INDIAN PRACTICE OF SITE EVALUATION FOR NUCLEAR FACILITIES

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INTRODUCTION

Site of a nuclear facility (NF) is the geographical location under the management of an organization authorized to construct, operate and decommission the facility, or to perform specific activity involving radiological and nuclear safety. Robust siting of an NF, i.e. proper selection of the site and its adequate evaluation is necessary so that the plant design ensures that the structures, systems and components (SSC) important to safety remain operational to accomplish the nuclear and radiation safety objective.

Atomic Energy Regulatory Board (AERB), Indian national regulatory authority for civilian nuclear facilitates (NF), has published a safety code AERB/NF/SC/S (Rev.1) [AERB, 2014], which specifies the requirements and criteria for different stages of siting. The code along with 12 companion Safety Guides cover both Greenfield site and site with existing operating nuclear facilities. In AERB (2014), extensive references are made to IAEA-NS-R-3.

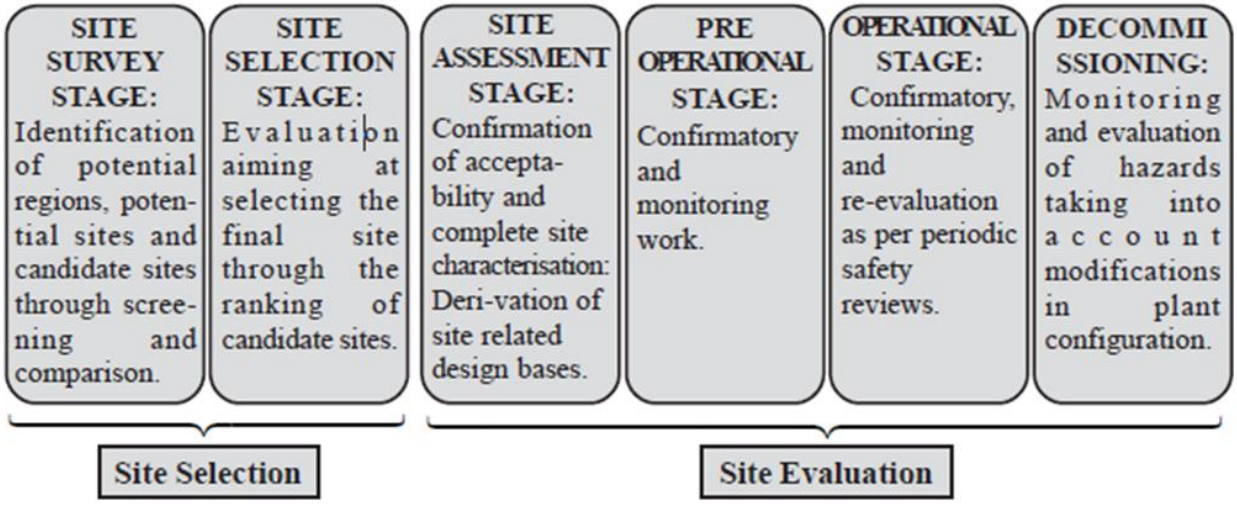

Figure 1, Indian siting process for nuclear facilities [AERB, 2014]

Siting process, in accordance with AERB (2014) consists of two sub processes - site selection and site evaluation; activities of which together are divided in to total six stages, Fig.1[AERB, 2014]. While, IAEA-SSG-35 describes these two sub processes together in have five stages [IAEA, 2014]. In both the documents first five stages are same; and site selection is covered in first two stages – site survey stage and site selection stage. Second to fifth stage, i.e., site selection, site assessment, pre operational, and operational stage are designated for site evaluation in IAEA document. Third to sixth stage of AERB document deal with site evaluation; sixth stage being decommissioning stage.

The Nuclear facilities other than nuclear power plant (NPP) covered under the scope of AERB/NF/SC/S (Rev.1) [AERB, 2014] are research reactors, as well as nuclear fuel cycle facilities, including but not limited to enrichment plants, processing plants, independent spent fuel storage facilities, independent waste management plants and vitrified waste storage facilities and reprocessing plants. The facilities for short term near surface storage of solid/solidified radioactive waste as well as near surface disposal facilities are within the scope of this code.

The objective of this paper is to outline the Indian siting process for nuclear facilities (NF). The paper provides an overview and considerations of Indian practice of site selection and site evaluation for NF.

SITING SAFETY CRITERIA

The safety objective of design, construction and operation of nuclear facilities is to ensure protection of the plant personnel, public and the environment from the harmful effects of ionizing radiation, both during normal operation of the facility as well as during and following accident scenarios. For a green field site, all proposed facilities are considered in assessing the radiological dose. In case of an existing site, all collocated existing facilities and future facilities are considered in the assessment.

The safety objective is accomplished by implementing the safety measures adopting the defense-in-depth (DID) concept. The defense-in-depth as practiced presently in India is similar to that of IAEA-INSAG-10 [IAEA, 1996]. There is a proposal to modify it, which would account Design Extension Condition A (DEC-A) and Design Extension Condition B (DEC- B) separately and explicitly, Table 1. The proposed DID strategy is in line with the INSAG-10 up to level three (design basis level). Level 4 is divided in to two parts 4a and 4b which will address DEC-A and DEC-B respectively (AERB, 2015b; IAEA, 2016a). Level 5 is in line with IAEA-INSAG-10. Then the concept of site evaluation activities at different stages [Fig.1 of reference IAEA (2014)] is superimposed.

The safe design, operation procedures and mitigation measure like emergency management plan are three types of devices adopted in DID strategy. Site evaluation provides significant input for these three types of devices. Four co-centric external zones are established in the surrounding area of a site for effective implementation of emergency management plan, Fig.2. First zone is exclusion zone (EZ), within which the site is located. EZ, enclosed by a defined fence, is under the control of plant management. AERB (2014) specifies the prescribed and acceptable radiation dose limits on EZ fence and beyond during normal operation and accident situation respectively.

A site in India is deemed unsuitable for locating an NF of a given type and size if its evaluation indicates that the deficiencies identified in meeting the requirements and criteria of AERB (2014), cannot be compensated by means of engineering provisions (i.e. design features), measures for site protection and/or administrative procedures

SITE SELECTION PROCESS

Site selection in India is a four step process, which constitutes first two stages of Indian siting process, fig.1. All activities of site selection are conducted by the "Standing Site Selection Committee" (SSSC) constituted by the Central Government of India with experts from all related disciplines selected from different stake holding organizations.. The Secretariat of SSC is the largest utility company owning NPPs of India. Fig. 3 summarizes the Indian site selection process.

First activity of site survey stage is the first step, in which the desired regions or regions of interest (ROI) are identified considering the Central Government's policy of development, availability of resources, etc. In the second step, State Government of ROI identifies the potential sites satisfying the techno-economic guidelines provided by SSSC. In the third step, potential sites are screened using safety and non-safety related exclusionary criteria. The approach of Screening Distance Value (SDV) is adopted for some exclusion criteria, Table 2. For some other external events and /issues, the exclusionary criteria are defined in terms of hazard of exclusionary nature, Table 3. Information available from reliable sources along with the results of preliminary geotechnical investigation is used in the screening evaluation.

Table 1: Defense in depth and site evaluation

DID Level	Operation states	Objective	Essential means	Site safety measures
I	Normal operation	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation	Site characterization, derivation of design basis of external events, RIA & EIA, conservative engineering. of site protection & stable foundation, monitoring of site protection & external hazards significant to safety and environment surveillance
II	Transient states	Control of abnormal operation and detection of failures	Control, limiting and protection system & other surveillance features	
III	Design basis accident (DBA)	Control of accidents within the design basis	Safety Systems / Engineered safety features and accident procedures	
IV	Design extension condition A (DEC-A)	Control of DEC-A conditions including prevention of accident progression (to core melt condition).	Additional safety Systems / Features and accident procedures	Monitoring of important external natural and human induced hazard, performance motoring of SSCs significant to safety against external hazards & design margin with respect to cliff edge effect, and environment surveillance.
	Design extension condition B (DEC-B), Severe Accidents (SA)	Control of DEC-B condition with core melt, to limit off-site releases and mitigation of the consequences of SA	Complementary safety features to mitigate core melt, management of accidents with core melt (severe accidents)	
V	Severe accident with impairment of containment	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response and intervention levels	Site characterization for RIA, re-calculation for RIA with prevailing data for first few days and then environment surveillance

A potential site is generally rejected if it does not satisfy a screening criterion though AERB/(2014) has provision of considering it acceptable provided there is suitable solution to withstand safely the hazardous effects of the evet associated with the site. All candidate sites are acceptable for detailed evaluation to locate an NF. Fourth step is to deal with ranking analysis of candidate sites in order to list them in order of preference. In India, the demand of site is so high that necessity of detailed quantitative ranking analysis of

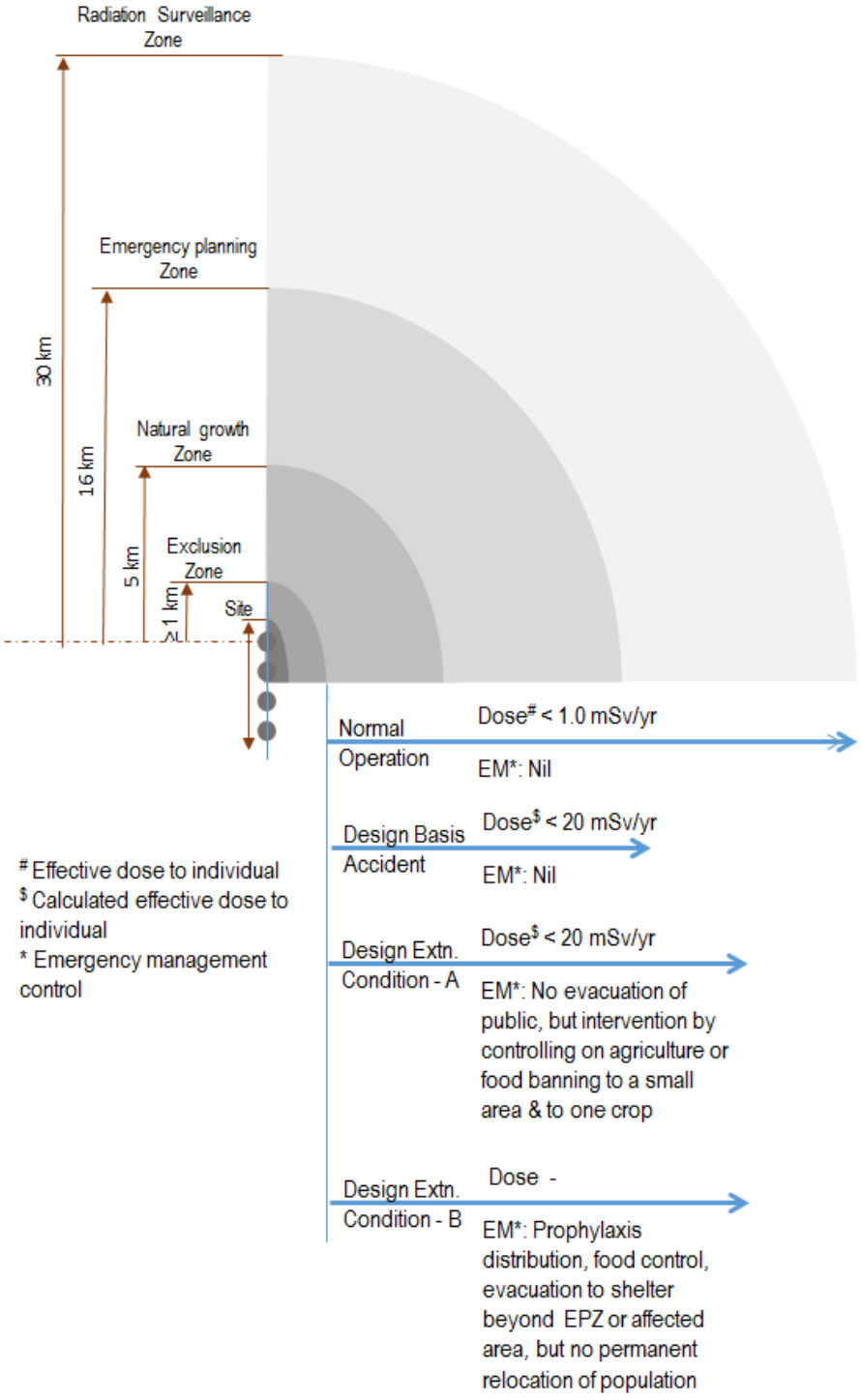

Figure 2: Siting Safety Criteria

Note: These safety criteria are for emergency preparedness, which design has to meet.

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Table 2: Exclusion criteria - screening distance value (SDV) of external events (AERB, 2014)

Events / Issue	Classification	Screening Distance value
Natural		
Distance of site (center of reactor building) from nearest capable fault.	Safety related	5.0 Km.
Bio sensitive region and reserve forest	Safety related	Exclusion zone.
Sand dune	Safety related	Location potential to dune should be avoided.
Human Induced		
Distance from airports including military air fields	Safety related	16.0 km
Military installations storing ammunitions etc.	Safety related	16.0 km
Facilities involving storing handling inflammable, toxic, corrosive or explosive material and mining activities.	Safety related	16.0 km
Places of architectural/ historical monuments, pilgrimage, tourists interest	Safety related	5.0 km

Table 3: Exclusion criteria – other external events (AERB, 2014, IAEA, 2014)

Events / Issue	Potential Hazard Attributed Exclusionary	Classification
Earthquake	Surface rupture	Safety related
Geotechnical	Slope instability (massive land slide) Massive liquefaction Massive Karst	Safety related
Volcanism	Lava flow Pyroclastic flow Ground deformation Massive Lahars	Safety related
	Feasibility of implementation of emergency procedure	Safety related
Water	Availability of cooling water	Non safety related
Thermal and chemical pollution	Non radiological environmental impact	Non safety related

candidate site is yet to be felt. However, qualitative ranking analysis is conducted in some cases considering the attributes like topography, infrastructure available for construction power and water supply, power evacuation, transportation of over dimension consignments (ODC), etc. At the end of this final step, SSSC recommends a list of acceptable sites ranked in order of preference. Finally the Central Government selects site/sites from the recommended list

SITE EVALUATION IN SITE ASSESSMENT STAGE

This stage lies in the period between decisions taken to build an NF at a site after its selection and beginning of major design activities. Majority of the site evaluation work is taken up in this stage. Acceptability of site is also confirmed with successful completion of this stage. Entire site evaluation work leading to confirmation of

the site acceptability is of two categories - site safety aspect and environmental aspect. AERB (2014) further sub divide the first one in to three more aspects - effect of site characteristics on nuclear facilities; effect of nuclear facilities on public and environment; and considerations for emergency planning

Effect of Site Characteristics on Nuclear Facilities

First aspect of site evaluation involves with characterization of site and derivation of design basis for credible external events. The design basis of an event is described in terms of suitable parameters that could be used in design of SSC. The credible external events are identified by screening. AERB (2014) specifies detailed and advance investigation and approach for site characterization. The code also requires employing state-of-the-art method for hazard analysis to derive the site specific design basis hazard parameters using region and site specific prehistorical, historical and instrumental data. Deterministic and probabilistic approaches or combination of both is acceptable for hazard analysis. Generally deterministic approach is used. Irrespective of methodology used, uncertainties involved due to data inadequacy and limitation of evaluation procedure are taken into account [e.g., Roshan et al, 2016. If probabilistic approach is adopted, physical upper and lower bounds of the input parameters, as applicable, are taken into account and design bases are derived with appropriate confidence levels and for mean annual frequency Table 4 contains the typical values of mean annual frequency of major natural events for nuclear facilities.

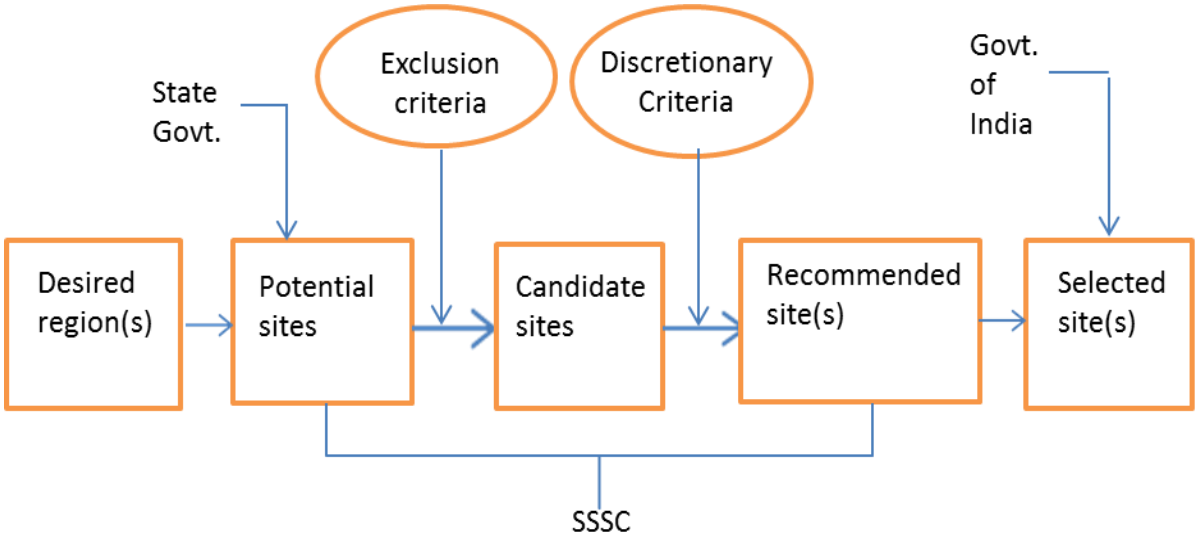

Figure 3: Indian Siting Process for Nuclear Facilities

Screening of External Events

Deterministic approach is generally adopted for screening of natural events and human induced (both existing and proposed) activities for identifying credible ones. AERB (2014) specifies that all natural events which have a probability of occurrence of more than 10^{-7} per year shall be considered. Available instrumental, historical and prehistorical data on the occurrences and severity of these events in the region are considered in the screening exercise. All screened in external events are further evaluated for site characterization and derivation of design basis.

External Natural Events

Seismic and Geological Considerations

In India, NPP and other Category-I facilities (see table 4) are not sited in seismic zone V as defined in BIS 1893 [BIS, 2002]. Potential hazards of permanent ground displacement such as surface faulting or folding, fault creep; subsidence or collapse; and vibratory ground motion caused by seismic evet are evaluated. To preclude the eventuality of rejection of a site due to surface faulting, no site of these facilities located within a shortest distance of 5 Km from a capable fault is acceptable. As a practice any geological fault, which cannot be established as non-active, is taken as active.

AERB/SG/S-11 [AERB, 1990] provides guidance of seismic studies and hazard analysis. Seismically induced hazards are assessed by evaluating seismotectonic model of the region having 300 Km radius from the site, precisely center of the reactor or the plant. The model takes into consideration site-specific conditions; seismically active structures and active faults, and other features that can substantially affect the severity of earthquake in the region; the geological and seismotectonic conditions in the region and geotechnical aspects of the site area. Information on all pre-historical, historical and instrumentally recorded earthquakes in the region is super imposed in the model. Potential reservoir-triggered seismicity on account of water control structure existing or sanctioned to be built in the region is also considered.

Ground motion parameters of two level earthquakes S1 and S2, termed as operating basis earthquake (OBE) and safe shutdown earthquake (SSE) respectively, are derived for engineering of NPP. Details of the method for fixing the S1 level motion are left to the applicant. S2 earthquake is design basis earthquake. AERB (2014) accepts only site specific design basis ground motion (DBGM) parameters. Both deterministic seismic hazard analysis (DSHA) and probabilistic seismic hazard analysis (PSHA) are acceptable. The criteria for deriving DBGM parameters for different categories of NFs are given in Table-3. In practice, DSHA is generally used. Uncertainties are accounted irrespective of methodology adopted.

The DBGM parameters determined at base rock level are modified accounting local site condition to determine these at free field conditions. For category-I facilities site-specific DBGM parameters is not taken less conservative than corresponding ground motion level specified for industrial facilities of highest safety or hazard category of BIS 1893 [BIS, 2002]. The peak ground acceleration (PGA) not less than 0.10g is considered for Category I facility...

Meteorological Events

AERB (2014) stipulates for evaluating an NPP site for both extreme meteorological phenomena and rare meteorological events. The meteorological phenomena considered are wind, precipitation, storm surge, tropical cyclone, air temperature (dry bulb and wet bulb), cooling water temperature, and humidity. Data on frequency and parameters indicating severity of hazards are available for these phenomena and are used in deriving the design basis. AERB/NF/SG/S-3 [AERB, 2008b] provides guidance to evaluate extreme values of meteorological parameters including that of wind. Table 4 specifies the annual frequency of exceedance for derivation of design basis wind speed for different category of nuclear facilities if probabilistic methodology is used. AERB (2014) accepts its derivation from IS 875 Part-3 BIS, 1997] if adequate and reliable site specific data is not available.

However the information on severity is hardly available for rare meteorological events. Example of such events that need to be considered for site evaluation of Indian NFs are - lightning, tornado, waterspouts, dust

and sand storms, hail storm, cloud burst, and any other phenomena specific to site, etc. Design basis of the rare events are derived deterministically with available information.

Flood

Indian sites are either in-land or coastal site. As per AERB (2014), the initiating external event for inland flooding are storms, precipitation, wind induced waves, seiches, failure of water storage/carrying structures, melting of snow, etc. AERB/SG/6A [AERB, 1998b] contains guidance of determining site specific design basis flood level (DBFL) for inland site. The regional meteorological and hydrological database is established using instrumental and historical data on heavy rain/cloud burst/flash flood in the region. In addition, impact of flood generation potential of an upstream reservoir; possibility of sudden release of water from upstream water control system and accidental release of water due to upstream dam failure and rise in water level in downstream dam are considered in determining the DBFL. The site is also evaluated for flooding from local intense precipitation for designing the site drainage system.

River morphology study is necessary especially for a site on riverbank in deltaic region with deep alluvial soil deposit. The potential of river course change should be studied. .

High tides, cyclones/storm surge, wind induced waves, tsunami generated waves, and etc. initiates flood at coastal sites. Coastal sites are evaluated for flooding following the provisions of AERB/SG/S-6B [AERB, 2002]. Data related to both meteorological and hydrological data of the site and surrounding region are examined to derive site specific DBFL.

In case of site on estuary, rise in river water level due to storm surge and its impact on site are evaluated. An appropriate combination of both the effect of cyclone and flood in the river due to same storm as well as upstream dam break are considered for a site on estuary. Impact due to probable maximum flood (PMF) or dam break occurring at upstream locations is also considered.

Indian coast is vulnerable to the hazards of tsunami. AERB (20014) specifies design basis for tsunami are derived for both for potential drawdown and run up including hydrodynamic forces.

The acceptable annual frequency of exceedance are given in Table 4 for derivation of DBFL for different category of nuclear facilities if the hazard analysis is conducted adopting probabilistic methods

Geological/Geotechnical Considerations

The purpose of site evaluation from geological/geotechnical consideration is two folds: assessing the suitability of site against ground failure, and safe design of foundation systems. The purpose of geotechnical and geological investigations is to obtain information or basic data needed for safe design of NPP foundation for all plant states. The investigations are carried out to obtain information on geological features (stratigraphic, structural, and seismic), description of extent and nature of subsurface materials, soil and rock characterization (properties), and ground water (regime, location, extent, chemical properties, etc.). In India, the investigation is conducted in three stages. AERB/NF/SG/CSE-4 [AERB, 2008a] provides detailed guidelines on conducting geotechnical investigations for and assessment of ground failure, and Safe design of foundation systems.

1) Preliminary investigations during site survey or selection stage:

2) Detailed investigations in site assessment stage:

3) Confirmatory investigations after excavation of foundation pits.

The site and its vicinity are evaluated for the following geotechnical hazards depending on whether the site is on soil deposit or on rocky strata and relevant feature/potential exist [AERB, 2008a].

i. *Slope Instability:* The site and its vicinity are evaluated for slope instability (such as land and rock slides and land erosion) which could affect the safety of the NPP. The hazard is evaluated using site specific parameters such as DBGM and/or due to heavy rain, etc.

ii. *Surface Collapse, Subsidence or Uplift:* Geological and other appropriate information of the region are examined for existence of natural features like caverns, karstic formations and subsidence and human induced features/activities like mines, water extraction and gas/oil wells. If potential for surface collapse, subsidence or uplift exists in the site vicinity, corresponding hazard is evaluated.

iii. *Soil Liquefaction:* The potential for soil liquefaction at the site is evaluated using DBGM parameters.

Other external natural events:

i. A site in regions prone to or having migratory *sand dunes* is generally avoided unless there is engineering solution.

ii India does not have history of *volcanic eruption* excepting the region of Andaman and Nicobar isles. AERB (2014) stipulates requirements of addressing volcanism during site evaluation.

iii Potential for *shore line instability* due to erosion or sedimentation are investigated for coastal site. Similarly, potential of riverbank erosion or change of river course is investigated in case of inland sites flood pain on riverbanks. Intake and out fall structures, and shore protection measures that could alter the erosion/deposition regime are taken up together as part of plant design.

iv Loss of Ultimate Heat Sink occurs due to failure of downstream dam, blockage/diversion of river, excessive growth of marine organism, ship collision and consequent damage to intake structure, oil spill, draw-down due to tsunami, etc. are investigated during this stage of site evaluation.

Human-Induced External Events

An NF site is evaluated with respect to external human induced external events of accidental as well as malevolent origin. This paper deals with events of the first kind only. Potential hazards due to aircraft crash, chemical explosion/toxic gas release in industrial facilities, external fire, explosions and asphyxiant/corrosive/toxic gas releases, oil slick, blasting operations, mining, drilling and water extraction are investigated. The site is evaluated not only for the present human induced activities, but also for future proposals as well as expected growth of any such activities. External events that satisfy the screening distance value given in Tables 2 and 3 are not further investigated. In case of an NPP site not satisfying the SDV with respect to a human induced event, a detailed investigation is permissible to find a feasible solution. AERB/NPP/SG-S-7 [AERB, 2015a] provides guidelines on evaluation of design basis for external human induced events for NPP.

Impact of operating co-located industrial / radiation/ nuclear facilities in a site on new facility proposed and vice versa is one of the major considerations in evaluating a non-greenfield site. Release of radioactive materials from adjacent operating nuclear facilities and from vehicles transporting radioactive material on the proposed facilities is evaluated considering possible scenarios.

Other Events:

Site specific natural and human induced events, other than those addressed in preceding sections, and that could cause loss of functions of SSC important to safety, or could cause hindrance in implementing emergency planning are investigated in this stage of site evaluation. Examples of such events are blockage/diversion of a river, depletion of a reservoir, electromagnetic interferences, eddy current in ground, etc. Installations that may give rise to missiles of any type that could affect safety of nuclear facility are also investigated.

Changes of Hazard with Time

AERB (2014) outlines the requirement for site evaluation to account for the changes of hazards with time. The code postulates that the global climatic change over a period of time is a major source for change of the meteorological and hydrological hazard with time. AERB (2014) stipulates to provide additional safety margin to account for the future changes in hazards in the design of NF. Cliff edge effect on the safety of nuclear facility is evaluated. Example of other causes of change of hazards with time are forest fire, changes in the terrain, urbanization, construction of dams and irrigation channels, sedimentation/erosion, land subsidence, permanent uplift/subsidence of the earth's surface due to an earthquake, etc. The design parameters established at the site assessment stage are reviewed using current data and evidence during periodic safety review [AERB, 2000b].

Effect of Nuclear Facilities on Public and Environment

In India, the effect of a nuclear facility on public and environment of surrounding area of the site is assessed through two separate assessment exercises:

a. Radiological impact assessment (RIA) study, and
b. Environmental (non-radiological) impact assessment (EIA) study.

The first one concerns with the assessment of radiological dose at the EZ boundary and beyond due to dispersion of radiological substances released during normal and accident situation The second assessment work deals with non-radiological impact; for example, dust and noise during construction, temperatures at the outfall discharge point, chemical effluents discharged in water bodies and atmosphere.

AERB (2014) provides the requirements and criteria for site evaluation related to RIA. The site evaluation for these activities is related to meteorological characterization of the site for dispersion through air [AERB, 2008c]; hydrological characterization for surface dispersion [AERB, 1998]; hydrogeological characterization for subsurface dispersion [AERB, 200a]. In addition to normal meteorological data, information on effects of bowls and uneven topography is collected if the site is on river valley. For coastal site, related information is required for examining the effects of sea breeze and land breeze phenomena and formation of coastal boundary. Additional data is collected for special investigation to evaluate the influence of any unusual site conditions, such as thermal interference from complex natural topography, cooling towers.

The radiation dose to the public is assessed using the data on land and water use, cattle and livestock, dairy production, agricultural produce, fish catches and other related features. AERB/SG/S-5 [AERB 2005a] provides guidance on methodologies for environmental radiation dose assessment.

The program for acquisition of site specific data starts before commencement of construction and continues till decommissioning. Preliminary RIA report is prepared on the basis of data imported from similar site at the time of site assessment stage. Final work is completed before major commissioning activities.

Considerations for Emergency Planning

Onsite emergency covers site and EZ and is concern of the plant management. The offsite emergency planning deals with NGZ, EPZ and RSZ and is under the principal responsibility of local government administration and disaster management agencies. AERB (20014) specifies the requirements of safety measures for offsite emergency. The siting safety criteria for offsite zones summarized in Fig.2 are for emergency preparedness that the design has to meet. In a multi-unit/multi-facility site, emergencies arising out of common cause failures due to external events are considered. AERB (2005b) provides guidance on site considerations for developing emergency planning of an NPP.

Detailed information and data on population within a radius of 30 Km is collected to formulate off site emergency plan. Information on population distribution (existing and projected), including permanent residents, transient and seasonal population are collected and updated periodically during the life time of the nuclear plant. The data are presented in terms of direction and distance from the plant. Data on land and water use of the region is important input.

Characteristics of the site and its surrounding areas are investigated and feasibility of effective implementation of emergency management plan in the event of onsite and offsite emergency is evaluated in the site assessment stage. The characteristics related to implementation of emergency plans such as evacuation routes, shelters, transportation, communication facilities and medical facilities are also investigated.

SITE EVALUATION IN PRE OPERATIONAL STAGE

The pre-operational stage of site evaluation spreads over the site construction period. Site evaluation activities during this stage cover confirmatory investigations, monitoring ambient radiation, and emergency management planning.

Investigations at this stage are required to confirm the outcome of some of the investigations carried out during site assessment stage. The confirmatory geotechnical investigation that is carried out after ground breaking or excavation of foundation pit/trench is an example of such investigations.

Hazards and conditions that are significant to safety of the NF are monitored and re-assessed throughout the life time of the plant. Micro seismic network is recommended to be installed at the beginning of this stage. Comprehensive periodic monitoring scheme is implemented for environmental surveillance program covering radiation safety zone (RSZ). The monitoring scheme commences at least three years before commissioning of the first facility and continued till decommissioning of last facility. Establishment of base line data and collection of information on ambient radiation level of the region is prerequisite. Before commissioning of the nuclear facility, the ambient radioactivity of the atmosphere, hydrosphere, lithosphere and biota in the RSZ are assessed for.

Offsite emergency management planning for Category-I facilities is finalized during this stage. Any additional features required for this purpose are implemented prior to commissioning of the facility [AERB, 2014].

SITE EVALUATION IN OPERATIONAL STAGE

This stage covers confirmatory and monitoring type activities. India has the practice of periodic safety review (PSR) of operating plant at a regular interval [AERB, 2007], which is generally once in every ten year. Hazards significant to safety are re-evaluated if any new regulation comes up, or new information emerges. In addition re-evaluation of natural hazards is undertaken in light of any major event in the site region to confirm if there is breach of design basis at any NPP site.

Table 4: Summary the grading of for different NFs and corresponding criteria for derivation of design basis for important external natural hazards [AERB, 2014].

Category	General Characteristics (Hazard potential)	Typical Nuclear Facilities	Mean Annual Frequency of Exceedance		
			Earthquake Ground Motion	Flood	Wind
I	Off-site radiological impact	(i) Nuclear power plant (ii) Fuel reprocessing plant (iii) High level waste management plant (iv) Vitrified waste storage facilities (v) Waste tank farm (vi) High power research reactors (vii) Plutonium fuel fabrication plants	SSE: ~1x10-4 OBE (NPP): 1E-2	1E-4	1E-4
II	On-site radiological impact	Fuel conversion (enrichment) plants (ii) Low power research reactors (iii) Mixed oxide fuel fabrication (iv) Spent fuel storage bay (independent) (v) Near surface disposal facilities (vi) Spent fuel dry storage facilities (vii) Intermediate and low level waste treatment facility (viii) Thorium storage facilities (ix) Tailing dams and associated check dams	4E-4	1E-3	2E-3
III	Radiological impact within plant boundary	Fuel fabrication plant (natural uranium fuel)	Deterministic method following graded approach[1],	1E-2	1E-2
	Radiological impact within plant boundary and off-site chemical hazard or off-site chemical hazard	Reprocessed uranium oxide plant (ii) Thorium plants (iii) Uranium mills (iv) H_2S based heavy water plant	Deterministic method following graded approach[2],	1E-2	1E-2
General	Conventional or industrial building	(i) Zirconium sponge plant (ii) Other plants	Deterministic Method[3]	1E-2	1E-2

[1] DBE with I=1.5 & R' = 0.67 x RI (response reduction factor defined in BIS 1893 for structures without any special provisions for seismic resistance (BIS 1893: Part-4).
[2] MCE with I=1.5 & R' = 0.67 x RI (BIS 1893: Part-4).
[3] DBE with I=1.0 & R' = 0.67 x value of response reduction factor (BIS 1893: Pt-4).

SITE EVALUATION IN DECOMMISSIONING STAGE

India does not have experience of decommissioning of any NPP or other Category-I facility. However a strategy for site evaluation could be worked out. Re-evaluation of design basis for natural hazards could be taken up considering the new configuration of the plant

GRADED APPROACH

AERB (2014) prescribes requirements and criteria of site evaluation so that site plant interaction does not cause the radiological impact beyond the limiting value during normal operation and accident conditions. Applicability of these requirements and criteria depends on the hazard potential of the facilities, which, in turn, is function of type, size and inventory of radiological material of the plant. These requirements are applied to the site evaluation for different nuclear facilities using a graded approach. An NPP has the highest grading hence its site too. AERB (2014) graded the NFs falling under its purview into four categories depending on its potential radiological impact. Table 4 summarizes the grading of different NFs and corresponding criterion for derivation of design basis for important external hazards.

MANAGEMENT SYSTEM AND QUALITY ASSURANCE

A comprehensive quality assurance program is established to enhance the effectiveness of the execution of the investigations, assessments and other engineering activities performed during different stages of the site evaluation of NFs. AERB (20014) and AERB (2005c) provide the requirements and guidance respectively for developing the quality assurance program for NFs. The program is graded in accordance with the importance to safety from the individual activity under consideration.

REGULATORY INTERFACE

AERB has the responsibility to ensure that a civilian NF to be sited, constructed, commissioned, operated and decommissioned without resulting in unacceptable radiological, chemical or industrial risk to site personnel, the public and environment. AERB fulfill its responsibility through the consenting process which consists of appropriate safety review and inspection of the project site and/or plant.

India has five stage consenting process to regulate an NPP project from radiological and nuclear safety considerations: siting, construction, commissioning, operation and decommissioning. The construction consent can be split in to three stages of approval – excavation, first pour of concrete and major equipment erection [AERB, 200b and AERB, 2007]

Consenting process is a continuing assessment covering all the above stages. Separate categories of consents shall be required at each stage of the consenting process. However, AERB has the discretion to combine two or more stages of activity in a single consent depending on the hazard potential of the facility.

The consent of each stage is issued after successful completion of three tire safety review – first tire review by a safety committee, second tire by an advisory committee and finally by the Board, which takes the decision of granting consent.

Though no regulatory control is exercise on site selection activities in India all related technical activities are performed satisfying the related regulatory requirements and in line of regulatory requirements and guidance. For siting consent, collection of siting and environmental data begins well in advance. The site evaluation report (SER) containing site characteristics and design basis for credible external events and their combinations, a report on relevant design basis information (DBI) of the proposed facility are reviewed along with its environmental impact. Two separate reports are prepared for the review of environmental impact - radiological impact assessment (RIA) and environmental (non-radiological) impact assessment (EIA). AERB reviews RIA along with SER and DBI. The EIA document is reviewed by the Ministry of Environment, Forest Climate Change (MoEFCC). The review system by two regulatory authorities is balanced and there is no

overlapping, but there exists enough avenue of sharing information by one from other when necessity arises. Successful review by both is mandatory for acceptance of an NF site.

An important activity in relation to clearance of EIA in India is Public Consultation-process through which the concerns of local affected persons and other stake holders regarding the impact of the project on environment, social and cultural aspect of the surrounding areas are addressed. The Public Consultation comprises of as minimum

i. A public hearing at the site or in its close proximity, and

ii. Obtaining responses in writing from the stake holders.

The local administrative authority generally conducts the public hearing and forwards the proceedings to the concerned regulatory authority.

Site evaluation activities carried out at different stages for NPP are reviewed in different stages of consenting process of the plant. Derivation of design bases parameters of external events is reviewed in different sub stages of construction consent but completed prior to approval for FPC.

SUMMARY

An overview of Indian siting process of nuclear facilities, which consists of two sub processes – site selection and site evaluation, are presented in this paper. India has a well-established non regulated site selection procedure. The selected sites are evaluated in detail from site safety and environmental considerations for regulatory acceptance. The site safety consideration includes site characterization, derivation of design basis of external events and development of emergency management planning. Two main studies are conducted from environmental consideration – radiological impact assessment (RIA) and environmental (non-radiological) impact assessment (EIA). RIA is reviewed by Atomic Energy Regulatory Board (AERB) and EIA by Ministry of Environment, Forest and Climate Change (MoEFCC). Public consultaion is an important component of EIA review. AERB imposes its control over nuclear facility to ensure safety by means of five-stage consenting process – siting, construction, commissioning, operation and decommissioning. Siting consent is granted after successful review of site evaluation report, design basis information report of the plant, RIA report and other associated documents by AERB and EIA report by MoEFCC. The review of reports related to radiological and nuclear safety is done with reference to relevant Safety Codes and companion Safety Guides published by AERB. As per Indian practice similar requirements, criteria and guidance are applicable for site evaluation for NPP and other NFs of different types and sizes with the concept of graded approach.

ACKNOWLEDGEMENT

The author acknowledges and conveys his thanks to Mr. L. R. Bishnoi, Director, SSED, AERB, India for his review of the paper and valuable suggestions. Any opinions, findings and conclusions expressed in this paper are those of the author and do not necessarily reflect the views of AERB or any agency or organization.

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