Water quality monitoring of Reactor TRIGA PUSPATI

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\textbf{Abstract.} At present, Reactor TRIGA PUSPATI (RTP) is the only nuclear research reactor in operation in Malaysia since 1982. Each year, the reactor is operated on average for about 600 hours mainly for the advanced neutron and gamma radiation studies as well as for isotope production, sample activation and student training. About one-third of the RTP’s core volume is occupied by water. The water-cooling and purification systems maintain low water conductivity, remove impurities, maintained the optical clarity of the water and dissipating the reactor heat. They consist of a water surface skimmer, pump, filter, demineralizer, heat exchanger unit, associated piping and valves as well as other miscellaneous instrumentations. Thus, the aim of this study is to investigate water quality and maintains the water chemistry to the required specifications at all times in order to ensure longevity and performance of the reactor system.

1. Introduction

Cooling water chemistry and its effects on fuel elements cladding and reactor components materials performance are important factors for safe and reliable operation of research reactor. This is because at elevated temperature, water is an aggressive medium and may causes corrosion problems in fuel elements cladding and reactor structural materials. For this reason, reliability and safety for research reactor are achieved by using proper fuel cladding and structural materials. Also, cooling water regimes must be adjusted and proved to prevent dangerous corrosion problems. Thus, the aim of this study is to investigate water quality and maintains the water chemistry to the required specifications at all times in order to ensure longevity and performance of the reactor system.

Water is used as a primary coolant in most of research reactor and as a medium in the secondary circuit as well as in associated auxiliary systems. At elevated temperatures water is an aggressive substance when it is in contact with structural materials, which means that the reliability of many systems in research reactor depends strongly on cooling water control. Water coolant chemistry and corrosion problems are issues of special importance in the safe and reliable operation of nuclear power plants. So that water regimes for research reactor must be developed and proved to be satisfactory. Normally, reliability and safety are achieved by using proper fuel cladding and structural materials and by taking special measures to prevent dangerous corrosion, erosion and other processes.
High purity water coolant should ensure adequate corrosion resistance of all the materials used such as stainless and carbon steels, zirconium, copper and nickel alloys. Table 1 shows the sources of impurities that could enter into the reactor and the measures that could be taken to prevent or decrease the accumulation of impurities.

Table 1. Source of impurities that could enter into the reactor and the measures that could be taken to prevent or decrease the accumulation of impurities.

| Source of impurities | Chemical composition of impurities | Measures to prevent or decrease impurity accumulation |
|----------------------|------------------------------------|-----------------------------------------------------|
| Initial water for circuit | Soluble salts (Na, K, Mg, Ca, Cl etc) | Efficient purification of water |
| Make-up water | Soluble salts (Na, K, Mg, Ca, Cl) | Efficient purification of water |
| Cladding materials | Corrosion products | Suppression of corrosion by water conditioning |
| Structural Materials | Corrosion products: Fe, Co, Cr, Ni, Mu, Cu, etc | Suppression of corrosion by water conditioning |

Research reactors have a variety of applications, such as training, neutron activation analysis and radioisotope production. In the majority, most of the research reactors use water as a core cooling fluid, moderator and biological shielding. RTP is a pool type reactor, where the reactor core sits at the bottom of a 7-meter high aluminium tank and this is surrounded by a biological shield made of high density concrete.

2. Methodology

Reactor’s water (350ml) was sampled at the reactor tank before and after operation at three different places; surface of the pool reactor, 3 meter from the surface of the pool reactor and at the bottom of the pool reactor using vertical water sampling bottle as shown in Figure 1.

![Figure 1. Reactor’s water sampling location.](image-url)
Reactor’s water was then being inserted into a transparent 350ml acrylic sample bottles and sent to reactor physics laboratory for further analysis. The sample bottles were tightly sealed to prevent spillage. These steps have been replicates at 3 times and the temperature was recorded. In average, the temperature recorded for all the sampling is around 35°C. A gamma ray spectroscopy consists of hyper pure Germanium (HpGe) detector with 8192 channels computerized multi-channel analyzer were used to qualitatively determine the radionuclides and quantitatively calculate the specific activities. All samples were position at a distance of 5cm from the detector surface. A 5cm thick lead shield was used to reduce the effects of surrounding background radiation. The counting process was conducted for 90 minutes while the detector dead time kept below that 20%. The specific activity for each radionuclide was calculated using equation [2] as shown below:

$$As = \frac{(Cs - Cb)}{t \times \gamma \times P \times Ms}$$

where:
- $As$ = specific activity (Bq kg$^{-1}$)
- $Cs$ = net count intensity from samples (cps)
- $Cb$ = count rate intensity of background (cps)
- $t$ = counting period
- $\gamma$ = efficiency of the detector for particular gamma energy
- $P$ = branching ration
- $Ms$ = mass of the reactor water samples

3. Results and Discussion
The concentration level of various impurity elements and radionuclides production rate in reactor water is important to maintain the safe operational of the reactor. The determination of activated nuclides using gamma spectrometry has found several radionuclides including of $^{24}$Na, $^{27}$Mg, $^{41}$Ar, $^{56}$Mn and $^{60}$Co at three different places are shown in Table 2 below. The highest specific activity was found to be in Ar-41 at pool surface, 3 meter form surface and bottom of the pool reactor. It is known that Ar-41 is produced by activation of stable Ar-40 nuclide [1]. Certain amount of activated argon radionuclides decays while in the water and the rest might escape from the reactor pool water. The increase of water temperature will reduce the solubility of argon in water which consequently accelerates the increase of argon concentration in reactor hall [3].

On the other hand, Na-24 nuclide can be produced through the reaction of salt impurities in reactor water or an activation of structural aluminum through Al-27 and Na-24 reaction [4]. Radionuclides of Mg-27, Mn-56 and Co-60 were produced from activation of metals or alloys that has been used in Systems, Structures and Components (SSCS) in reactor pool tank.

| Nuclides | Energy (keV) | Half-life (m/h/y) | Abundance | Specific Activity (Bq kg$^{-1}$) |
|----------|-------------|-----------------|-----------|-------------------------------|
|          |             |                 |           | Pool Surface | 3m from surface | Bottom pool |
| Na-24    | 1368.60     | 14.96h          | 100.00    | 2186.48±0.001 | 2036.56±0.001 | 2109.87±0.001 |
| Mg-27    | 843.76      | 9.46m           | 71.40     | 563.18±0.001 | 523.90±0.001 | 536.31±0.001 |
| Ar-41    | 1293.64     | 1.83h           | 99.16     | 40985.12±0.001 | 51236.78±0.001 | 43741.42±0.001 |
| Mn-56    | 846.76      | 2.58h           | 98.87     | 2133.78±0.001 | 2366.90±0.001 | 2190.41±0.001 |
| Co-60    | 1173.24     | 5.27y           | 99.90     | 226.54±0.001 | 189.82±0.001 | 197.33±0.001 |
4. Conclusion
The concentration level of various impurity elements and radionuclides production rate in reactor water is important to maintain the safe operational of the reactor. The determination of activated nuclides using gamma spectrometry has found several radionuclides including of Na-24, Mg-27, Ar-41, Mn-56 and Co-60.

5. References
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