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Determination of heavy metals in condenser cooling water system of FBTR

M. V. Subitha[1], S. Sathiakala[1], K. G. Subramanian[2] and B. S. Panigrahi[*2]
[1]On deputation to IGCAR from BHAVINI, [2]Technical Services Division, ROMG,
Indira Gandhi Centre for Atomic Research, Kalpakkam (TN), India
bsp@igcar.gov.in, bspanigrahi2001@yahoo.com[*]

Abstract

Fast Breeder Test Reactor (FBTR) is a 40MWt/13Mwe, sodium cooled nuclear reactor. Its cooling water system (CWS) consists of an open re-circulating type with an induced draft cooling tower and Palar river water is used the cooling medium. The metallurgy of CWS consists of carbon steel, copper, admiralty brass, aluminum brass, bronze, cupronickel etc. The possible release of metals (including heavy metals) to the environment from the CWS as a result of corrosion or due to the cooling water treatment chemicals are examined in this study using High Pressure Ion Chromatography (HPIC). The Zinc and Nickel concentrations in the makeup water as well as CWS blow down samples were found to at trace level. The concentrations of transition metals are well within the general standards for discharge of Environmental pollutants.

Keywords: FBTR, cooling water, water analysis, effluent, HPIC.

Introduction

Fast Breeder Test Reactor (FBTR) is a 40MWt/13Mwe, sodium cooled, loop type fast reactor using Plutonium-Uranium mixed carbide fuel. Condenser cooling and service water systems together serve as the cooling water system of FBTR. Service water system forms the terminal heat sink for various process heat exchangers and steam water system auxiliary coolers. The CWS consists of an open re-circulating type with an induced draft cooling tower as the ultimate heat sink. Palar river water is used as the cooling medium. The material of construction of pipe line is carbon steel and the heat exchanger tube and other equipment materials are copper, admiralty brass, aluminium brass, bronze, Cu-Ni and carbon steel. The cooling water system consists of a cooling water pit with capacity of 55 m^3 (6.5 x 4.4 x 2.2 m) and induced draft cooling tower with basin capacity of 288 m^3 (24.54 x 12.04 x 1.0 m). The system parameters during reactor operation at 15MWt (and shut down state) are Flow rate- 3400 m^3 /h (1800), Temperature range- 6 ^{0}C (1), Make up- 350 m^3 (100) and Cycles of Concentration- 3 (1.5).

The condenser cooling water (CCW) system caters to main condenser, dump condenser, turbine oil cooler, generator air cooler and condensate cooler. Both the systems share a common induced draft-cooling tower, cooling water pit, corrosion monitoring set up, chlorinator and side stream filtration unit. Cooling water treatment involves addition of chemicals and the use of mechanical techniques to minimize corrosion and formation of inorganic and biological deposits in order to maintain satisfactorily heat transfer condition in cooling circuitry (Modern Power Station Practice, 1992; Hans-Gunter Heitmann, 1993). Chemistry control using proprietary formulations comprising corrosion inhibitor, inorganic dispersant, bio-dispersant, chlorine activator and biocides along with chlorination is adopted in FBTR cooling water system. The treatment program is non metallic type and is free from Zinc and Nickel. The discharge of cooling tower blow down containing Zinc and Nickel is to be limited due to its aquatic toxicity. In order to limit the metals it is necessary to estimate the metals in cooling water. The specific objective of the present work was to determine levels of Zinc and Nickel in cooling water systems of FBTR.

Corrosion and scaling are related phenomena and to minimize it without releasing chemical toxicity to environment, a non-metallic treatment formulation was chosen. One of the effective programs relies on a combination of Zinc and Phosphonate (G.E.Power & Water, 2010) for corrosion inhibition. However, the non-metallic treatment program adopted in the cooling water system of FBTR is free from Zinc. The estimation of Zinc and Nickel in CW system samples not only ascertains the absence of these metals in the treatment formulations but also ensures the quality of the discharge water. Even though the general standards for discharge of environmental pollutants (General Standards For Discharge Of Environmental Pollutants and Indian standard specifications for drinking water IS: 10500) limits the Zinc concentration to 5mg/L and 3mg/L for Iron, Copper & Nickel and 2mg/L for Manganese, generally estimation of Zinc and Nickel are used to judge the effluent water quality. The ecotoxicological (Zinc and water: reaction mechanisms, environmental impact and health effects - water treatment solutions, LENNTECH) tests attributed a total concentration of 200mg/L of Zinc in water as Predicted No Effect Concentration (PNEC) value. In order to estimate the level of Zinc and Nickel, different methods including AAS, ICPMS are generally used. In the present study Ion chromatography was used as other transition elements can also be analyzed accurately along with Zinc and Nickel.

Experimental

A High Performance Ion Chromatograph (Dionex) ICS 2000 was used to estimate transition elements in the water samples. IonPac CS5A 2x250mm Analytical Column with CG5A 2x50mm Guard Column was used. AD-25 UV-VIS Detector with PEEK cell was used as the detector. 6mM PDCA (Pyridine Di Carboxylic Acid) with

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0.36g/L of Lithium hydroxide was used as eluent. The post column reagent was $4x10^{-4}$M PAR (Pyridyl azo Resorcinol). All the chemicals were of Analytical Reagent grade and solutions were prepared using Deionized water (18 MΩ-cm resistivity). 100µL sample loop was used. Water samples were collected from Open reservoirs (OP-old, OP-new), Nuclear Desalination Demonstration Project (NDDP), Make up water for CW (RW) which are used as Cooling water and also for make up for the loss of inventory & Cooling water system (CW) and analyzed for transition elements. 18 MΩ-cm resistivity water was used for establishing blank.

Table 1. Metal concentration in cooling water system of FBTR (all concentrations in ppb)

Sample	Fe	Cu	Ni	Zn	Co	Mn
Blank	-----	----	----	-----	---	-----
Raw water	13	5.7	3.7	254	---	3.9
Op new	6.7	----	----	26	---	3.58
Op old	16.5	----	----	12.3	---	-----
NDDP	3.0	----	3.9	6.0	---	3.6
Cooling water	60	15	----	158	---	------

Results and discussion

A mixed standard comprising 100ppb of Iron, copper, Nickel, Zinc, Cobalt and Manganese was used for the quantification of transition metals in the samples. Each analysis was repeated and the average values were considered (Table 1). Typical chromatograms are depicted in Fig.1 & 2.

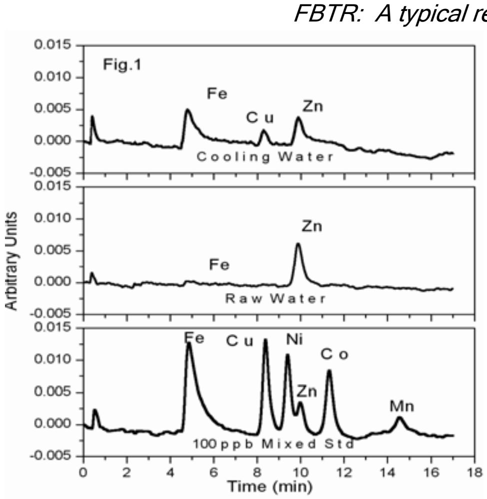
The typical chromatograms obtained for 100ppb mixed standards, Makeup water (RW) and Cooling water are shown in Fig 1. The typical chromatograms obtained for Open Reservoir new and old, NDDP and high pure water (blank) samples are shown in Fig.2. The blank does not show the presence of transition elements. NDDP sample is very close to the blank showing the presence of <10ppb of Iron, Nickel, Zinc and Manganese. This indicates that the desalination is effective in removing the transition elements. The open reservoir samples contain <20ppb of Iron and <10ppb of Zinc and Manganese.

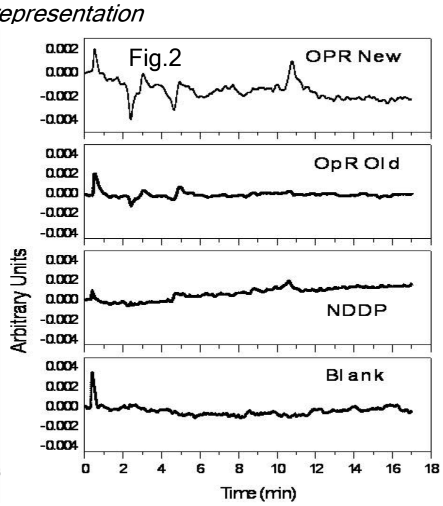
The retention time (Dionex reference Library Product Manual. IonPac CS5A Aanalytical columns. pp: 15) for each transition metal was established using individual standard. The makeup water contains iron, copper, Manganese, Nickel and Zinc. There is a variation in concentration of the transition metals in RW and CW samples. In RW samples, Zinc varies from 100 to 254ppb. The nickel concentration was found to be <5ppb. The Zinc concentration in cooling water samples (from the system as well as blow down samples) was ranging from 80 to 158ppb and no peak was obtained for Nickel. These results clearly indicate that the Zinc and Nickel concentrations are not significant in the CW with respect to environment pollution and it also shows that the treatment chemicals used for inhibiting corrosion and deposition are free from Zinc and Nickel. Iron and Copper were also found to be 60 and 15ppb respectively. These levels indicate that the corrosion process taking place in the system is negligible. The periodic estimation of corrosion rates for the CS coupons (<3mpy) and the brass coupons (<0.5mpy) in the CW system also supports these analytical results.

Conclusion

The Zinc and Nickel concentrations in CW system as well as blow down samples from cooling water system were found to be very low. The concentrations of other transition metals are well within the general standards for discharge of environmental pollutants. The discharge of water from CW system (at this metal concentrations) to the environment does not affect the aquatic system with respect to Zinc, Nickel and other transition metals measured. The treatment formulations, used for inhibiting corrosion and scale in the system were found to be free from these metals. The corrosion rates are significantly less which is shown by the presence of very low levels of Iron and Copper. This study has clearly brought out the fact that Ion chromatography can be effectively used for monitoring transition metals affecting the eco system in effluent water of cooling water system and also for ensuring the non metallic treatment of the CW system. Power plant operation is generally considered to be an ecologically burdening exercise. But adoption of suitable methods and monitoring are the key factors for the implementation of any energy project in the era of environmental crisis.

Estimation of metals in the cooling water samples of FBTR: A typical representation





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