Important Radionuclide to be considered for Environmental Impact Assessment

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Abstract: Anthropogenic radionuclide has been introduced to the environment for almost a century. The main source has been the nuclear weapons testing programmers, but accidental releases from the nuclear power production industries have also contributed. The risk to humans from potential releases from nuclear facilities is evaluated in safety assessments. Essential components of these assessments are exposure models, which estimate the transport of radionuclide in the environment, the uptake in biota, and transfer to humans. Recently, there has been a growing concern for radiological protection of the whole environment, not only humans, and a first attempt has been to employ the model approaches based on stylized environments and transfer functions to biota based exclusively on bioconcentration factors. They are generally of a non-mechanistic nature and involve no knowledge of the actual processes involved, which is a severe limitation when assessing real ecosystems.

Keywords: Evaluation; Monitoring; Nuclear power plant; Radionuclide;

I. INTRODUCTION

The current drive for new sources of energy in the power industry has been driven in part, by the growing demand for electricity worldwide. One viable option to using oil related energy is the use of nuclear power. The use of nuclear power has raised many safety questions, as well as possible subsequent health issues and environmental risks. The possible implications of living near a nuclear power plant and the long-term effects of a nuclear power disaster, has yet to reach a consensus (Wang, Lee, Zou, Fan, & Yaung, 2010). The lack of consensus around two questions is the basis for this paper: Do we have nuclear power under control? How much risk reduction is humankind willing to undertake? 09

II. BACKGROUND

Nuclear power plant expansion in the United States has been driven by the relatively comparable cost of nuclear power to coal or natural gas and the reduced reliance on other countries for energy. In addition, nuclear power plants have been found to emit relatively few greenhouse gases in comparison to other forms of energy sources, such as coal (Ferguson, 2007). However, for nuclear power to have a substantial effect on reversing the damage on the environment and to combat human-induced climate change, the amount of new nuclear power plants would have to expand at a rapid rate, thereby resulting in lack of adequate materials, and personnel to operate and run the plants safely (Ferguson, 2007).Other concerns of nuclear power plants stem from the use of uranium in less developed countries. Attacks on nuclear power plants could have detrimental effects and allow individuals to use the uranium for purposes of terrorism (Ferguson, 2007). In the United States the focus is on reducing the need for energy from unstable regions and on increasing energy security through having a constant and predictable source. Despite concerns over nuclear power, the subject has moved to the forefront of possible new solutions to the energy crisis that the world faces (Ferguson, 2007).

III. ENVIRONMENTAL IMPLICATIONS

This century has seen a rise in the observance of environmentally friendly practices. Nuclear energy is typically considered one of the more environmentally friendly sources of energy, except that plants require large amounts of water to be able to function and properly cool the reactive core (Garrick & Christie, 2002). The environmental effect of using large amounts of water at nuclear power plants has revealed mixed results, and has resulted in studies looking at ways to improve some of the effects of the discharged water, which can be an average of 7°C higher than in control areas (Teixeira, Neves, & Araujo, 2009). The effected water discharge areas change the natural environment by decreasing benthic cover, increasing the amount of bare rock, and increasing the number of opportunistic species. Chlorine added to the discharged water also contributes to the decreased habitat, which in turn, effects the fish population. The effects on the habitat of aquatic species due to discharged water from nuclear power plants are an example of thermal pollution (Teixeira, et al., 2009).

Efforts have been made in south China to reduce effects of nuclear power on the ecosystem. Assessments of the current state of the ecosystem as a whole were conducted to assess current efforts to reverse previous damage caused by water usage at a nuclear power plant (Chen et al., 2010). Although some positive changes were found, such as phytoplankton returning to original levels, the number of zooplankton and benthos continued to decrease. In this example, water quality worsened, sediment quality remained the same, the control of emissions was found to not be effective, and fishery resources were not restored. Priority areas for future restoration included habitat reconstruction, fisheries, coastal plants, and wastewater management (Chen, et al., 2010).It is important to understand the effect that nuclear power plants can have on the land environment that surrounds them. Studies conducted both at functioning power plant locations, and at nuclear power plant accident locations have found minimal radiation in the soil and plants (Micieta & Murin, 2007; Wallberg & Moberg, 2002). The minimal radionuclides found in the surrounding.

IV. ALGORITHM

Important Radionuclide to be considered for Environmental Impact Assessment:

• Fission Product Noble Gas (FPNG) [Gamma dose]

– Nuclides that produce during the nuclear fission chain reaction (Reactor: Source)

– Cs-137 and I-131 [Atmospheric route]

• Iodine (I-131 and its daughters including Tellurium) [Atmospheric route]

• Sr-90 (Beta dose) [Important in the aquatic route]

• Tritium (${}_1H^3$) (Beta dose) [Atmospheric and aquatic route]

• Argon-41 (Ar-41) [Activation Product]

Importance of Radiological Risk Computation

• Operation of any industry (e.g. nuclear facility) discharges gaseous and liquid effluent in the environment

• Limit of these discharges should be within technical specification of the facility

• Violation of the technical specification is termed as failure of the facility

• Discharges above the limits stipulated by the Regulatory Authority cause exposures to the environment and members of the public

• Exposure to radiation is measured in terms of dose

• Annual dose to the members of the public around a nuclear power plant (beyond 1.6 km from the foot of the stack, exclusion zone) is 1 mSv

Importance of Radiological Risk Computation (contd.):

• It is required to determine the maximum potential risk for the discharge of gaseous and liquid effluents from the various Nuclear Power Plants in India

• Based on the graded risk based approach the liquid effluent sources can be classified into various categories and monitoring and treatment schemes can be designed for each category for their discharge into the environment

• The ICRP risk factor 7.3 x 10-5per mSv for total lifetime is used for determining the ranges of risk per annum

• It is required to ensure that members of the public are only exposed to levels of “Risk” which are considered acceptable from routine discharges of radionuclide.

• Various studies indicate that there is a linear relationship between dose and risk from cancer at low doses

• However, it is assumed that there is no threshold below which a radiation dose does not result in an additional risk of cancer

• Mortality Risk, generally expressed as probability of death of number of persons in a population of 100000 due to the radiation exposure

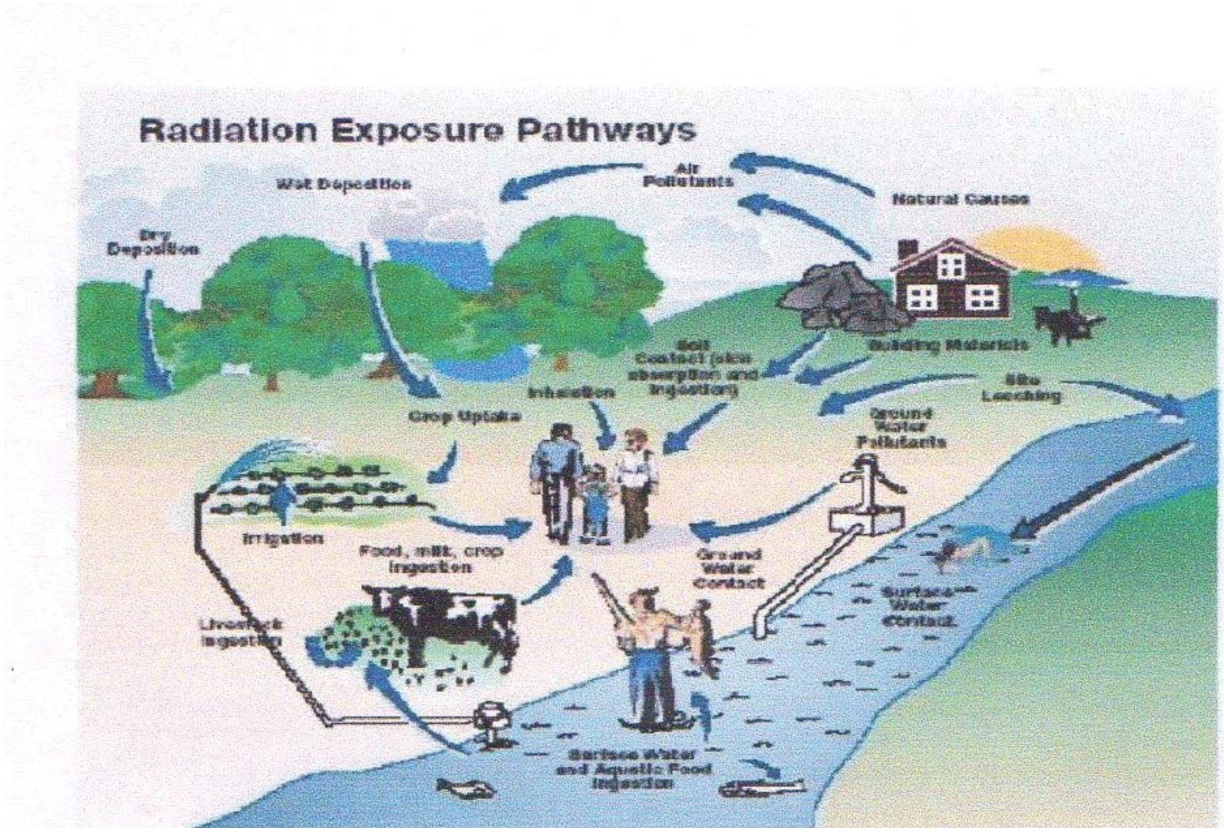

Figure I. Radiation Exposure Pathways

We are exposed to ionizing radiation by many pathways. The main ones for most people are exposure to cosmic radiation. exposure to and breathing indoor and outdoor air, exposure to radiation from rocks and salls, and drinking and eating foods with naturally occurring radioactive Clements.

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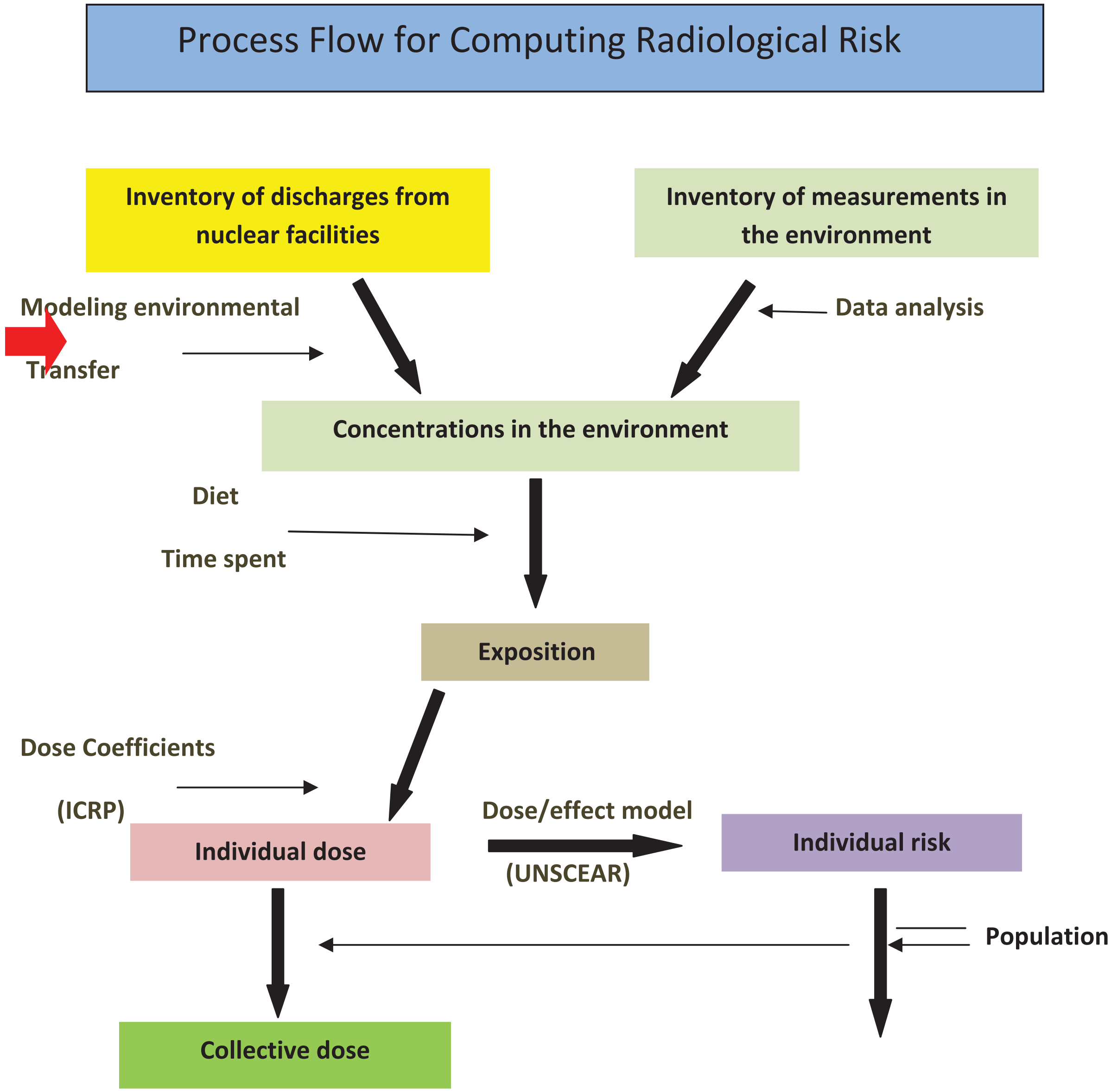

Figure II. Process Flow for Computing Radiological Risk

V. RISK COMPUTATION

(Present Methodology)

- **Risk (/yr) due to each individual radionuclide is computed using**

  Activity (Bq/y) = Conc.(Bq/ml) * Intake (g/y) * CF * %PI

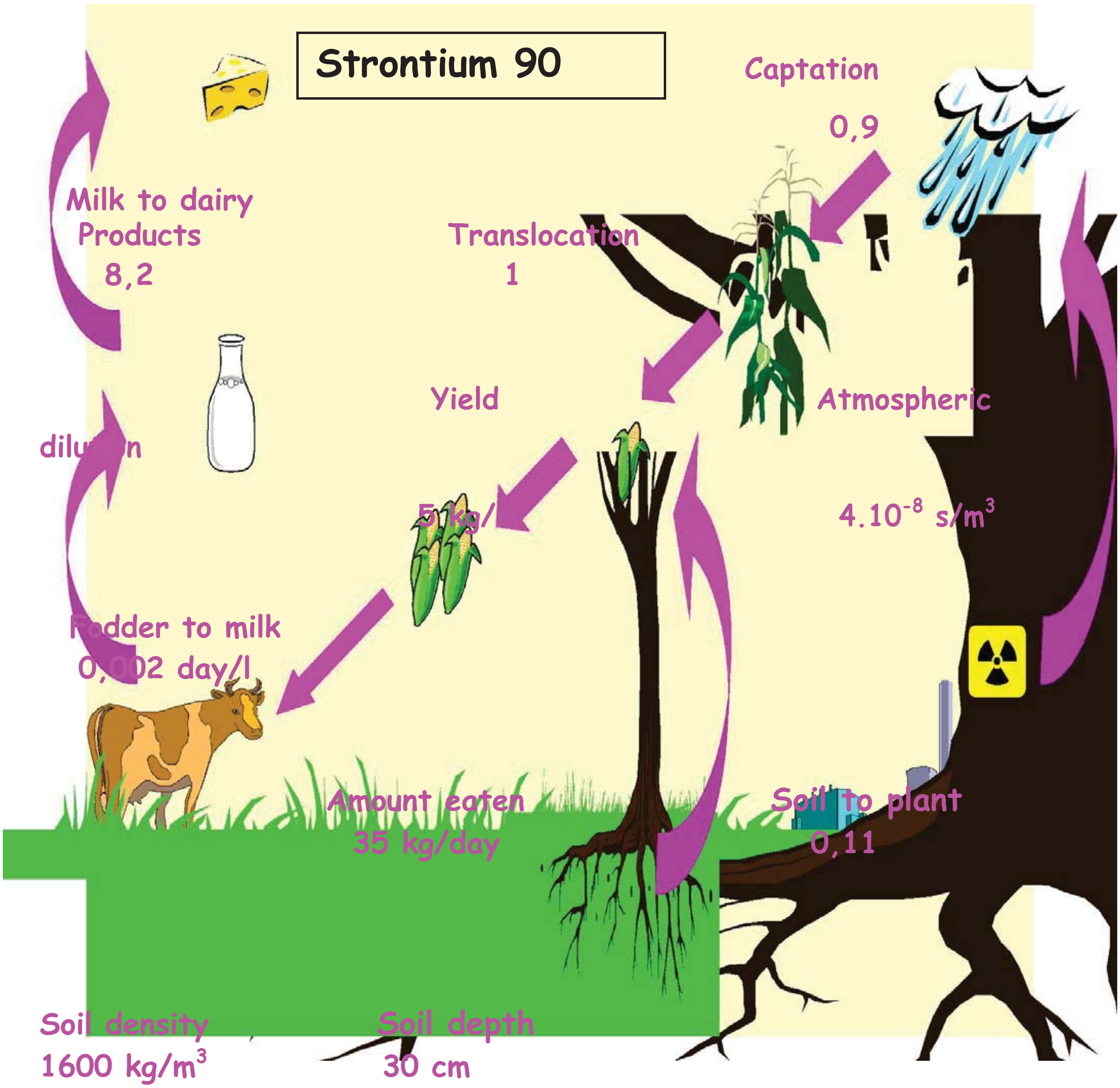

Figure III. Hazard quotient index Strontium 90.

Risk (/y) = Activity(Bq/y) * Risk Factor (/Bq)

• Total Risk (/y) = $\sum$ Risk, k signifies radionuclide

• Risk Factors of each radionuclide used to compute the cancer risk coefficients for environmental exposure to radionuclide are used according to ICRP-2000 recommendations (FGR-13 database)

• Note that: Risk factor (cancer slope factor) is used for radionuclide

• Hazard quotient index (HQI) is used for non-radioactive materials

VI. RISK ANALYSIS EXAMPLE

• Pathway : Ingestion of food (Wheat, Rice, Pulses etc)

• Formulation of the specified model

– Risk $(/\text{Year})_{p,f,r} = I_f \, A_{f,r} G$

Where I_f : Intake of food = [min, avg, max] in kg/year

$A_{f,r}$: Activity of radionuclide r contained in that food in Bq/kg = [min, avg, max]

G: Either Mortality Risk Factor (Risk/Bq or Risk/Sv)

or Morbidity Risk Factor [quoted from FGR-13]

• Total Risk due to all pathways for a particular radionucleide,

say $^{137}Cs = R_r = \sum_{fp} R(/\text{Year})_{p,f,r.}$

VII. EXPOSURES FROM AIR POLLUTION

• Plume submersion = Air conc. (Bq.s/m3) x dcf (Sv/Bq.s/m3)

• Inhalation = Air conc. (Bq.s/m3) x Brate (m3/s) x dcf (Sv/Bq)

• Deposited activity on the ground = Air conc. (Bq.s/m3) x deposition velocity (m /s) x dcf (Sv/Bq.s/m2)

• In all of the above expression, ‘dcf’ stands for dose conversion factor

• Air concentration will be obtained from modeling and this model in its simplistic form is called as Gaussian Plume Model

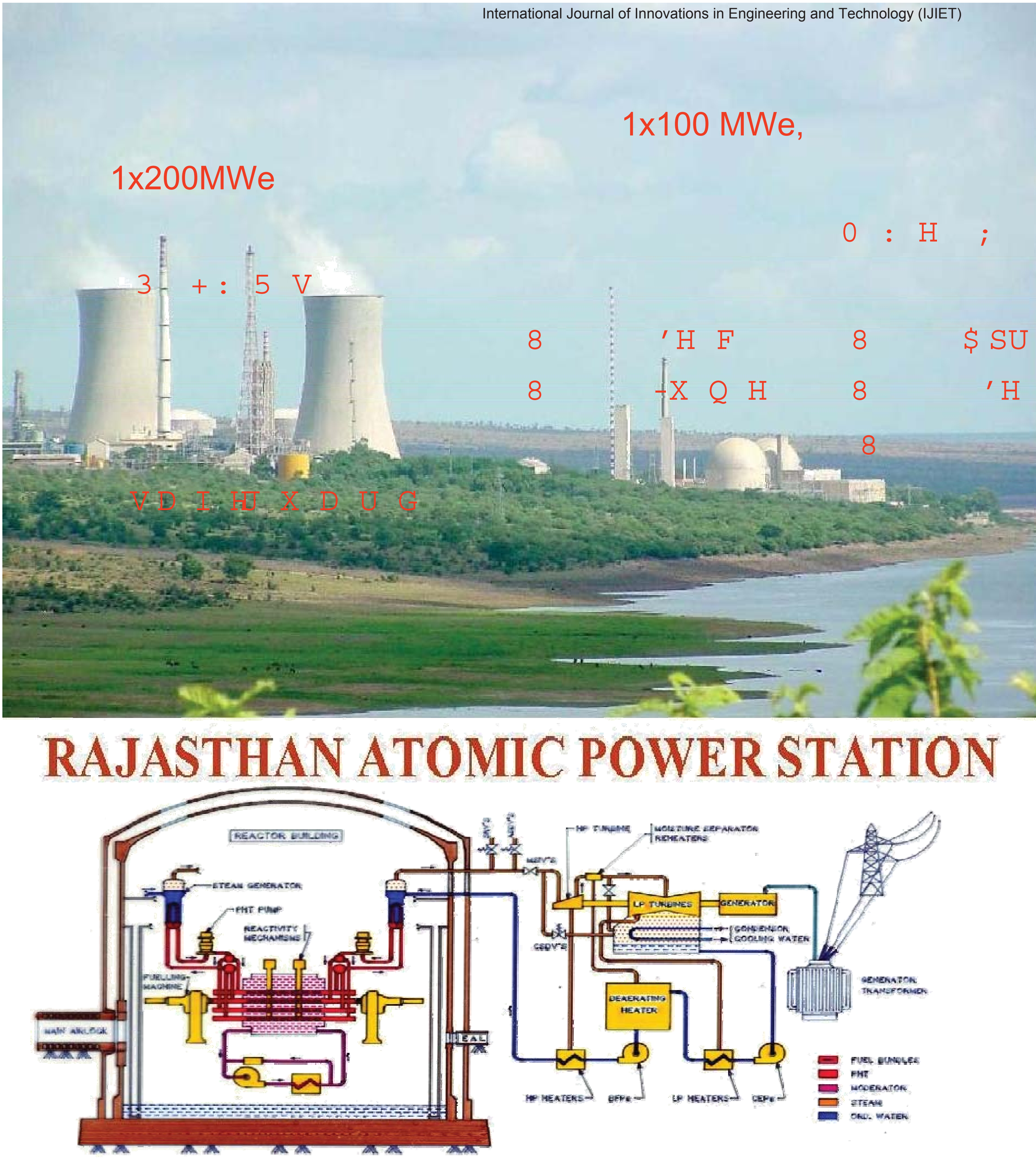

Figure IV. Rajasthan Atomic Power StationU#1 U#2 under IAEA safeguard

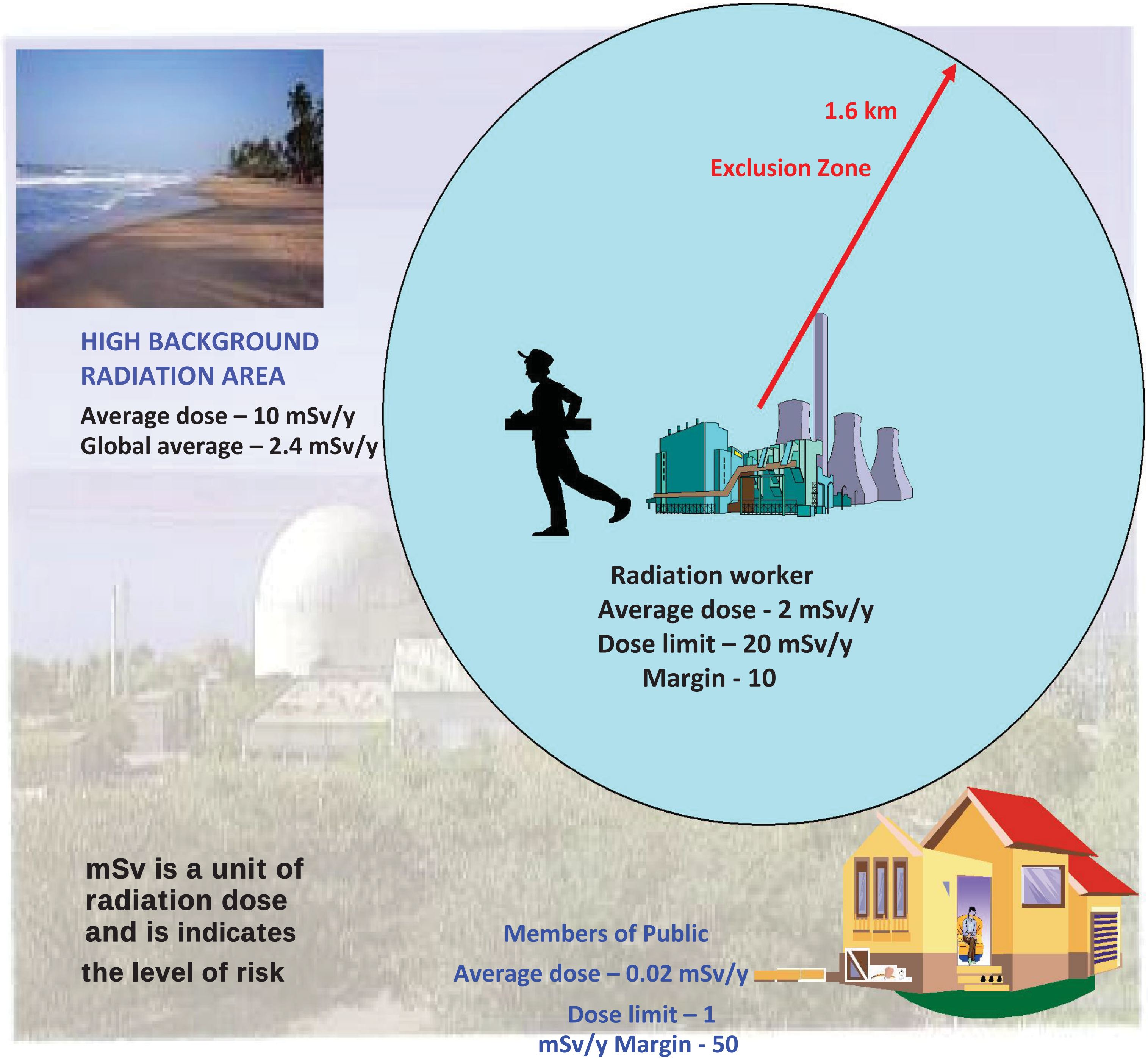

Figure V. HIGH BACKGROUND RADIATION AREA

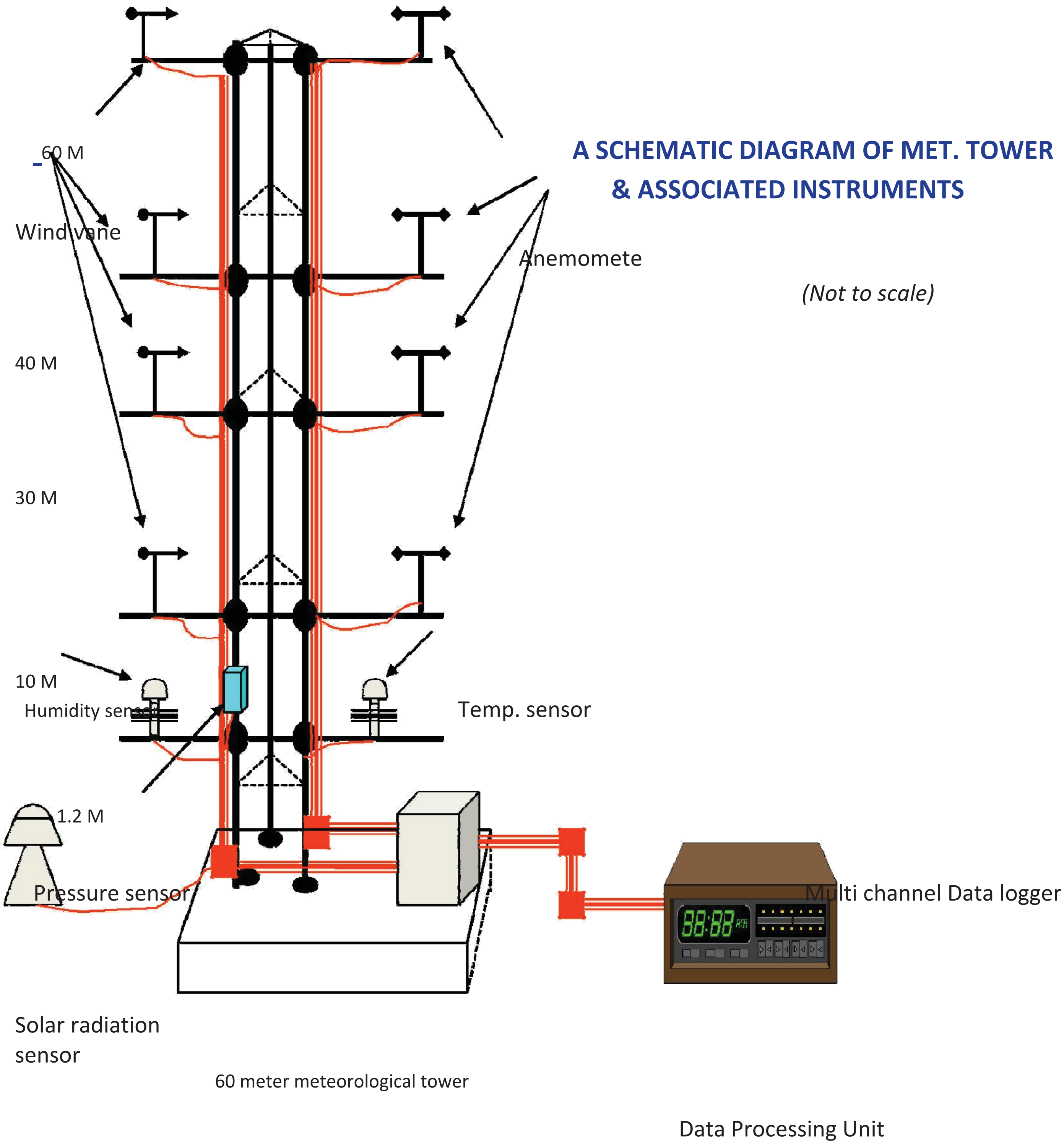

Figure VI. A schematic diagram of meteorological tower & associated instruments

VIII. ATMOSPHERIC DISPERSION MODELS

- Standard Gaussian Plume Model
- Gaussian Puff Model – Concentration distribution in an individual puff is Gaussian in all three dimensions
- RIMPUFF (Riso Mesoscale PUFF Model) – Lagrangian mesoscale atmospheric dispersion puff model designed for computing the concentration and doses from the dispersion of airborne materials
- CFD based Model

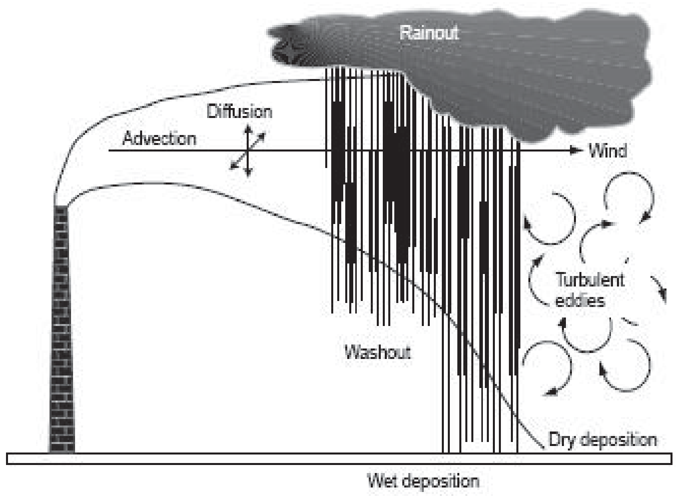

Figure VII. Dispersion of air Material

GAUSSIAN PLUME MODEL

• Dispersion over flat, non-complex terrain
• Short range transport (about 100m to 20Km downwind)
• Steady state meteorological conditions
• No elevated temperature inversions
• Quasi-continuous releases
• Non- depositing materials such as noble gases

IX. GAUSSIAN PLUME MODEL

• Gaussian plume model is the most widely used method of estimating downwind concentration of airborne material released to the atmosphere

• When the release occurs from an elevated source the plume will disperse down to ground level from where it is effectively reflected back into the atmosphere, increasing the ground level concentration by a factor of 2

• The plume can be reflected from the top of the atmosphere mixing layer and when this occurs just above the level of the stack height, the plume concentration at ground level could be increased by a further factor of 2

• The probability of occurrence of this latter condition is low and the effect of mixing layer height on the average annual plume concentration within a few km of the release point can therefore be neglected.

X. CONCLUSION

Overall, properly functioning nuclear power plants pose little risk to the health of people, and to the environment, and can be considered a relatively cost-effective means of energy (Chatzimouratidis & Pilavachi, 2008). To reduce the risk that can arise from nuclear disasters, such as Chernobyl (1986), and more recently Fukushima (2011), increased precautions need to be followed. These precautions include increased safety measures, more comprehensive emergency planning, and safer power plant sites (Kopytko & Perkins, 2011). With advancing technology, and knowledge about ways to further protect individuals and the environment from nuclear power disasters, nuclear power plants have the potential to provide a more environmentally friendly source of energy, thereby contributing to environmental risk reduction.

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