these nuclei are called radioactive nuclei. The phenomenon in which the unstable nuclei became stable by emitting radiations like α, β and γ radiations is radioactivity or radioactive disintegration. Due to the existence of various types of the radiations, life has been possible in the earth [1].

The radiation can be ionizing or nonionizing depending upon the energy content in it. The radiations with more than $10eV$ of energy are considered to be ionizing radiation and this radiation is capable of breaking chemical bond and ionize the molecule. Ionizing radiation has numerous uses. Most commonly they are used in the sterilization of medical equipment, treatment of the medical patients and diagnosing imaging [2]. The man-made sources of ionizing radiation can produce background radiation which can produce dangerous radiation exposure to human life. When the ionizing radiation came in contact with the living tissue it can easily excite the atoms and ionize the molecules [3]. This can result in division of living cells and effect the genetic materials of the cells ultimately resulting to cancer if the exposure is for a long time.

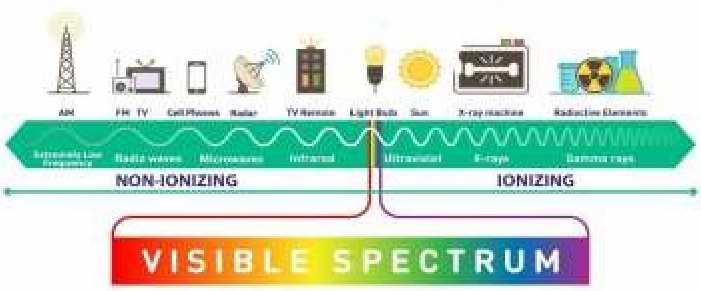

Figure 1: Source of Electromagnetic Radiation

Background radiation is defined as the radiant energy that remains after the source of the radiation exposure and is found everywhere. This remaining radiation can cause serious biological side effects if patients or employees are exposed to high doses. Therefore, device most commonly used in the medical field for the measurement of background radiation is known as the thermo luminescent dosimeters (TLD). This device is used to observe background radiation in the radiography department as well as the surrounding departments to ensure there are no background radiation leaks. It is the duty of the radiation safety department to analyze background radiation measurements within medical exposure rooms.

There is always a health risk when exposed to radiation but it is possible to reduce the radiation when equipment is managed correctly and by following the regulations as is required. It's important that the medical staffs should be given proper trainings before managing devices within the radiography department. Radioactive materials have high radiations effective in small doses. Radiation monitors must be used to check the surroundings each and every time that radioactive materials are handled.

1.1.1 Cobalt 60- Radiation Source in Hospitals

Cobalt -60 is the radioactive isotopes of Cobalt of half- life 5.272 years. This isotope has been used for radiotherapy cancer treatment, food irradiation and industrial applications. As cobalt-60 decays into a stable nickel-60 isotope, two wavelengths of high-energy gamma-rays are emitted (1.17 and 1.33 MeV- average of 1.25 MeV used). The decay equation of Co-60 is as follows:

Co60 −→ $Ni60 + e- + \tilde{v}$

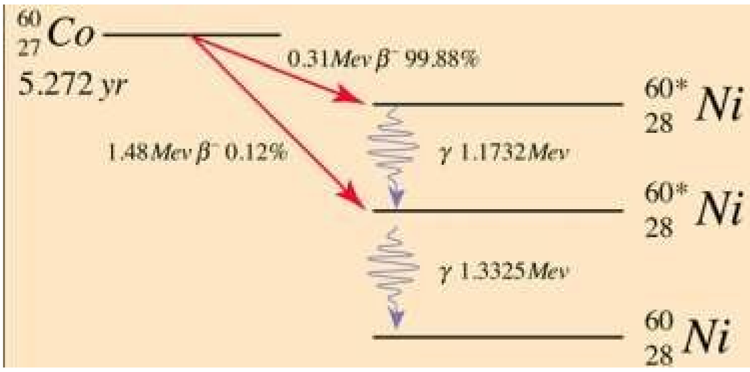

Figure 2: *Decay of Cobalt 60*

1.2 Thermo Luminescence Dosimeter (TLD)

A thermo luminescence dosimeter (TLD) is a device that measures the ionization radiation exposure with the help of visible light intensity which emitted in a detector when the crystal is heated [4]. It was invented in 1954 by the professor Farrington Daniels of the university of Wisconsin-Madison. It is based on the use of lithium fluoride which traps the energy received from ionizing radiation. When it gets heated during the assessment period, the trapped energy is released as light. The amount of light released is proportional to the radiation dose [International atomic energy agency (IAEA)]

Figure 3: Thermo - Luminescent Dosimeter

1.3 Mechanism of TLD

Thermo luminescence dosimeter works on the principle of thermo luminescence in which initially there is the conversion of system equilibrium to metastable state by absorption of energy from UV or ionizing radiation and then there is relaxation of the system back to the equilibrium by releasing of energy such as light with the help of thermal stimulation.

In pure solid, electron do not trap in band gap between conduction and valance band but if impurity is added in solid can trap electrons in the band gap and hold them there. These trapped electrons represent stored energy for the time that the electrons are held. As the energy is given to the

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electron in the form of heat, then the electron returns to the ground state releasing light. This light can be measured and use to determine amount of radiation at which dosimeter was exposed [5].

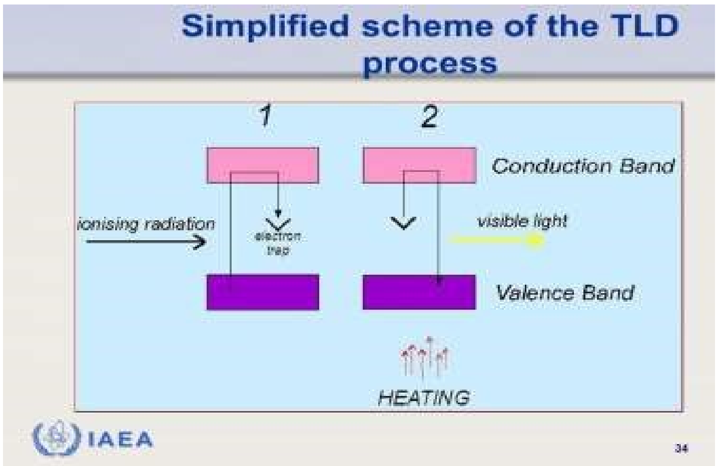

Figure 4: Simplified Scheme of The TLD Process

1.4 Basic Concept of Dose and Measurement

i Absorbed Dose

It is the concentration of energy deposited in tissue as a result of an exposure to ionizing radiation. It is used to assess the potential for biochemical changes in specific tissues.

ii Equivalent Dose

It is an amount that takes the damaging properties of different types of radiation into account. It is used to assess how much biological damage is expected from the absorbed dose.

iii Effective Dose

It is a calculated value measured in Sv (Sievert). It is used to assess the potential for long term effects that might occur in the future. Its SI based unit is m^2s^{-2}. One Sievert is equals 100 rem. The rem is an older, non-SI unit of measurement. One Sievert carries with it a 5.5 percent chance of eventually developing cancer. Frequently used SI prefixes are the millisievert (1 mSv = 0.001 Sv).

1 Sv = 1 joule/kilogram – a biological effect Effective dose can be expressed as:

$E=W_T*H_T$

Where, H_T is the equivalent dose in tissue or organ and W_T is the tissue weighing factor for that tissue or organ.

1.5 Dose Limit

There are no dose limits to the patient at this time for medical procedures. There are limits to those individuals who may get exposed as a result of their employment and to those individuals who may get exposed because they are in the area where radiation is used [6]. The limit of effective doses reduces the risk arose from radiation effect. The dose limit may help to aware from the deterministic effect in almost all tissue [7].

According to Nuclear Regulatory Commission Dose Limits (2004), dose limit for some fields are as;

i. Whole body (50 mSv/year)
ii. Lens of eye (150 mSv/year)
iii. Skin/Extremities (500 mSv/year)
iv. Whole body over life time(10mSv/year)
v. Fetus for none month (5mSv/year)
vi. Fetus for one month (0.5mSv/year) vii. All Time Public exposure(1mSv/year)
viii. All time public exposure shall not exceed (5mSv/year)

1.6 General Objectives

The general objective of this work is to check whether the medical staffs of B.P. Koirala Institute of Health Science, Dharan in Radiology Department are working safely or not through the analysis of data given by Dosimeter.

LITERATURE REVIEW

2.1 Literature Review

B.F. Wall work on radiation protection dosimetry for diagnostic radiology patients. Suitable radiation risk projection models are used to predict the risk to patients in the UK from computed tomography examinations, as a function of age at

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exposure and sex and show that the lifetime risk of fatal cancer can reach 1 in 1000 for children [8].

Giri *et al.*, surveyed 13 different hospitals of Kathmandu valley and studied exposure of radiation to the person visiting radiology department. The findings show increased exposure to radiation in some place and in some parts very high level of unintentional exposure to radiation [9].

Adhikari *et al.,* studied the status of radiation protection at 33 Hospital in Kathmandu and also from different hospital all over Nepal in order to aware people about radiation health hazard and its long-term effect. 28 hospitals with diagnostic radiology facility were chosen for this research study according to patient loads, equipment and working staffs which include forty-six X-ray, ten CT scan, two Mammogram and two Catheterization Laboratory [10].

T.T. Dude conducted a survey in the hospitals of Iceland on the radiation exposure. He found that average background radiation measurements for hospital A were 27.25 mSv over the three months inside exposure rooms. In hospital B-RT 28.4 mSv was measured, inside the radiography room and 0.122 mSv in the control rooms. In hospital B-NM scan room, waiting area, earshot lab, injection room and I-131 rooms murid 1.91 mSv. In the clinic the scan measured mSv 6.5; which is inside where radiations exposure [11].

Mahato *et al*, use TL dosimeter to measure the entrance surface dose of chest and pelvis x-ray examination and compare those data with national and international recommendations of diagnostic reference level of these two examinations. These examinations found that the entrance surface dose for chest and pelvis found to be 0.348 mGy and 2.624 mGy. The diagnostic reference level for the chest obtained higher then international recommendation and lower for pelvis then international recommendation [12].

2.1.1 Specific Objectives

We calculate effective dose, limit of dose at which they can be safe. The main aim of this project is to calculate the dose rate at B. P. Koirala Institute of Health Science to check whether the rate of dose is as Low as Reasonably Achieved (ALARA) or not. Our specific objective is

1. To compare the radiation exposure in different years with the recommended value by ICRP.
2. To check whether the different staffs are exposed to same level or different level of radiation.
3. To check the radiations exposure is same or different in different years.
4. To compare the radiation exposure of male and female.
5. To understand the concept of dosimeter.

I. METHODOLOGY

3.1 Methodology

We intended to apply following methods in order to complete our research work:

3.1.1 Theoretical Concepts

If 'N' radioactive nuclei are present at time 't' and if no new nuclei are introduced into the sample, then the number dN decaying in a time dt is proportional to N, and so

$$\lambda = \frac{-dN/dt}{N} \quad (3.1.1)$$

In which λ is a constant called the disintegration or decay constant. where, $\frac{-dN/dt}{N}$ is the probability per unit time for the decay of an atoms? That this probability is constant, regardless of the age of the atoms, is the basic assumption of the statistical theory of radioactive decay.

The time taken for the activity of a radionuclide to fall to half its original value is called the half-life, symbol t1/2, or can be defined as the time for half the nuclei in a sample to decay. Each radionuclide has a unique Half- life, which can range from fractions of a second to billions of years. For iodine-131, it is 8 days; caesium-137, 30 years; carbon-14, 5730 years; plutonium-239, 24,000 years; and million uranium238 4,470 years.

3.1.2 Primary Methodology

We collected the data of B. P. Koirala Institute of Health Science. We will use the following statistical tools to analyze the all obtained data:

3.1.2.1 Z – Test

The test which is applied in the case of large samples is called Z-test.

Assumptions of Z - test

The Z-test is used under the following assumptions [13].

- The sample must be simple random sample. (i.e., having equal chances of occurrence for the same size of sample.)
- The population standard deviation should be known i.e., σ known. But for the large sample, σ=s
- The samples are independent.

Test of Significance of Single Mean:
From a normal population, let say 'n' sample size is selected randomly with the mean μ and variance σ^2[13].

The sample mean X is also normal variant with mean.
$E(X) = \mu$
Then the Z statistics is:

$$Z = \frac{\overline{X}-E(X)}{S.E(X)} = \frac{\overline{X}-\mu}{\sigma/\sqrt{n}} \qquad (3.2.1)$$

But for large sample $\sigma = s$, So.

$$Z = \frac{\overline{X}-\mu}{S/\sqrt{n}} \quad \text{and variance, } V(X) = \frac{\sigma^2}{n} \qquad (3.2.2)$$

Then the steps to test the significance for large sample size are:

Step1: Setting Hypothesis
Null Hypothesis: H_0: $\mu = \mu_0$ (I. e. there is not the significant difference between sample mean and population mean)

Alternative Hypothesis: H_1: μ 6= μ_0 (i.e., there is a significant difference between sample mean and population mean)

OR,
H_0: $\mu > \mu_0$ (Right tailed test)
H_1: $\mu < \mu_0$ (Left tailed test)

Step II: Test Statistic:
Under null hypothesis, test statistic is

$$Z = \frac{X-E(X)}{S.E(X)} = \frac{\overline{X}-\mu}{S/\sqrt{n}} \qquad (3.2.3)$$

[$\sigma = S$ for large sample] and s can be calculated with the help of sample variance as:

$$S^2 = \frac{\sum(X-\overline{X})^2}{n-1} \qquad (3.2.4)$$

for large n, $n - 1 \approx n$

$$S^2 = \frac{\sum(X-\overline{X})^2}{n} \qquad (3.2.5)$$

Step III: Level of Significance:
Take $\alpha = 0.01$ [for life and death level of significance is 1%]
Step IV: Critical value:
The tabulated value or critical value of Z (i.e. Z_α or $Z_{\alpha 1/2}$) at 1% level of significance.
Step V: Decision:
- If $|Z| > |Z_{\alpha 1/2}|$ (for two tailed Z-test) or $|Z| > |Z_\alpha|$ (for one tailed), then it is significant and can reject H_0. Hence accept H_1.
-
- If $|Z| < |Z_{\alpha 1/2}|$ (for two tailed Z-test) or $|Z| < |Z_\alpha|$ (for one tailed), then it is not significant and can accept H_0. Hence reject H_1.

3.1.2.2 Chi-Square (χ2) test
This test is use to compare the observed and expected frequencies. The observed frequencies (O) are those obtained empirically by direct observation or experiment. The expected frequencies are those generated on the basis of some hypothesis or line of theoretical speculation. The (χ^2) test statistic is given by,
(χ^2) =
Some of the uses of (χ^2) statistic are:

- To test the independence of attributes.
- To test the goodness of fit
- To test the population of variation.

II. RESULT AND DISCUSSION

Many staffs are working in the B. P. Koirala Institute of Health Science. The hypothesis test, two-way ANOVA test, chi- square test and Krusukal Wallis test is carried out to ensure the overall protection level of Staffs. And for these tests, the whole-body dose value is taken with the help of the dosimeter and the data are collected from respective hospitals.

4.1 Z- Test

Table 1: *Total amount of dose in 2018-2022(mSv)*

Staff	2018	2019	2020	2021	2022	Block dose in 2018-2022
B1	0	0	0	0	0	0
B2	0	0.15	0	0	0	0.15
B3	0	0	0	0	0	0
B4	0	0	0	0	0	0
B5	0	0	0.2	0	0	0.2
B6	0	0	0	0	0	0
B7	0	0	0	0.15	0	0.15
B8	0	0.15	0	0	0	0.15
B9	0	0	0	0	0	0
B10	0	0	0	0	0	0
B11	0	0	0.1	0	0	0.1
B12	0	0	0	0	0	0
B13	0	0.1	0	0	0	0.1
B14	0	0.15	0	0	0	0.15
B15	0.4	0	0	0.2	0	0.6
B16	0	0	0	0	0	0
B17	0.2	0.35	0	0.65	0.2	1.4
B18	0	0.18	0	0	0	0.6
B19	0	0.3	0.3	1.3	0	1.9
B20	0	0	0	0	0	0
B21	0	0.1	0	0	0	0.1
B22	0	0	0	0	0.2	0.2
B23	0	0.35	0.15	3.75	0	4.25
B24	0	0.3	0	0	0.35	0.65
B25	0	0	0	0	0	0
B26	1.3	0	0.35	0	0	1.65
B27	0	0.1	0	0	0	0.1
B28	0	0	0.25	0	0	0.25
B29	0	0	0	0	0	0
B30	0	0.1	0.1	0	0	0.2
B31	0	0.15	0	0	0	0.15
B32	0.3	0.15	0	0.15	0	0.6
B33	0	0.15	0	0	0	0.15

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B34	0	0	0	0	0	0
B35	0.65	0	0	0	0	0.65
B36	0	0	0	0	0	0
B37	0	0.15	0	0	0	0.15
B38	0.2	0	0	0	0	0.2
B39	0.2	0	0	0	0	0.2
B40	0	0	0	0	0	0
B41	0	0	0	0	0	0
B42	0	0	0.85	0.15	0	1
B43	0.15	0.1	0.15	0.85	0	1.25
B44	0	0	0	0	0	0
B45		0.1	0	0	0.25	0.35
B46		0	0	0.25	0	0.25
B47		0	0	0.1	0	0.1
B48		0	0	0	0.35	0.35
B49		0	0	0	0	0
B50		0.2	0	0	0	0.2
B51		0.1	0	0	0	0.1
B52			0.6	0	0.1	0.7

A) Hypothesis Testing

4.1.1 In 2018

Table 2: Dose in 2018

Staff	Total dose (msv) in 2018 (x)	$(x-\bar{x})$	$(x-\bar{x})^2$
B1	0.00	-0.0772727	0.00597107
B2	0.00	-0.0772727	0.00597107
B3	0.00	-0.0772727	0.00597107
B4	0.00	-0.0772727	0.00597107
B5	0.00	-0.0772727	0.00597107
B6	0.00	-0.0772727	0.00597107
B7	0.00	-0.0772727	0.00597107
B8	0.00	-0.0772727	0.00597107
B9	0.00	-0.0772727	0.00597107
B10	0.00	-0.0772727	0.00597107
B11	0.00	-0.0772727	0.00597107
B12	0.00	-0.0772727	0.00597107
B13	0.00	-0.0772727	0.00597107
B14	0.00	-0.0772727	0.00597107
B15	0.40	0.32272727	0.10415289
B16	0.00	-0.0772727	0.00597107
B17	0.20	0.12272727	0.01506198
B18	0.00	-0.0772727	0.00597107

B19	0.00	-0.0772727	0.00597107
B20	0.00	-0.0772727	0.00597107
B21	0.00	-0.0772727	0.00597107
B22	0.00	-0.0772727	0.00597107
B23	0.00	-0.0772727	0.00597107
B24	0.00	-0.0772727	0.00597107
B25	0.00	-0.0772727	0.00597107
B26	1.30	1.22272727	1.49506198
B27	0.00	-0.0772727	0.00597107
B28	0.00	-0.0772727	0.00597107
B29	0.00	-0.0772727	0.00597107
B30	0.00	-0.0772727	0.00597107
B31	0.00	-0.0772727	0.00597107
B32	0.30	0.22272727	0.04960744
B33	0.00	-0.0772727	0.00597107
B34	0.00	-0.0772727	0.00597107
B35	0.65	0.57272727	0.32801653
B36	0.00	-0.0772727	0.00597107
B37	0.00	-0.0772727	0.00597107
B38	0.20	0.12272727	0.01506198
B39	0.20	0.12272727	0.01506198
B40	0.00	-0.0772727	0.00597107
B41	0.00	-0.0772727	0.00597107
B42	0.00	-0.0772727	0.00597107
B43	0.15	0.07272727	0.00528926
B44	0.00	-0.0772727	0.00597107
Total	3.4	-7.494E-16	2.24227273
Count	44		
Average	0.077272727		

Here,
$\sum_{i=1}^{44} X = 3.4$
$\sum_{i=1}^{44} (X - \overline{X})^2 = 2.242272727$
Then to check whether the workers are working safely or not, we apply the Z-test and firstly calculating sample variance.

$$S^2 = \frac{\sum (X - \overline{X})^2}{n-1}$$

For large n, $n - 1 \approx n$

$$S^2 = \frac{\sum (X - \overline{X})^2}{n} = \frac{2.242272727}{44} = 0.0509607438$$

Therefore,

$S = \sqrt{0.0509607438} = 0.22574$
Step I: Setting Hypothesis:
Null Hypothesis: H_0: $\mu \geq 20mSv$

Alternative Hypothesis: H: $\mu < 20mSv$ [Left tailed test]
Step II: Test Statistic:
Under null hypothesis, test statistic is

$$Z = \frac{\overline{X} - E(X)}{S.E(X)} = \frac{\overline{X} - \mu}{\sigma/\sqrt{n}} = \frac{0.07727273 - 20}{0.22574/\sqrt{44}} = -585.42$$

So,
$|Z| = 585.42$
Step III: Level of significance:

Take $\alpha = 0.01$[For life and death level of significance is 1%]
Step IV: Critical value: the tabulated value at $\alpha = 1\% = 0.01$ is
$Z_\alpha = Z0.01 = -2.33$
So,
$|Z_{0.01}| = 2.33$ Step V: Decision:

Since, $|Z| > |Z_\alpha|$ at $\alpha = 0.01$, null hypothesis is rejected i.e., alternative accepted which means $\mu <$ 20 mSv. By this we can say that the effective dose of the staff of B. P. Koirala Institute of Health Science does not exceed the dose limitation as per recommended by ICRP. So, the staffs are working safely.

B) Graphical Analysis

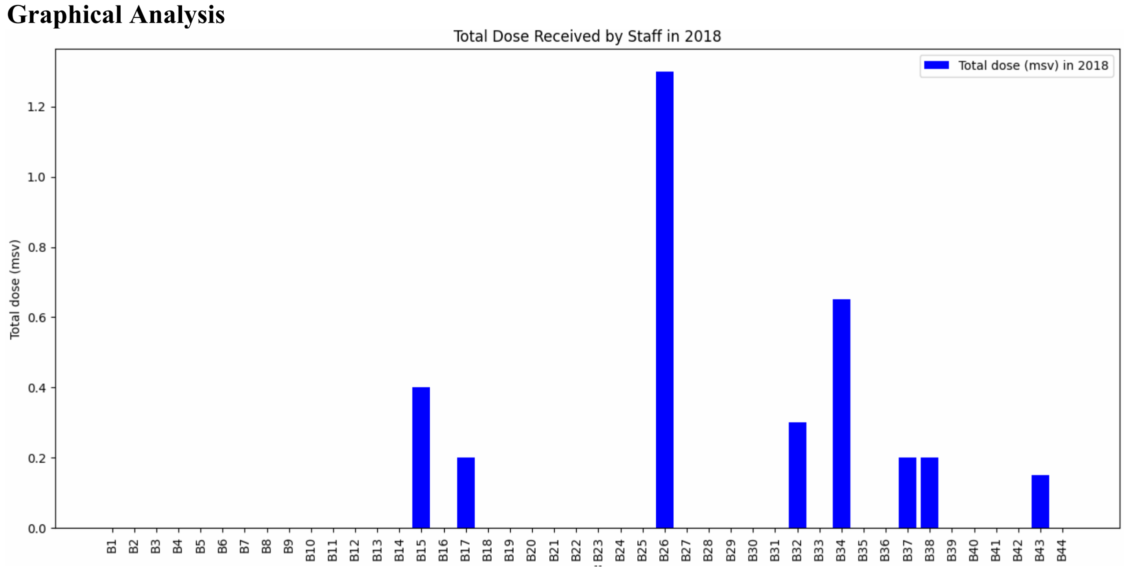

Figure 5: Bar diagram representation of radiation faced by the staffs in 2018

Discussion on Graphs: From both of the graphs we can say that in the year 2018, staff B26 absorbed quite a greater number of radiations compared to others. We may say that the staff B26 might have longer duty hours nearby to the man-made sources of radiation. But also, the dose limits the staff absorb doesn't exceed 20 mSv. Hence, we can say the environment is safe from radiation in the Radiological Unit.

4.1.2 In 2019

A) Hypothesis Testing

Table 3: Dose in 2019

Staff	Total dose (msv) in 2019(x)	$(x-\overline{x})$	$(x-\overline{x})^2$
B1	0	-0.0755	0.0057
B2	0.15	0.07451	0.00555
B3	0	-0.0755	0.0057

B4	0	-0.0755	0.0057
B5	0	-0.0755	0.0057
B6	0	-0.0755	0.0057
B7	0	-0.0755	0.0057
B8	0.15	0.07451	0.00555
B9	0	-0.0755	0.0057
B10	0	-0.0755	0.0057
B11	0	-0.0755	0.0057
B12	0	-0.0755	0.0057
B13	0.1	0.02451	0.0006
B14	0.15	0.07451	0.00555
B15	0	-0.0755	0.0057
B16	0	-0.0755	0.0057
B17	0.35	0.27451	0.07536
B18	0.6	0.52451	0.27511
B19	0.3	0.22451	0.0504
B20	0	-0.0755	0.0057
B21	0.1	0.02451	0.0006
B22	0	-0.0755	0.0057
B23	0.35	0.27451	0.07536
B24	0.3	0.22451	0.0504
B25	0	-0.0755	0.0057
B26	0	-0.0755	0.0057
B27	0.1	0.02451	0.0006
B28	0	-0.0755	0.0057
B29	0	-0.0755	0.0057
B30	0.1	0.02451	0.0006
B31	0.15	0.07451	0.00555
B32	0.15	0.07451	0.00555
B33	0.15	0.07451	0.00555
B34	0	-0.0755	0.0057
B35	0	-0.0755	0.0057
B36	0	-0.0755	0.0057
B37	0.15	0.07451	0.00555
B38	0	-0.0755	0.0057
B39	0	-0.0755	0.0057
B40	0	-0.0755	0.0057
B41	0	-0.0755	0.0057
B42	0	-0.0755	0.0057

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Here,

B43	0.1	0.02451	0.0006
B44	0	-0.0755	0.0057
B45	0.1	0.02451	0.0006
B46	0	-0.0755	0.0057
B47	0	-0.0755	0.0057
B48	0	-0.0755	0.0057
B49	0	-0.0755	0.0057
B50	0.2	0.12451	0.0155
B51	0.1	0.02451	0.0006
B52	3.85	2.8E-16	0.76186
Total count	51		
Mean	0.07549		

$\sum_{i=1}^{51} X = 3.85$

$\sum_{i=1}^{51} (X - \overline{X})^2 = 0.7618627451$

Then to check whether the workers are working safely or not, we apply the Z-test and firstly calculating sample variance.

$$S^2 = \frac{\sum (X - \overline{X})^2}{n - 1}$$

$n - 1 \approx n$

For large n,

$$S^2 = \frac{\sum (X - \overline{X})^2}{n} = \frac{0.7618627451}{51} = 0.0149385$$

Therefore,

$S = \sqrt{0.0149385} = 0.1222$

Step I: Setting Hypothesis:

Null Hypothesis: H_0: $\mu \geq 20mSv$

Alternative Hypothesis: H_1: $\mu < 20mSv$ [Left tailed test] Step II: Test Statistic:

Under null hypothesis, test statistic is

$$Z = \frac{\overline{X} - E(X)}{S.E(X)} = \frac{\overline{X} - \mu}{\sigma/\sqrt{n}} = \frac{0.0754901961 - 20}{0.12222/\sqrt{51}} = -1164.21$$

So,

$|Z| = 1164.21$

Step III: Level of significance:

Take $\alpha = 0.01$ [for life and death level of significance is 1%]

Step IV: Critical value: the tabulated value at $\alpha = 1\% = 0.01$ is

$Z_\alpha = Z0.01 = -2.33$ so, $|Z_{0.01}| = 2.33$ Step V: Decision:

since, $|Z| > |Z_\alpha|$ at $\alpha = 0.01$, null hypothesis is rejected i.e., alternative accepted which means $\mu < 20mSv$. By this we can say that the effective dose of the staff of B. P. Koirala Institute of Health Science does not exceed the dose limitation as per recommended by ICRP. So, the staffs are working safely.

B) Graphical Analysis

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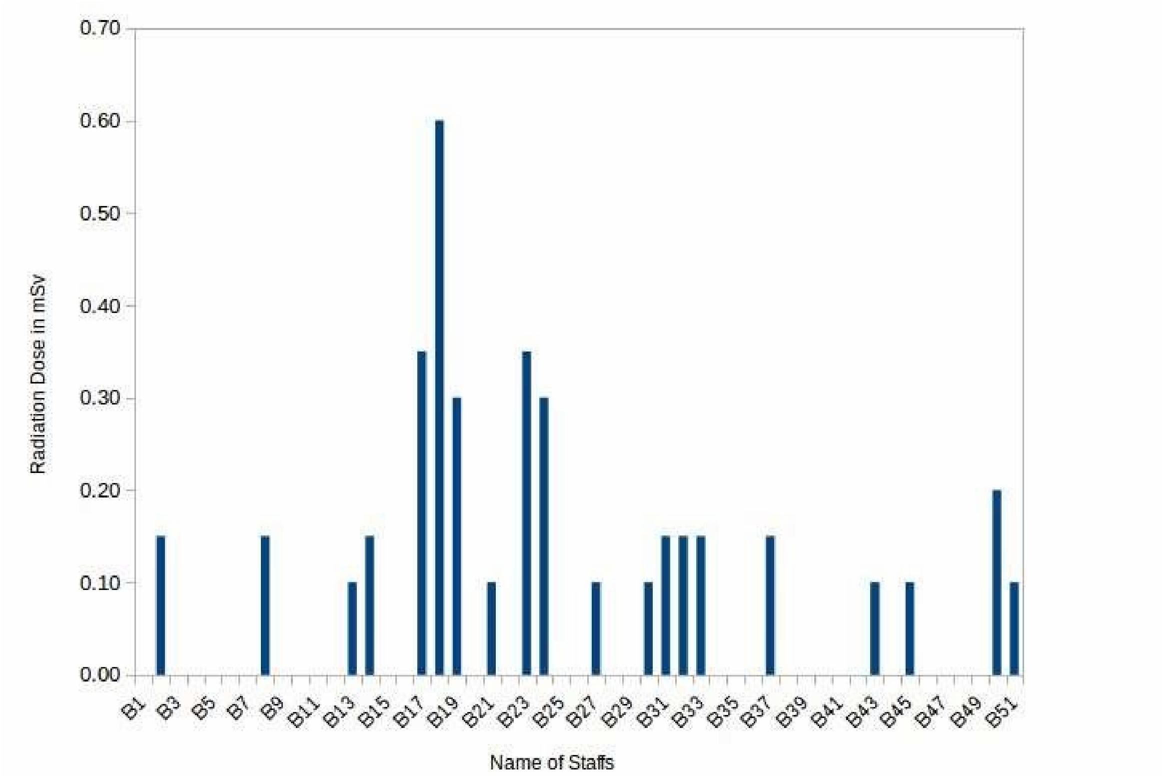

Figure 6: Bar Graph Representation of Radiation absorbed by the staffs in 2019

Discussion on Graphs: From both the graph of the graphs we can say that in the year 2019, staff B17, B19, B27 absorbed quite a greater number of radiations compared to others. We may say that those staff might have longer duty hours nearby to the manmade sources of radiation. But also, the dose limits the staff absorb doesn't exceed 20 mSv. Hence, we can say the environment is safe from radiation in the Radiological Units. The trend line shows the nature of distribution is non-uniform.

4.1.3 In 2020
A) Hypothesis Testing

Table 4: Dose in 2020

Staff	Total doses (msv) in 2015 (x)	$(x-\bar{x})$	$(x-\bar{x})^2$
B1	0.00	-0.058653846	0.003440274
B2	0.00	-0.058653846	0.003440274
B3	0.00	-0.058653846	0.003440274
B4	0.00	-0.058653846	0.003440274
B5	0.20	0.141346154	0.019978735
B6	0.00	-0.058653846	0.003440274
B7	0.00	-0.058653846	0.003440274
B8	0.00	-0.058653846	0.003440274
B9	0.00	-0.058653846	0.003440274
B10	0.00	-0.058653846	0.003440274
B11	0.10	0.041346154	0.001709504

B12	0.00	-0.058653846	0.003440274
B13	0.00	-0.058653846	0.003440274
B14	0.00	-0.058653846	0.003440274
B15	0.00	-0.058653846	0.003440274
B16	0.00	-0.058653846	0.003440274
B17	0.00	-0.058653846	0.003440274
B18	0.00	-0.058653846	0.003440274
B19	0.30	0.241346154	0.058247966
B20	0.00	-0.058653846	0.003440274
B21	0.00	-0.058653846	0.003440274
B22	0.00	-0.058653846	0.003440274
B23	0.15	0.091346154	0.00834412
B24	0.00	-0.058653846	0.003440274
B25	0.00	-0.058653846	0.003440274
B26	0.35	0.291346154	0.084882581
B27	0.00	-0.058653846	0.003440274
B28	0.25	0.191346154	0.036613351
B29	0.00	-0.058653846	0.003440274
B30	0.10	0.041346154	0.001709504
B31	0.00	-0.058653846	0.003440274
B32	0.00	-0.058653846	0.003440274
B33	0.00	-0.058653846	0.003440274
B34	0.00	-0.058653846	0.003440274
B35	0.00	-0.058653846	0.003440274
B36	0.00	-0.058653846	0.003440274
B37	0.00	-0.058653846	0.003440274
B38	0.00	-0.058653846	0.003440274
B39	0.00	-0.058653846	0.003440274
B40	0.00	-0.058653846	0.003440274
B41	0.00	-0.058653846	0.003440274
B42	0.85	0.791346154	0.626228735
B43	0.15	0.091346154	0.00834412
B44	0.00	-0.058653846	0.003440274
B45	0.00	-0.058653846	0.003440274
B46	0.00	-0.058653846	0.003440274
B47	0.00	-0.058653846	0.003440274
B48	0.00	-0.058653846	0.003440274
B49	0.00	-0.058653846	0.003440274
B50	0.00	-0.058653846	0.003440274
B51	0.00	-0.058653846	0.003440274
B52	0.6	0.541346154	0.293055658
Total	3.05	0	1.283605769
count	52		
Mean	0.058653846		

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Here,

$$\sum_{i=1}^{52} X = 3.05$$
$$\sum_{i=1}^{52}(X - \overline{X})^2 = 1.2836057692$$

Then to check whether the workers are working safely or not, we apply the Z-test and firstly calculating sample variance.

$$S^2 = \frac{\sum(X - \overline{X})^2}{n-1}$$

for large n, $n - 1 \approx n$

$$S^2 = \frac{\sum(X - \overline{X})^2}{n} = \frac{1.2836057692}{52} = 0.024684726$$

Therefore,

$S = \sqrt{0.024684726} = 0.15711$ Step I: Setting Hypothesis:
Null Hypothesis: H_0: $\mu \geq 20mSv$
Alternative Hypothesis: H: $\mu < 20mSv$ [Left tailed test]
Step II: Test Statistic:
Under null hypothesis, test statistic is

$$Z = \frac{\overline{X} - E(X)}{S.E(X)} = \frac{\overline{X} - \mu}{\sigma/\sqrt{n}} = \frac{0.0586538462 - 20}{0.15711/\sqrt{52}} = -915.28$$

So,
$|Z| = 915.28$
Step III: Level of significance:
Take $\alpha = 0.01$ [for life and death level of significance is 1%]
Step IV: Critical value: the tabulated value at $\alpha = 1\% = 0.01$ is
$Z_\alpha = Z0.01 = -2.33$ so, $|Z_{0.01}| = 2.33$
Step V: Decision:

since, $|Z| > |Z_\alpha|$ at $\alpha = 0.01$, null hypothesis is rejected i.e., alternative accepted which means $\mu < 20mSv$. By this we can say that the effective dose of the staff of B. P. Koirala Institute of Health Science does not exceed the dose limitation as per recommended by ICRP. So, the staffs are working safely.

B) **Graphical Analysis**

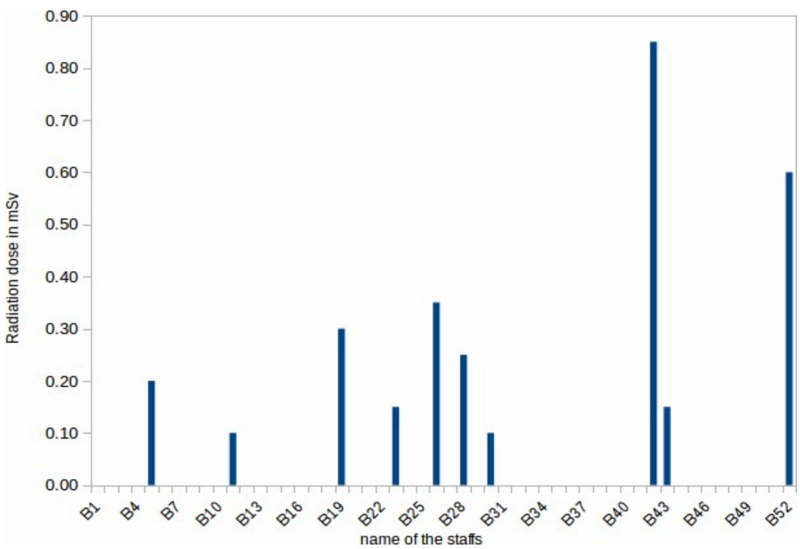

Figure 7: Bar diagram representation of the radiation faced by the staff in 2020

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Discussion on Graphs: we can say that in the year2020, staff B42 absorbed quite a greater number of radiations compared to others. We may say that the staff B42 might have longer duty hours nearby to the manmade sources of radiation. But also, the dose limits the staff absorb doesn't exceed 20 mSv. Hence, we can say the environment is safe from radiation in the Radiological Unit.

4.2 Chi Square test

Test for absorption of radiation is done according to the gender. χ^2 test is applied to test.

- Total number of females=17
- Total number of males=35
- Total block dose received by male=9.75
- Total block done received by female=8.25
- Average dose by female=0.49
- Average dose by male=0.28

Hypothesis

Null Hypothesis (H0): Male and Female absorb radiation equal.

Alternative Hypothesis (H1): There is significant difference in radiation absorb by male and female.

Table 5: Calculation of Chi-Square test

Gender	Average Radiation Absorbed(O)	Expected(E)	(O-E)	$(O-E)^2/E$
Male	0.28	0.35	0.0049	0.014
Female	0.49	0.35	0.00196	0.056
				$P(O-E)^2/E=0.07$

From calculation $\chi^2 = 0.07$ χ^2_{tab} at 1 df at 1% level of significance is 6.635 from the standard χ^2 table.

Thus $\chi 2tab > \chi 2cal$

Hence, Null hypothesis is accepted.

Conclusion: Male and Female absorb radiation equally.

Graphical Analysis

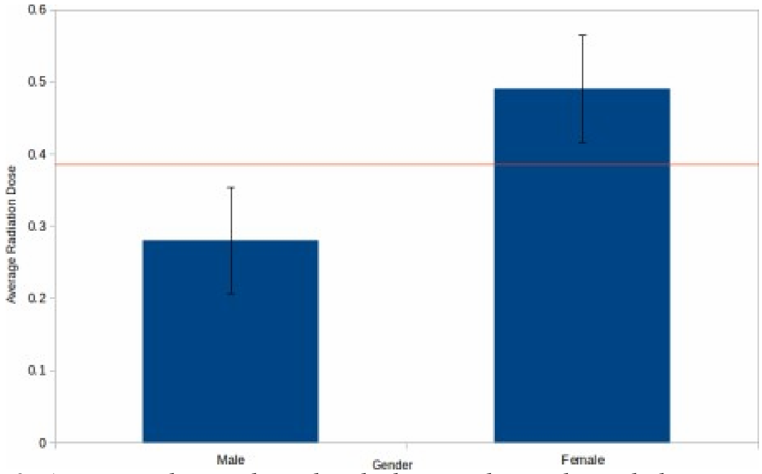

Figure 8: Average radiation dose absorbed as per the gender with the expected line

Discussion on the graph

The graphs shown that there is difference between the radiation absorbed by the male staffs and female staffs. But, the result from Chi-square test shows that the male and female are absorbing the radiation equally. This is due to the contribution of single female staff who absorbed very much greater than others. So, we can say that male and female are equally absorbing the radiation.

III. CONCLUSION AND FUTURE PROSPECT

5.1 Conclusions

In the year 2018, staff B26 absorbed quite a greater number of radiations compared to others. We may say that the staff B26 might have longer duty hours nearby to the man-made sources of radiation. But also, the dose limits the staff absorb doesn't exceed 20 mSv. In the year 2019, staff B17, B19, B27 absorbed quite a greater number of radiations compared to others. We may say that those staff might have longer duty hours nearby to the manmade sources of radiation. But also, the dose limits the staff absorb doesn't exceed 20 mSv. In the year2020, staff B42 absorbed quite a greater number of radiations compared to others. We may say that the staff B42 might have longer duty hours nearby to the manmade sources of radiation. The result from Chi-square test shows that the male and female are absorbing the radiation equally. This is due to the contribution of single female staff who absorbed very much greater than others. So, we can say that male and female are equally absorbing the radiation. Hence, we can say the environment is safe from radiation in the Radiological Unit.

- From the z-test we came to conclusion that the dose limit of the B.P. Koirala Institute of Health Science is very less as compared to that of the dose limit given by ICRP. Hence, the staffs of the B.P. Koirala Institute of Health Science are working safely in the department of Nuclear Medicine.
- Chi square analysis of the gender wise absorption resulted that the both genders are receiving nearly the same level of radiation in B.P. Koirala Institute of Health Science.

5.2 Future Prospects

The data analysis of the dosimeters of hospitals can become very much supportive for the medical Physicist to make the medical staffs aware about their health conditions. The data analysis can be helpful to make the environment of hospitals leakage free from the radiation. The study could be a model to check radiation leakage in many hospitals. Moreover, from this type of study could be beneficial in making plan and policies by the hospitals and other radiation leakage centers to work safely using safety measures.

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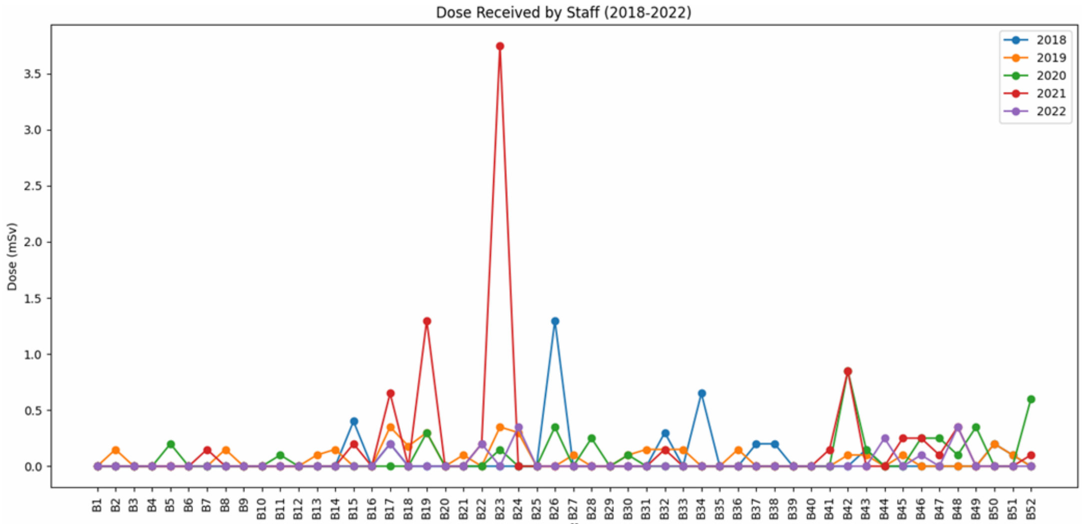
Dose Received by Staff (2018-2022)
2018
2019
2020
2021
2022
Dose (mSv)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
B1 B2 B3 B4 B5 B6 B7 B8 B9 B10 B11 B12 B13 B14 B15 B16 B17 B18 B19 B20 B21 B22 B23 B24 B25 B26 B27 B28 B29 B30 B31 B32 B33 B34 B35 B36 B37 B38 B39 B40 B41 B42 B43 B44 B45 B46 B47 B48 B49 B50 B51 B52

Appendix

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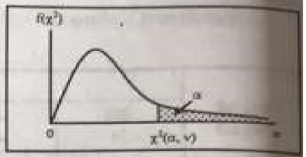
Significant values of chi-square distribution with ν d.f. at α-level
i.e. $P(\chi^2 > \chi^2_\alpha) = \alpha$



d.f. ν	Level of significance α									
	0.995	0.990	0.975	0.950	0.900	0.100	0.050	0.025	0.010	0.005
1	0.0000393	0.000157	0.000982	0.00393	0.0158	2.71	3.84	5.02	6.64	7.88
2	0.0100	0.0201	0.0506	0.103	0.211	4.61	5.99	7.38	9.21	10.59
3	0.0717	0.115	0.216	0.352	0.584	6.25	7.81	9.35	11.35	12.84
4	0.207	0.297	0.484	0.711	1.064	7.78	9.49	11.14	13.28	14.86
5	0.412	0.554	0.831	1.15	1.61	9.24	11.07	12.83	15.09	16.75
6	0.676	0.872	1.24	1.64	2.20	10.64	12.59	14.45	16.81	18.55
7	0.990	1.24	1.69	2.17	2.83	12.02	14.07	16.01	18.48	20.28
8	1.34	1.65	2.18	2.73	3.49	13.36	15.51	17.53	20.09	21.96
9	1.73	2.09	2.70	3.33	4.17	14.68	16.92	19.02	21.67	23.59
10	2.16	2.56	3.25	3.94	4.87	15.99	18.31	20.48	23.21	25.19
11	2.60	3.05	3.82	4.58	5.58	17.28	19.68	21.92	24.73	26.76
12	3.07	3.57	4.40	5.23	6.30	18.55	21.03	23.34	26.22	28.30
13	3.57	4.11	5.01	5.90	7.04	19.81	22.36	24.74	27.89	29.82
14	4.07	4.66	5.63	6.57	7.79	21.06	23.68	26.12	29.14	31.32
15	4.60	5.23	6.26	7.26	8.55	22.31	24.99	27.49	30.58	32.80
16	5.14	5.81	6.91	7.96	9.31	23.54	26.30	28.85	32.00	34.27
17	5.70	6.41	7.56	8.67	10.08	24.77	27.59	30.19	33.41	35.72
18	6.26	7.01	8.23	9.39	10.86	25.99	28.87	31.53	34.81	37.16
19	6.84	7.63	8.91	10.12	11.65	27.20	30.14	32.85	36.19	38.58
20	7.43	8.26	9.59	10.85	12.44	28.41	31.41	34.17	37.57	40.00
21	8.03	8.90	10.28	11.59	13.24	29.62	32.67	35.48	38.93	41.40
22	8.64	9.54	10.98	12.34	14.04	30.81	33.92	36.78	40.29	42.80
23	9.26	10.20	11.69	13.09	14.85	32.01	35.17	38.08	41.64	44.18
24	9.89	10.86	12.40	13.85	15.66	33.20	36.42	39.36	42.98	45.56
25	10.52	11.52	13.12	14.61	16.47	34.38	37.65	40.65	44.31	46.93
26	11.16	12.20	13.84	15.38	17.29	35.56	38.89	41.92	45.64	48.29
27	11.81	12.88	14.57	16.15	18.11	36.74	40.11	43.19	46.96	49.65
28	12.46	13.56	15.31	16.93	18.94	37.92	41.34	44.46	48.28	51.00
29	13.12	4.26	16.05	17.71	19.77	39.09	42.56	45.72	49.59	52.34
30	13.79	14.95	16.79	18.49	20.60	40.26	43.77	46.98	50.89	53.67
40	20.71	22.16	24.43	26.51	29.05	51.81	55.76	59.34	63.69	66.77
50	27.99	29.71	32.36	34.76	37.69	63.17	67.50	71.42	76.15	79.49
60	35.53	37.48	40.48	43.19	46.46	74.40	79.08	83.30	88.38	91.95
70	43.27	45.44	48.76	51.74	55.33	85.53	90.53	95.02	100.43	104.22
80	51.17	53.54	57.15	60.39	64.28	96.58	101.88	106.63	112.33	116.32
90	59.19	61.75	65.65	69.13	73.29	107.57	113.15	118.14	124.12	128.30
100	67.33	70.06	74.22	77.93	82.36	118.50	124.34	129.56	135.81	140.17

Figure 9: Table for Chi-Square Test

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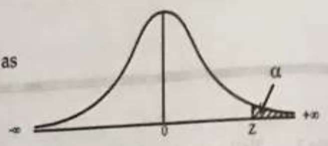
Tail area (probability) under standard normal probability curve from z to ∞ i.e.

$P(Z > z_c) = p_0$, the probabilities associated with values as extreme as observed values of z in the standard normal distribution. Where

$Z = \frac{X - \mu}{\sigma} \sim N(0, 1), X \sim N(\mu, \sigma^2)$. That is

$P(Z < -z_\alpha) = P(Z > z_\alpha) = \alpha$ and $\Phi(z) = 1 - \Phi(-z)$



Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641
.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
.7	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1171
1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
1.5	.0668	.0655	.0643	.0630	.0680	.0606	.0594	.0582	.0571	.0559
1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
1.7	.0446	.0436	.0427	.0480	.0409	.0401	.0392	.0384	.0375	.0367
1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
2.2	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
2.9	.0019	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014
3.0	.0013	.0013	.0013	.0012	.0012	.0011	.0011	.0011	.0010	.0010
3.1	.0010	.0009	.0009	.0009	.0008	.0008	.0008	.0008	.0007	.0007
3.2	.0007	.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
3.3	.0005	.0005	.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
3.4	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	0.0002
3.5	.00023									
3.6	.00016									
3.7	.00011									
3.8	.00007									
3.9	.00005									
4.0	.00003									

Figure 10: Standard Normal Z table