Indira Gandhi Centre for Atomic Research

Annual Report 2022

Government of India
Department of Atomic Energy
Indira Gandhi Centre for Atomic Research
Kalpakkam - 603 102

V.24 Development of Linear Kalman-Filter Technique for Source Term and Dose Rate Estimation

Source term is an important input for dose projections using atmospheric dispersion models during accident condition. Kalman Filter (KF) method is one of most reliable and useful technique in modelling and prediction of environmental data in space time domain.

Linear Kalman Filters

Kalman Filter (KF) is basically a predictor-corrector recursive algorithm for instantaneous state estimation of linear dynamical system from a set of noisy measurements. A Python based in-house Extended Kalman Filter (EKF) algorithm with Gaussian Plume model (GPM) (Dt(qt)) for short range dispersion is developed to compute source term (qt) taking the case of routine release of ^{41}Ar from Madras Atomic Power Station (MAPS). EKF algorithm is developed based on following equations

$$q_t = q_{t-1} + w(t) \quad \text{.....(1)}$$

$$q_t^+ = q_t^- + K_t[d_t - q_t^- D_t(q_t = 1)] \text{.....(2)}$$

w(t), is the noise associated with time evolution of source term with noise covariance 10^{15} Bq^2.s^{-2} which is arrived by innovation technique. Following GPM inversion methodology and gamma detector data, the initial release rate (q0) is estimated to be ~10^9 Bq/s. In the next time step source term is predicted (q_t^-) using Eq. 1. Using observed dose rate information (d_t) adjustments are done through Kalman Gain (K_t) and updated source term (q_t^+) is estimated using Eq. 2. q_t^+ is used as initial source term for next time step. This algorithm is iteratively used to obtain the time series of release rate.

From literature measurement noise standard deviation is taken as 5% of mean dose rate for each detector. The EKF approach is tested using three Autonomous Gamma Dose Loggers (AGDL) installed in South-West wind sector (plume sector). Data from 50 m meteorological tower for 10 days in February, 2021 is used in EKF model during north-easterly wind flow.

Model Predicted Source Term

EKF model predicted source term for 10 min sampling time is shown in Figure 1. The actual source is taken from daily release value of MAPS reactor which is uniform. The scatter index or normalized root mean square error (NRMSE) for the model estimated source term is ~ 2.01. EKF predicted mean source term is 2.49 times higher compared to MAPS release data with a relative bias ~1.49.

Model Estimated Dose Rate

The observed, GPM predicted and EKF updated dose rates for AGDL-4 are shown in Figure 2. Correlation in GPM predicted dose rate is 0.35 and EKF estimated dose rate is 0.60 which indicates improvement by a factor of 1.8. The RMSE in predicted dose rate is 0.04 µSv/h for EKF and 0.09 µSv/h for GPM suggesting error reduction by a factor of 2 with EKF. Present results show that EKF can be used as alternative method of source term estimation. It is proposed to evaluate its relative performance with simple inversion method for incorporation in the Decision Support System.

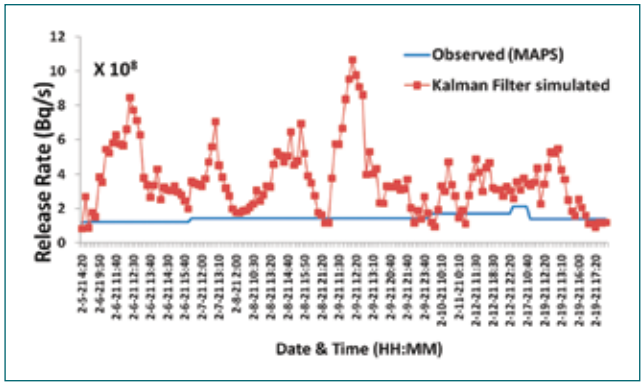

Fig. 1: KF model predicted release rate along with actual release rate

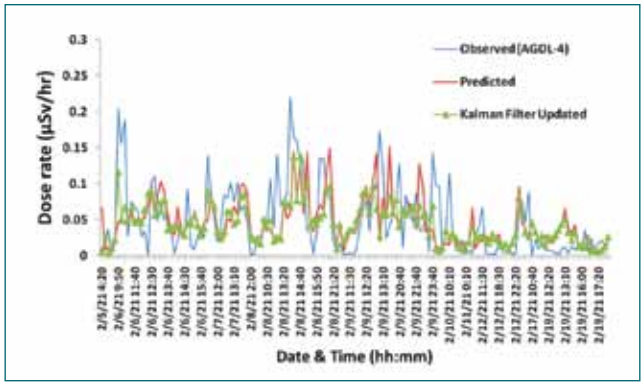

Fig. 2: Observed, model predicted and updated dose rate

VI.14 Incubation and Transfer of IGCAR Technologies

DAE Incubation Centre, IGCAR (IC-IGCAR) was inaugurated on 30th October 2020 on the occasion of 111th birth anniversary of Dr. Homi Jehangir Bhabha by Shri. K.N. Vyas, Secretary, Department of Atomic Energy (DAE). IC-IGCAR has a mandate of taking forward Government of India's mission of Atma Nirbhar Bharat and incubate/transfer various DAE technologies to encourage start-ups and commercialise the technologies.

Technology Transfers

Pulsating sensor based conductivity meter is a high performance instrument developed at EIG(Fig. 1).

This device is suitable for real-time monitoring of electrical conductivity of aqueous solutions in plants and field applications apart from its usage in chemical laboratories for analysis and quality control. Performance of this device has been validated with many applications in IGCAR and found to be robust even in demanding environments. The technology has been transferred to two start ups: one in Bengaluru and another in Udaipur (Rajasthan).

A portable high volume air sampler (HVAS) has been developed at SQRMG. It is a light-weight device, made of Fiber Reinforced Plastic (FRP) and has an in built embedded controller to start, stop, log and to calculate the total volume of air sampled. This is employed to collect airborne particulates in a filter paper medium at desired flow rates up to 2800 lpm. HVAS is used in nuclear installations for the collection of air samples to estimate air-borne radioactivity levels. This technology has been transferred to a Bengaluru based start up (Fig. 2).

Autonomous Gamma Dose Logger (AGDL) is a radiation monitor developed at SQRMG to measure environmental radiation in a wide range of 100 nGy/hr to 5 Gy/hr. Currently ~28 numbers of in-house made AGDL systems are operating successfully at DAE Kalpakkam site and connected to the Decision Support System for real-time radiation field inputs. This technology has been transferred to a Chennai based start up as well as to a Hyderabad based industry.

Incubation of Technologies

IC-IGCAR has signed a collaborative incubation agreement with a Mumbai based private manufacturer to complete development of the technology "Replaceable Feed-through Connectors for Glove Boxes". This is IGCAR's first technology incubation agreement with private sector following the DAE Incubation Policy (2021).

Another collaborative incubation agreement has been signed betwen IC-IGCAR and a start-up company based in IIT (Madras) for developing "Hydrogen Sensor" technology. This partnership with the start-up is expected to accelerate development of this IGCAR technology from its current technology readiness level (TRL) of '4' to TRL '8' or '9', suitable for commercialisation, during the incubation period of ~18-24 months (Fig. 3).

IC-IGCAR will continue to play a role of providing the start-ups with necessary guidance, technical support, networking, and facilitating a host of other resources that may be required for them to sustain and scale up.

Fig. 1: Conductivity meter

Fig. 2: Portable Air Volume Sampler

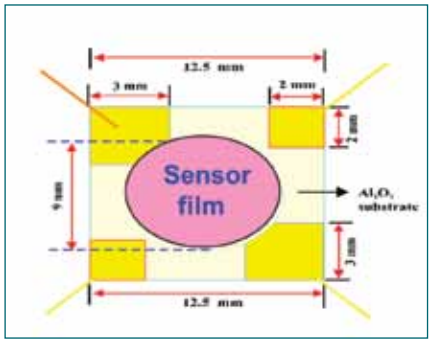

Fig. 3 Schematic of Hydrogen Sensor