Radiocarbon Dating Laboratory — BSIP, Lucknow

Facility Overview

Principle of Radiocarbon Dating

Radiocarbon (^{14}C) is a radioactive isotope of carbon produced in the upper atmosphere. Living organisms continuously exchange carbon with the atmosphere, maintaining a constant $^{14}C/^{12}C$ ratio. After death, ^{14}C decays with a half-life of **5730 ± 40 years** (Libby, 1955), enabling measurement of elapsed time since burial.

$$N(t) = N_0 e^{-\lambda t} \Rightarrow t = \frac{1}{\lambda} \ln \left(\frac{N_0}{N(t)} \right)$$

where
$N(t)$ = residual ^{14}C activity
N_0 = atmospheric activity
λ = decay constant

Conventional Radiocarbon Dating

(Benzene-Prep + Liquid Scintillation Counting Method)

<u>Steps involved:</u>

1. **Pretreatment** to remove contaminants (acid–alkali–acid)
2. **Combustion** → CO_2 generation
3. **CO_2 purification**
4. **Synthesis of benzene (C_6H_6)** through:
    - Li_2C_2 formation
    - Hydrolysis → acetylene
    - Catalytic trimerization → benzene
5. **Scintillation Cocktail** preparation with PPO/POPOP
6. **Measurement in Ultra-Low Background LSC**

LSC Principle

Beta decay from ^{14}C interacts with scintillator → light pulses → photomultiplier tubes detect counts → background correction → age calculation using standards.

Liquid Scintillation Counting System

PerkinElmer Quantulus: Ultra-low background α/β spectrometer optimised for environmental and geochronological ^{14}C samples (Old model, under maintenance)

Upgraded System (Procured)

Quantulus™ GCT-2000 — installation in progress

- **GCT** = Guard Compensation Technology
- Low background via enhanced passive/active shielding
- Time-resolved discrimination of β events
- Improved Minimum Detectable Activity (MDA)
- Reduced counting uncertainties → Higher precision ages

Merits & Limitations of LSC Radiocarbon

Parameter	Advantage	Limitation
Benzene target	High chemical stability; good optical properties	Requires complex synthesis setup
Sample size	Suitable for macro samples (1–5 g C)	Not suitable for microscale samples
Cost	Relatively economical	Limited precision for Late Holocene samples
Measuring system	Mature method, low background with Quantulus	Needs long counting times

AMS-Based Radiocarbon Dating at BSIP

We have here at BSIP an **AGE-III** Graphite Preparation System, which is sample prep unit for organic carbon containing samples for AMS based radiocarbon dating. Typically, a sample of less than a gram is required for this method.

Designed for micro- to milli-gram carbon fractions.

Steps involved:

1. CO_2 from samples → purification
2. Reduction to graphite using Fe catalyst
3. Direct $^{14}C/^{12}C$ atom counting by AMS
4. Results normalized using standards (Ox-II, IAEA)

Advantages of AMS Route

- **Very small sample size** (50–500 μg C)
- High precision, better signal-to-background
- We are accepting at present only organic carbon containing samples
- No carbonate shells will be graphitised.
- Faster throughput