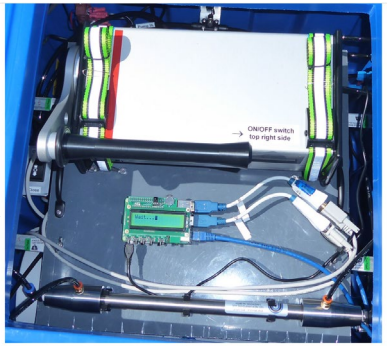
Autoflux system: characterization and applications

Claudia Grossi and Arturo Vargas

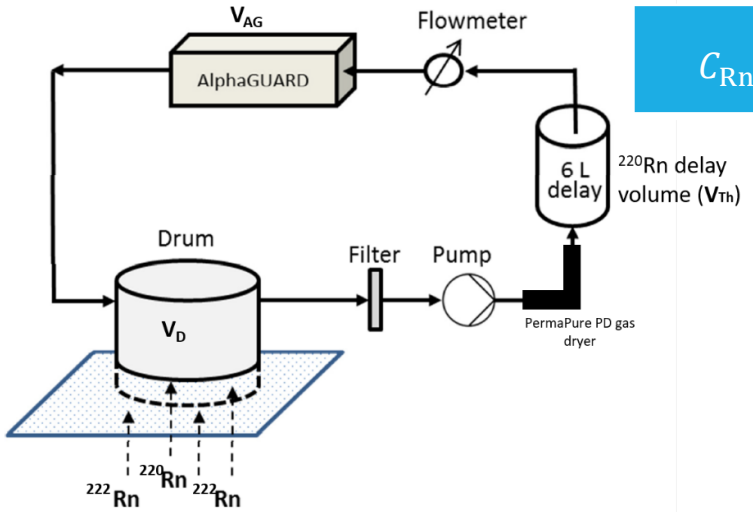
ANSTO AutoFlux system



***AutoFlux* system running in the field. The radon activity concentration, internal air temperature, differential pressure and soil characteristics are measured within the white drum. Ambient temperature, humidity, pressure and rainfall are measured on the side of the transport case (~50 cm a.g.l.), and the main system components are located inside the waterproof transport case.**

Variable (Label within the document)	Sensor	Location	Unit (S.I.)
Volumetric Water Content (VWC) in the soil	CSI CS655 Water Content Reflectometer	Inside Drum	m^3/m^3
Electrical soil conductivity (EC)	CSI CS655 Water Content Reflectometer	Inside Drum	dS/m
Water vapor pressure (VaporPress)	CSI CS655 Water Content Reflectometer	Inside Soil	kPa
Soil temperature (T)	CSI CS655 Water Content Reflectometer	Inside Soil	^0C
Drum air temperature (DrumTemp)	SDI-12 sensor Unidata 6508A	Inside Drum	^0C
Atmospheric air Pressure (AtmPress)	Integrated ATMOS-14 sensor	Outside attached to box	mbar
Ambient air Temperature (AirTemp)	Integrated ATMOS-14 sensor	Outside attached to box	^0C
Relative Humidity (RH)	Integrated ATMOS-14 sensor	Outside attached to box	%
Accumulated rain (Rain)	Hydreon RG-11 Optical Rain Gauge	Outside Drum	mm
Differential pressure between Drum and external atmosphere (DiffPress)	Novus NP785	Inside/Outside Drum	Pa

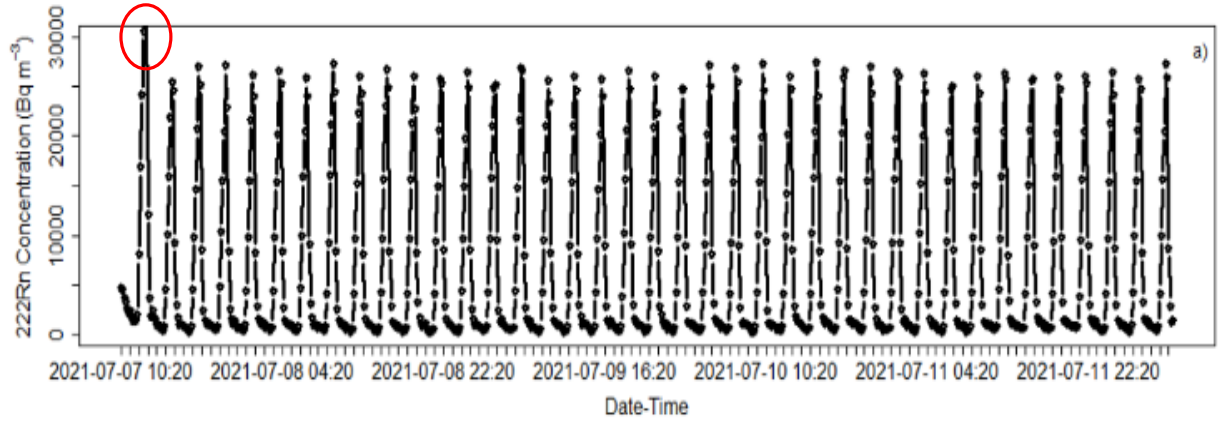
ANSTO AutoFlux system

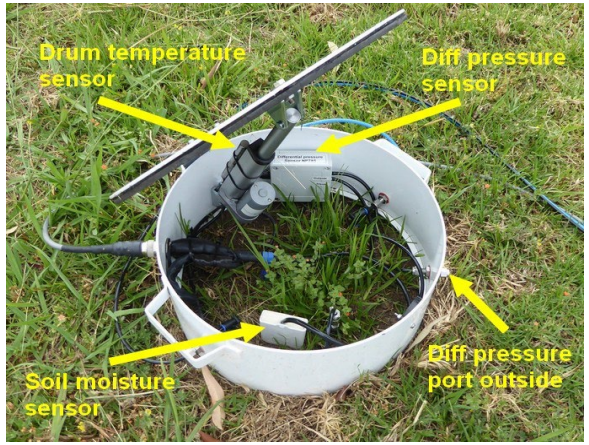


Schematic representation of the *AutoFlux* system (ANSTO).

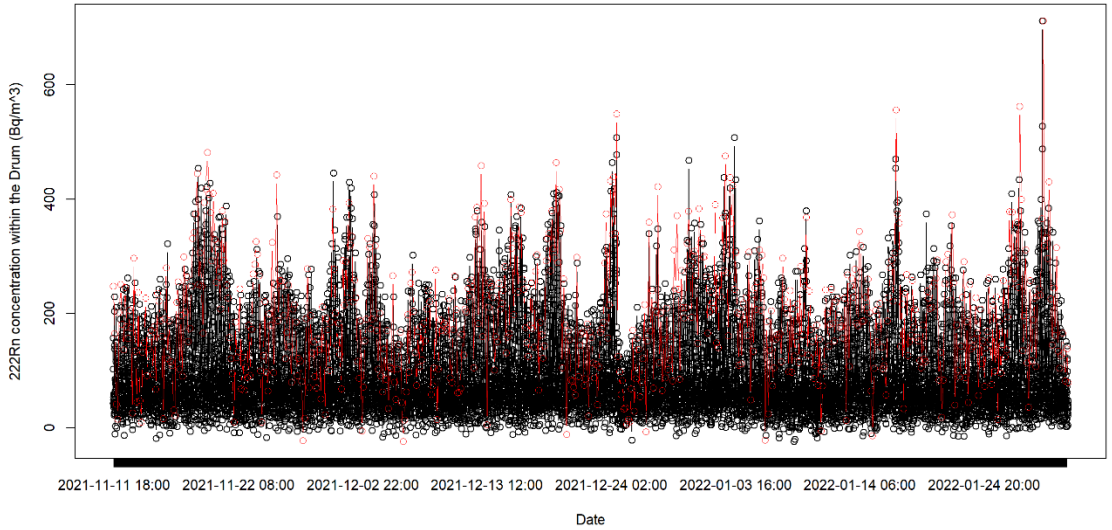
$$C_{Rn}(t) = C_0 e^{-\lambda_{eff} t} + \frac{F \cdot A}{V_{eff} \cdot \lambda_{eff}} \left(1 - e^{-\lambda_{eff} t}\right) \approx \frac{F \cdot A}{V_{eff} \cdot \lambda_{eff}} \cdot \lambda_{eff} t = \frac{F}{h_{eff}} \cdot t = b \cdot t$$

EB





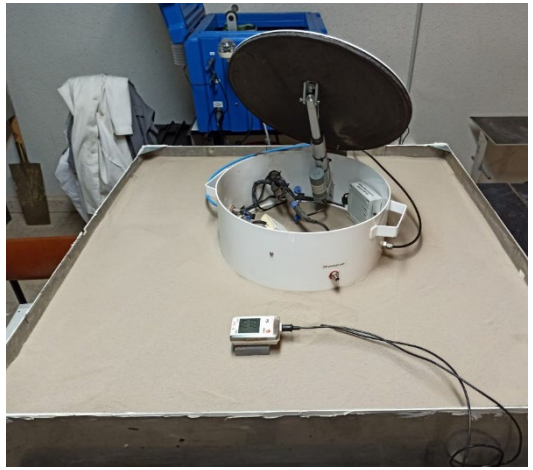
PTB

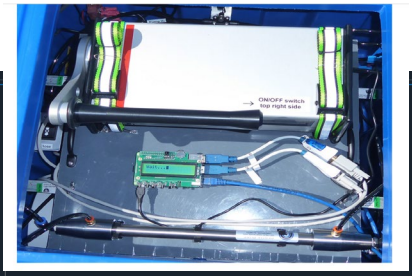


AutoFlux drum during a typical radon flux measurement: accumulation period (1 hour, on the left side) and ventilation period (2 hours, right side).

ANSTO AutoFlux system

Frequency	Script name	Script function
Every hour	read_CR1000.sh	Downloads the latest data records from CR1000 to the file AutoFlux_CR.csv
Every hour	alphaguard.py	Downloads the latest AlphaGUARD file and saves it as AutoFlux_AG.csv file
Every hour	AG_Update.py	Writes all AlphaGUARD data into one AutoFlux_AG_all.csv file
Every 3 hours WARNING	Merge_CR_AG.py	It reads AutoFlux_CR.csv and AutoFlux_AG_all.csv and merges them all into AutoFlux.csv.
Once a month	crontab	On 28th of very month 10 minutes before midnight, the scheduler gets the latest data from AlphaGUARD, synchronises the AG clock to UTC, and puts back AG in Flow mode and 10 minutes cycle.



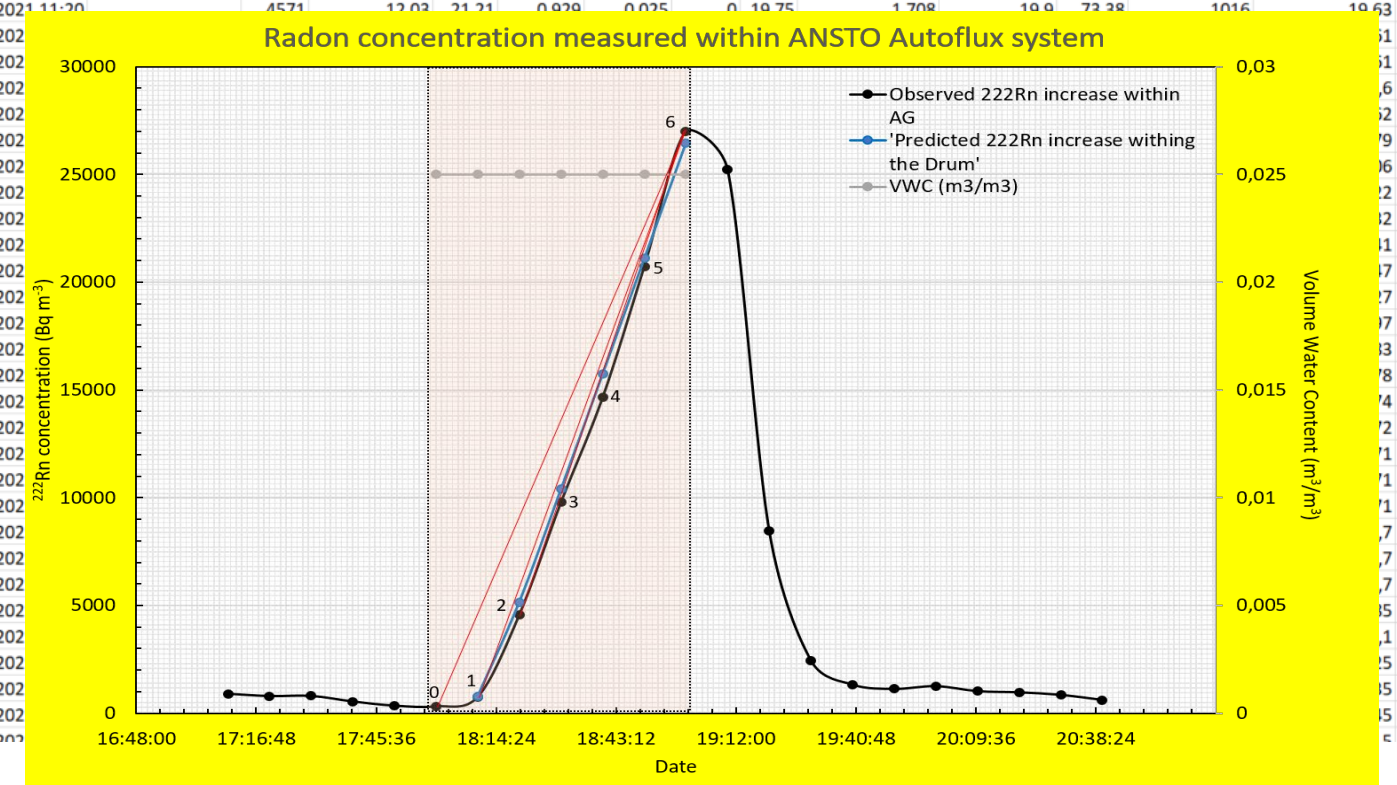


```
Created on Wed Oct  3 12:12:52 2018
Py3
@author: srw
"""

import pandas as pd
import numpy as np
from scipy.stats import linregress
import os.path
import csv
import ftplib
from datetime import datetime
import warnings
#import unicodecsv as csv

warnings.filterwarnings("ignore", category=FutureWarning)

file1 = pd.read_csv('C:/Users/gross/Desktop/traceRadon/WP2_scientific_material\A2.1.2/ANSTO_Flux/Pruebas_Autoflux_INTE/20230208WAO/AutoFlux_CR.csv', index_col=['Datetime'], parse_dates=True, dayfirst=True)
df = file1.resample('10Min').asfreq()
df.columns=df.columns.str.replace("b'","")
df.columns=df.columns.str.replace("'","")

file2 = pd.read_csv('C:/Users/gross/Desktop/traceRadon/WP2_scientific_material\A2.1.2/ANSTO_Flux/Pruebas_Autoflux_INTE/20230208WAO/AutoFlux_AG_all.csv',index_col=['Measurement time'], parse_dates=True, dayfirst=True)
file2 = file2.resample('10Min').asfreq()

dd=pd.merge(df,file2, left_index=True, right_index=True)
dd.index.names=['Datetime']
dd.to_csv('C:/Users/gross/Desktop/traceRadon/WP2_scientific_material\A2.1.2/ANSTO_Flux/Pruebas_Autoflux_INTE/20230208WAO/AutoFlux.csv', encoding='utf-8', index=True)


dfr=pd.read_csv('C:/Users/gross/Desktop/traceRadon/WP2_scientific_material\A2.1.2/ANSTO_Flux/Pruebas_Autoflux_INTE/20230208WAO/AutoFlux1.csv', index_col=['Datetime'], parse_dates=True, dayfirst=True)


def extract_events(dfr):
    startidx = (dfr["Activity"].diff()==1).to_numpy().nonzero()[0]
    stopidx = (dfr["Activity"].diff()==-1).to_numpy().nonzero()[0]
    events = [dfr.iloc[i0:i1, :].copy() for i0,i1 in zip(startidx, stopidx)]
    return events


run1=extract_events(dfr)

filename="C:/Users/gross/Desktop/traceRadon/WP2_scientific_material\A2.1.2/ANSTO_Flux/Pruebas_Autoflux_INTE/20230208WAO/AutoFlux_summary.csv"
file_exists = os.path.isfile(filename)
if file_exists:
    os.remove("C:/Users/gross/Desktop/traceRadon/WP2_scientific_material\A2.1.2/ANSTO_Flux/Pruebas_Autoflux_INTE/20230208WAO/AutoFlux_summary.csv")
    file_exists=False

    s=-1
    for i in run1:
        s += 1
        cf1 = (1 + 0.97 * ((run1[s].temperature - 0) / 293) * (130 / (130 - run1[s].temperature)))
        cf2 = (1 + (-0.18) * ((run1[s].AtmPress_Avg - 1013) / 1013) * (run1[s].AtmPress_Avg / (run1[s].AtmPress_Avg - 620)))
        run1[s]['r1'] = run1[s].radon.astype(float, errors = 'raise')
        in1 = pd.to_datetime(run1[s].index[2:], errors='coerce')
        in2 = pd.to_datetime(run1[s].index[0])
        date2sec = (in1 - in2 ).total_seconds()
        slope, intercept, r_value, p_value, std_err = linregress(date2sec, run1[s].r1[2:])
        RnFx = 0.204 * slope *  1000  * 3.6
        Err = 0.204* std_err *  1000  * 3.6
        ts=run1[s].index[0].strftime('%d/%m/%Y %H:%M')
        writer.writerow({'Datetime':ts, 'Flux':round(RnFx,2),  'Std_err':round(Err),'Flow_Avg':round(run1[s].Flow_Avg.mean(),2),  'VWC_Avg':round(run1[s].VWC_Avg.mean(),2),  'EC_Avg':round(run1[s].EC_Avg.mean(),2),
                         'T_Avg':round(run1[s].T_Avg.mean(),2),'VaporPress_Avg':round(run1[s].VaporPress_Avg.mean(),2),'AirTemp_Avg':round(run1[s].AirTemp_Avg.mean(),2),  'RH_Avg':round(run1[s].RH_Avg.mean(),2),
                        'AtmPress_Avg':round(run1[s].AtmPress_Avg.mean(),2),'DrumTemp_Avg':round(run1[s].DrumTemp_Avg.mean(),2),'DiffPress_Avg':round(run1[s].DiffPress_Avg.mean(),2),'Rain_Tot':round(run1[s].Rain_Tot.
```

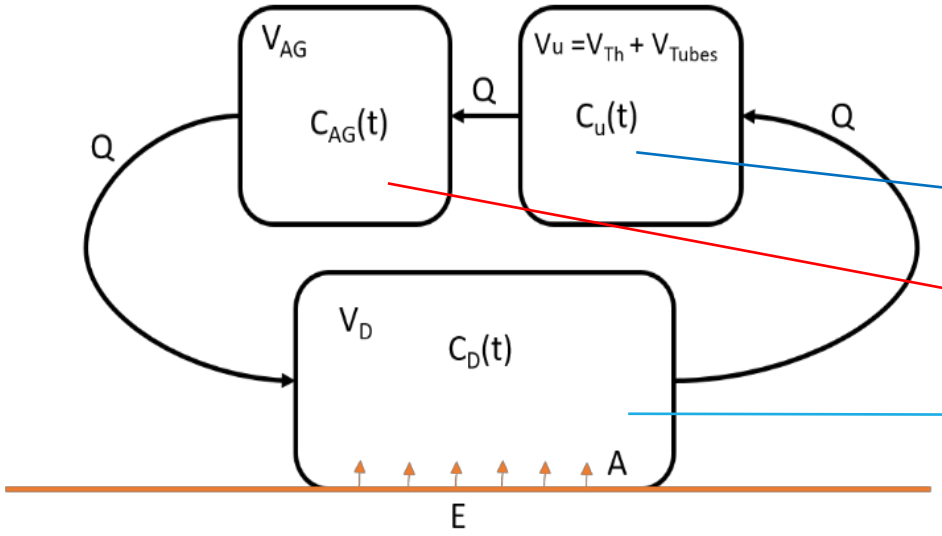
$$C_{\mathrm{Rn}}(t) = C_0 e^{-\lambda_{eff} t} + \frac{F \cdot A}{V_{eff} \cdot \lambda_{eff}} \left(1 - e^{-\lambda_{eff} t}\right) \approx \frac{F \cdot A}{V_{eff} \cdot \lambda_{eff}} \cdot \lambda_{eff} t = \frac{F}{h_{eff}} \cdot t = b \cdot t$$ **with heff = Veff/A**

ANSTO AutoFlux system

Datetime	RecNbr	batt_volt_Min	PTemp	Flow_Avg	VWC_Avg	EC_Avg	T_Avg	VaporPress_Avg	AirTemp_Avg	RH_Avg	AtmPress_Avg	DrumTemp_Avg	DiffPress_Avg	Rain_Tot	Activity	radon	radon error	noise	status	reloc	external input	reserved	temperature	pressure
07/07/2021 9:30	4560	12,04	19,23	0,978	0,02	0	19,71	1,722	19,5	76,07	1015	19,05	2,682	0	0	151	54,75	0	8	65	6	0	19,75	1013,91
07/07/2021 9:40	4561	12,02	19,42	0,953	0,025	0	19,84	1,728	19,57	75,9	1015	19,43	1,793	0	0	3840	302	0	8	4	6	0	20,375	1013,86
07/07/2021 9:50	4562	12,03	19,68	0,934	0,025	0	19,9	1,726	19,7	75,19	1015	19,65	1,618	0	0	7264	512	0	8	0	6	0	21,5	1014,15
07/07/2021 10:00	4563	12,04	19,94	0,932	0,025	0	19,88	1,714	19,7	74,53	1015	19,68	1,226	0	0	6624	488	0	8	0	6	0	22,375	1014,43
07/07/2021 10:10	4564	12,04	20,18	0,934	0,025	0	19,85	1,711	19,75	74,33	1015	19,69	1,491	0	0	5568	436	0	8	0	6	0	22,75	1014,47
07/07/2021 10:20	4565	12,04	20,4	0,93	0,025	0	19,84	1,709	19,8	74,21	1015	19,68	0,54	0	0	4704	408	32	8	0	6	0	23	1014,45
07/07/2021 10:30	4566	12,03	20,61	0,93	0,025	0	19,81	1,706	19,8	74,07	1015	19,68	0,724	0	0	4480	396	32	8	0	6	0	23,125	1014,4
07/07/2021 10:40	4567	12,03	20,77	0,931	0,025	0	19,8	1,703	19,8	73,93	1015	19,67	0,977	0	0	3600	354	32	8	0	6	0	23,25	1014,62
07/07/2021 10:50	4568	12,02	20,91	0,93	0,025	0	19,78	1,701	19,8	73,78	1016	19,66	1,06	0	0	3184	330	32	8	0	6	0	23,375	1015,0
07/07/2021 11:00	4569	12,04	21,02	0,93	0,025	0	19,76	1,704	19,85	73,57	1016	19,65	0,891	0	0	2496	276	0	8	0	6	0	23,5	1015,10
07/07/2021 11:10	4570	12,03	21,12	0,929	0,025	0	19,76	1,705	19,9	73,42	1016	19,64	1,017	0	0	2272	266	0	8	0	6	0	23,5	1015,20
07/07/2021 11:20	4571	12,03	21,21	0,929	0,025	0	19,75	1,708	19,9	73,38	1016	19,63	0,541	0	0	2400	280	0	8	0	6	0	23,625	1015,17
07/07/202													1,256	0	0	1688	228	0	8	0	6	0	23,625	1015,26
07/07/202													1,193	0	0	1360	212	0	8	0	6	0	23,625	1015,26
07/07/202													0,126	0	0	1456	215	0	8	0	6	0	23,625	1015,38
07/07/202													1,486	0	1	1344	206	0	8	0	6	0	23,75	1015,31
07/07/202													1,233	0	1	1920	243	0	8	0	6	0	23,625	1015,37
07/07/202													1,316	0	1	8032	592	0	8	0	6	0	23,625	1015,28
07/07/202													0,903	0	1	16896	1024	0	8	0	6	0	23,625	1015,34
07/07/202													1,138	0	1	24192	1376	0	8	0	6	0	23,625	1015,42
07/07/202													1,137	0	1	30592	1640	0	8	0	6	0	23,625	1015,42
07/07/202													0,448	0	1	36352	1688	0	8	0	6	0	23,625	1015,52
07/07/202													0,941	0	0	32768	1720	0	8	0	6	0	23,625	1015,58
07/07/202													0,965	0	0	12096	1104	0	8	0	6	0	23,625	1015,65
07/07/202													0,841	0	0	3680	652	0	8	0	6	0	23,625	1015,62
07/07/202													1,012	0	0	1816	500	0	8	0	6	0	23,5	1015,65
07/07/202													0,758	0	0	2320	500	0	8	0	6	0	23,5	1015,6
07/07/202													0,882	0	0	1688	420	0	8	0	6	0	23,5	1015,6
07/07/202													1,307	0	0	1584	378	0	8	0	6	0	23,5	1015,73
07/07/202													0,451	0	0	1000	334	0	8	0	6	0	23,5	1015,77
07/07/202													1,1	0	0	1000	306	0	8	0	6	0	23,5	1016,00
07/07/202													1,166	0	0	640	262	0	8	0	6	0	23,5	1016,11
07/07/202													1,624	0	0	672	253	0	8	0	6	0	23,5	1016,07
07/07/202													1,752	0	1	420	218	0	8	0	6	0	23,375	1016,17
07/07/202													0,706	0	1	796	223	0	8	0	6	0	23,375	1016,19
07/07/202													0,707	0	1	4544	454	0	8	0	6	0	23,375	1016,17
07/07/202													1,144	0	1	10112	740	0	8	0	6	0	23,375	1016,18
07/07/202													0,319	0	1	15872	1032	0	8	0	6	0	23,375	1016,19
07/07/202													1,366	0	1	21888	1336	0	8	0	6	0	23,375	1016,19



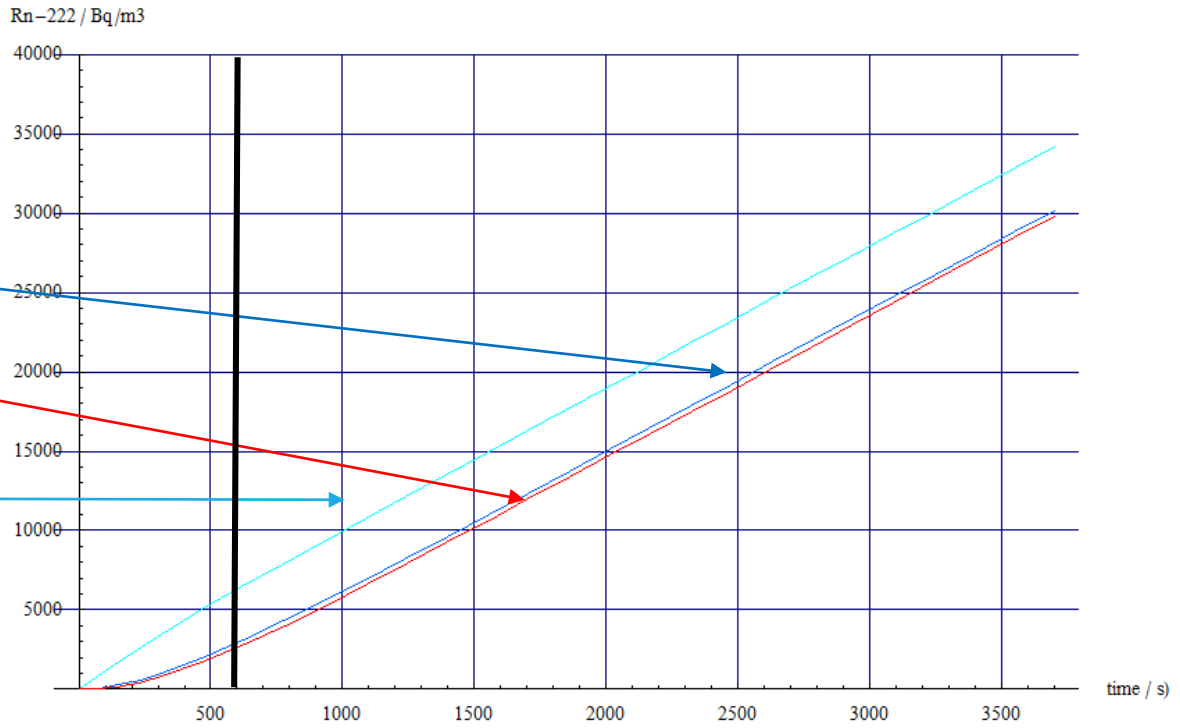
ANSTO AutoFlux system: Theorical and Experimental characterization



$$\frac{dC_D(t)}{dt} = \frac{F \cdot A}{V_D} - C_D(t) \cdot \frac{Q}{V_D} + C_{AG}(t) \cdot \frac{Q}{V_{AG}}$$

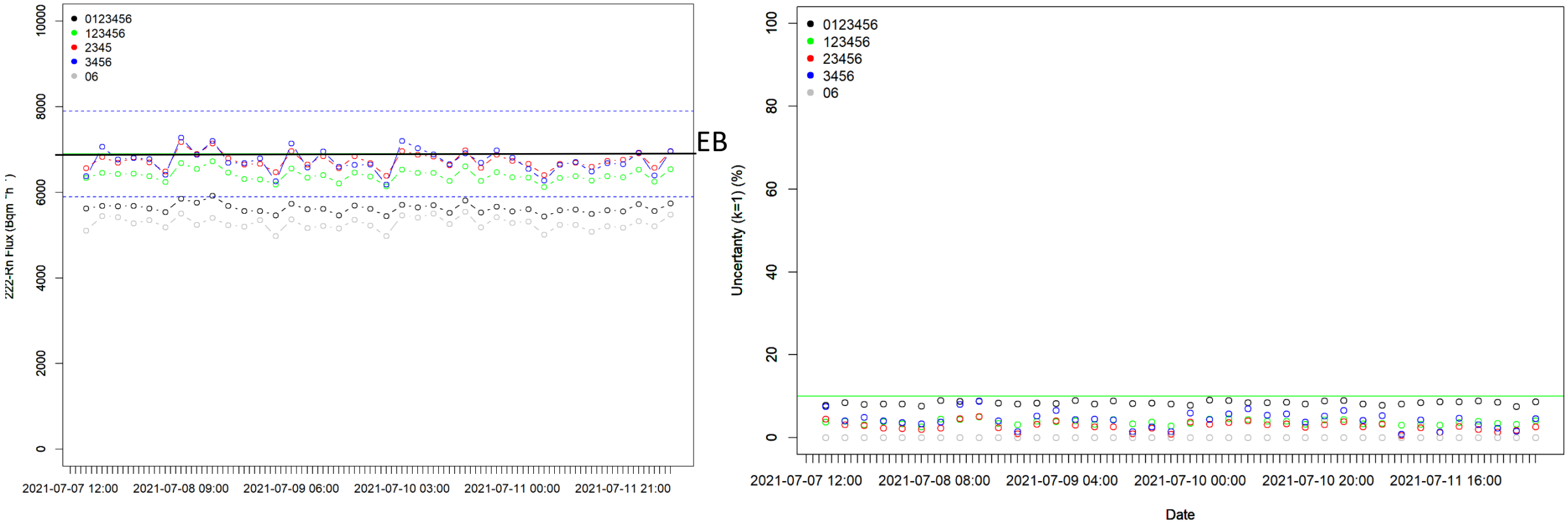
$$\frac{dC_u(t)}{dt} = C_D(t) \cdot \frac{Q}{V_D} + C_u(t) \cdot \frac{Q}{V_u}$$

$$\frac{dC_{AG}(t)}{dt} = C_u(t) \cdot \frac{Q}{V_u} + C_{AG}(t) \cdot \frac{Q}{V_{AG}}$$

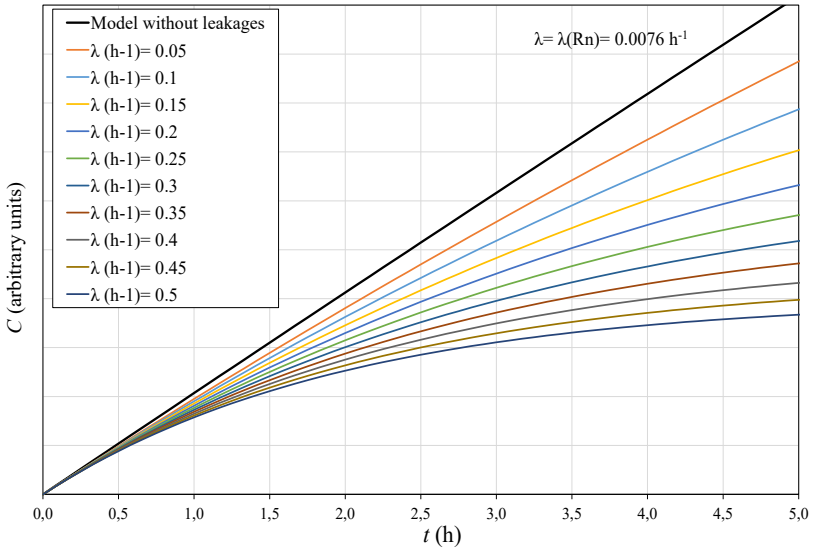


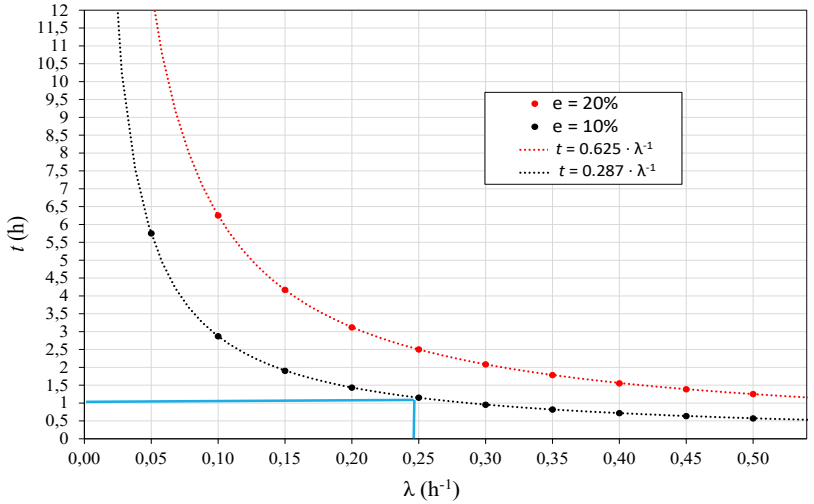
Simulated ^{222}Rn concentration behavior within each one of the volumes of the *AutoFlux* system during the hour for which the chamber was closed C_D (light blue line), C_u (blue line) and C_{AG} (red line).

ANSTO AutoFlux system: Theorical and Experimental characterization

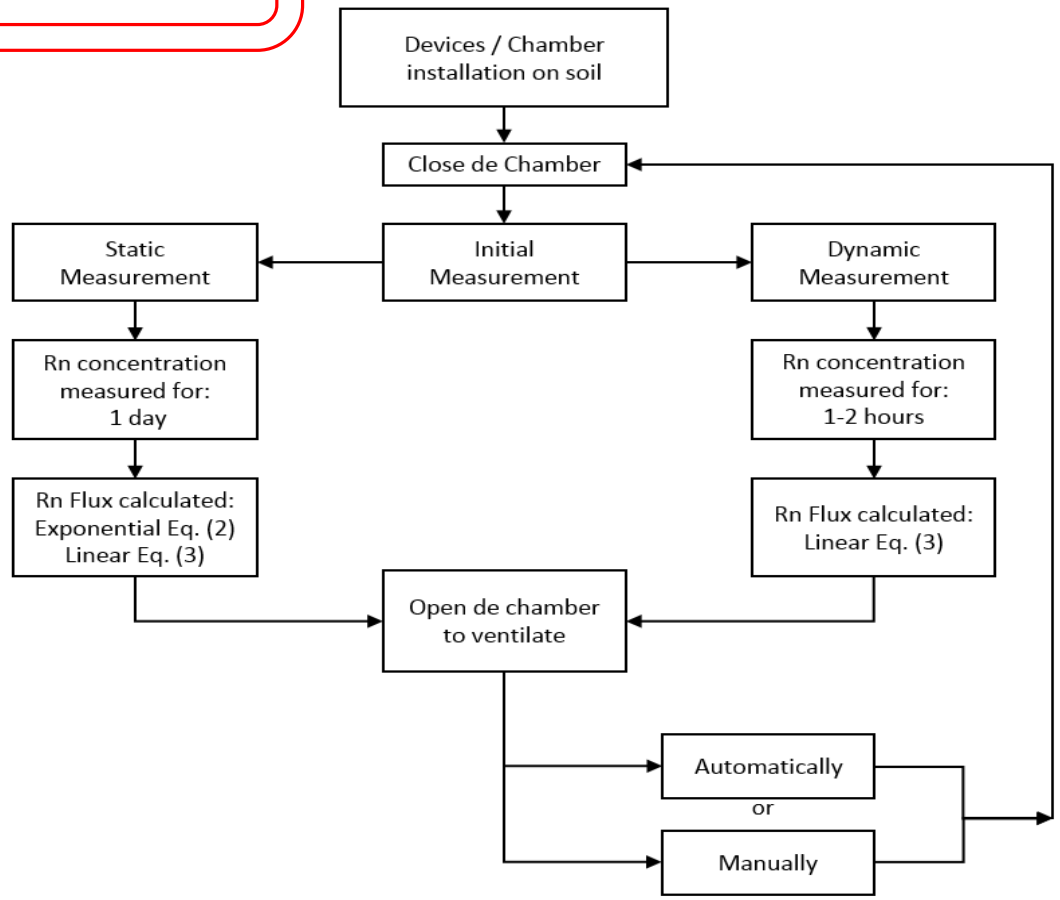


Linear Method with Flux systems





$$C_{\mathrm{Rn}}(t) = C_0 e^{-\lambda_{eff} t} + \frac{F \cdot A}{V_{eff} \cdot \lambda_{eff}}\left(1 - e^{-\lambda_{eff} t}\right) \approx \frac{F \cdot A}{V_{eff} \cdot \lambda_{eff}} \cdot \lambda_{eff} t = \frac{F}{h_{eff}} \cdot t = b \cdot t$$



Rabago et al., 2022


Thank
You