Assessment of Risk Zone by Nuclear Explosions in Proposed Rooppur Nuclear Power Plant, Bangladesh

By

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1. Abstract

Energy demand is significantly increasing in Bangladesh whereas the production to meet growing demands is very negligible. To meet energy need for economic development and modern lifestyles, the Bangladesh Govt. is going to establish a Nuclear Power Plant in Rooppur (RNPP), Pabna. Since the electricity production from NPP is inevitable to energy production, there is an extensive safety needed to be ensured along with expertise and general public' awareness about clean energy production and risks from NPP. The objective of the paper is to analyze past historic nuclear reactor accidents and to estimate a risk zone of Bangladesh Nuclear Reactor. The methodology of the analysis is to statistically and mathematically compare past risks areas, magnitude of explosions, and energy production from three major nuclear events and approximate a probable for Bangladesh RNPP. The study shows that around 20-km (radius) of Rooppur area can be exploded with radioactive materials. The atmospheric radioactive emissions would be determined by air monitoring stations depending on wind speed and the direction. The study recommends govt. and public without proper safety measures not to construct high rising infrastructure, long term agriculture, and industries and to create awareness about nuclear explosions and leakage with their severe impacts.

Key words: Nuclear Explosion, Energy Consumption, Safety, Risk Zone, Rooppur, Bangladesh

2. Introduction

2.1 BACKGROUND:

Bangladesh is a developing country with dense population. Because of its economic crisis, Bangladesh cannot supply enough electricity or energy to its public according to consumers' demands. The projection of energy uses in the near future is gradually increasing with the faster growth of population (see table 1). Energy Experts predict that the energy uses in Bangladesh would be double comparing to current use by 2050 (Das, 2012). Energy plays a significant role for running industries, manufacturing plants, and empowering agricultural

products. With overall production of energy [shown in table 3], around 70% of energy is utilized in urban and industrial purposes (Rashid, 2007). However, there are 65% of population who do not have access to energy/electricity that hinders financial growth for the people and eventually the country (Rashid, 2007). This energy gap to meet lacking demand is 800-100MW range (Rashid, 2007). In order to minimize the huge gaps of electricity supply, Bangladesh Government and energy specialists are seeking for more options of energy production.

Table 1: A prediction of Electricity uses of next 30 years in Bangladesh based on peak demand (Das, 2012)

Years	Estimated Peak Demand of Electricity (MW)
2011	6, 765
2012	7, 518
2015	10, 283
2020	17, 304
2021	18, 838
2025	25, 199
2030	33, 708

Table 1 shows the prediction of Electricity uses of next 30 years in Bangladesh based on peak demand which is a fast growing trend in Bangladesh.

Since Bangladesh has an immense population demand of energy, Bangladesh government strives to enlarge the production of electricity for public. As Bangladesh mostly depends upon natural gases as a main source of producing energy, they seek to include other alternative sources because natural gas is a non-renewable resource. Even natural gas resources are now becoming limited. Thus, Bangladesh government planned to build a nuclear power plant for reducing the large of electricity shortfall. In 2014, Bangladesh Power Development Board (BPDB) shows a data of producing maximum electricity supply of 100GW from various sources (see table 2). By analyzing the production of electricity, it seems that Bangladesh government and BPDB has an estimation is that many sources of energy would give variation in the production of electricity

(shown in table 3). This would help our country to meet public's demand in some extent and reduce the rate of price of electricity per unit and frequent power cut.

Table 2: Production of Electricity from Different Sources in Bangladesh in 2012 (Das, 2012)

Sources of Energy	Electricity (MW)	% of Electricity
Natural Gas	5, 394	67.38%
Coal	200	2.50%
Hydro	220	2.75%
Diesel	512	6.4%
Furnace Oil (FO)	1, 676	20.9%

Table 3: Energy Production in Bangladesh by BPDB in Mar, 2014 (BPDB, 2014)

Unit Type	Capacity(Unit)	Total (%)
Coal	250.00 MW	2.44 %
FO	0.00 MW	0 %
Gas	6615.00 MW	64.59 %
HFO	1963.00 MW	19.17 %
HSD	683.00 MW	6.67 %
Hydro	230.00 MW	2.25 %
Imported	500.00 MW	4.88 %
Total	10241.00 MW	100 %

However, with the growing necessity of electricity, the prices per unit watt even are tremendously increasing. For this reason and in order to enhance more sources of energy production, the government of Bangladesh has proposed and tried to build a nuclear power plant with the technological and financial help of the Republic of Russia. Since 1960, Roopur power plant is predicted to be viable and established in 1963. After conducting several studies,

specialist examined that Roopur power plant is economically and technically feasible (Das, 2012). After agreement of government and opposition party, the Roopur project is implemented by National Party in 2010 (Das, 2012). By inaugurating RNPP, the Bangladesh present govt. government also visualizes building a Digital Bangladesh. Thus, in other words, the govt. named this project as 'Vision 2021: Energy Security and Electricity for All' (Rahman, 2012). And this project would provide us 10% of overall energy all over Bangladesh by 2021 (Das, 2012). Since there is also an extensive safety measurement required for establishing NPP, the govt. energy expert, and nuclear technologist should also be prepared for safety and should design such tools for preventive measurements.

2.2 MOTIVATION OF THE PAPER

The project of Rooppur Power plant is inevitable to construct for producing electricity within next few years. When the power plant is going to start, there is also a concern of its operation. Moreover, the historical nuclear accidents are also a concern how the Bangladesh plant would be functioned and be controlled over challenges in reactor failures and disaster management by skilled and expertise human power. In context of Bangladesh, since it is a developing country and has less man power and experts in nuclear energy, the question rises how the nuclear technologists and govt. would co-operate and manage any nuclear disasters such happened in the history. Moreover, by having lessons taken from the historical accidents, what initiative we should be taking for building the Bangladesh power plant. Therefore, this study is considered to think about what would be the risk area if there is any nuclear explosion or leakage happens in the reactor. Since Bangladesh is geographically very tiny and has massive population, can we also design a risk zone like Russia and Japan before any explosions and be prepared for reducing the fear and fatalities? Therefore, the paper is going to explore establishing an area that might have higher concentration and doses of radioactive materials.

2.3 OBJECTIVES OF THE THESIS

The objectives of the study are following :

- Analyze Risk Zone from Past Nuclear Accidents
- Predict the Risk Area for RPPP, Bangladesh

The rest of paper includes Study Site, General View of NPP, Bangladesh Nuclear Power Plant Structure, Recent views on RNPP, Nuclear Accidents in Histories, Methodology of Assessment, Result and Discussion, Recommendations and Conclusion of the paper.

3. Literature review:

3.1 STUDY SITE:

Rooppur Power Plant is located at Ishwardi, in Pabna district, Bangladesh. The location of power plant is 200 kilometer from the center city, Dhaka (Slivyak, 2011). This power plant will be built within a kilometer of the Lalon Shaha Bridge on the main River Padma. The project site is under the Pakshi Union. The total land size of power plant is around 260 acre (Slivyak, 2011). Ishwardi Upazila is located at 24.15^{o} N and 89.07 ^{o} E with a total land 246.9 Km^{2}. The average maximum and minimum temperature are respectively 36.8 ^{o}C and 9.6 ^{o}C. The nearby upzilas are flood plains of Ganges, Karatoya, Jamuna and Barind Tract. in this region, the annual rainfall 1872 mm. The main occupation of the area is agriculture of 34%, daily labors of 5%, commerce of 13%, and service of 8%. There also main industries such as Pakshey paper mill, sugar mill, cotton mill, oil mill, jute press, Square Pharmaceuticals, and Purbasha Automatic Rice mills. There are also many schools, colleges, and universities such as Pabna University of Science and Technology. The union has several historical places as well such as Lalon Shah Bridge (Banglapedia, 2014).

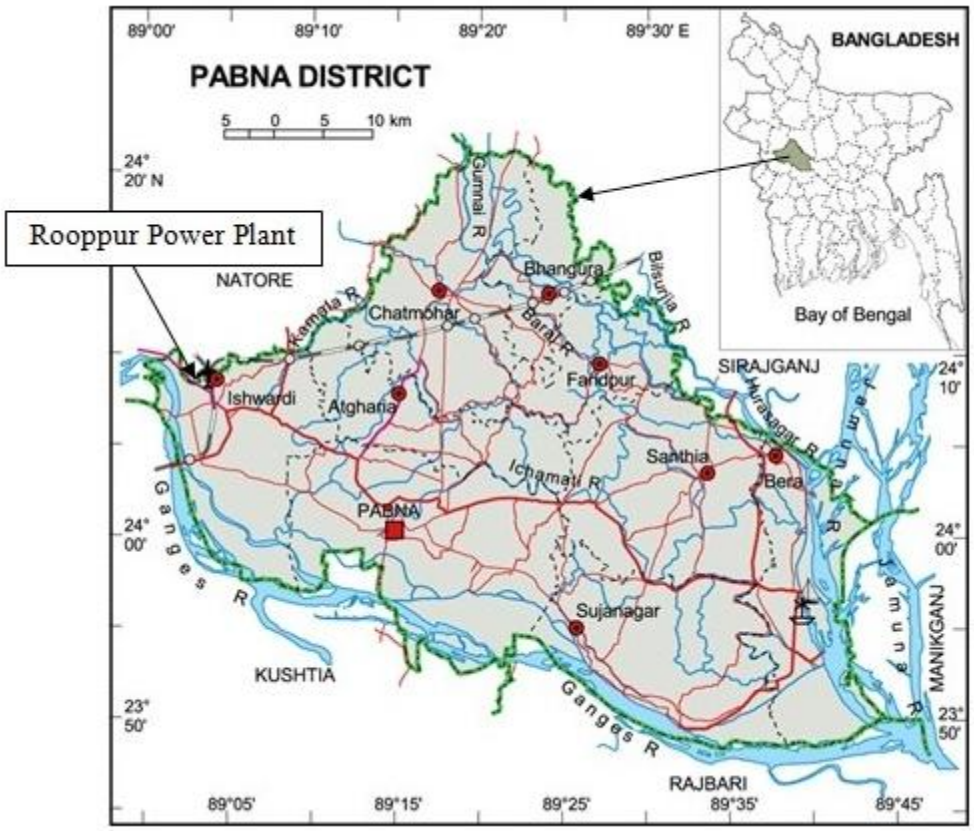

Figure 1: Study Site: the RNPP [North Bengal] in Pabna, Bangladesh (Source: Google Image)

3.2 GENERAL VIEW OF NPP

Nuclear energy is produced by division into more parts of uranium atoms and this process is called fission (US-EPA, 2012). The uranium fuel is a solid ceramic pellet (Nuclear Energy Institute, 2012). Uranium is gained from earth as mining [uranium ure] and taken out by traditional technique or chemical leaching (US-EPA, 2012). The uranium which is utilized in generating energy is U-238 and U-235. U-235 is divided more easily than U-238 in reactions because its neutrons and protons are very unstable (NEI, 2012).

There are some mechanical properties that a nuclear power plant has in order to generate energy. The plant can alienated into three major segments, such as Containment House, turbine, generator, condenser cooling water, and cooling tower. Containment House also contains several mechanisms, including reactor vessel, uranium fuel, control rods, steam generator, a pump which are connected through steam lines with turbine and condenser cooling water

(Cameco Corp, 2012). There is a basic technique of producing nuclear energy as mentioned in fig.2.

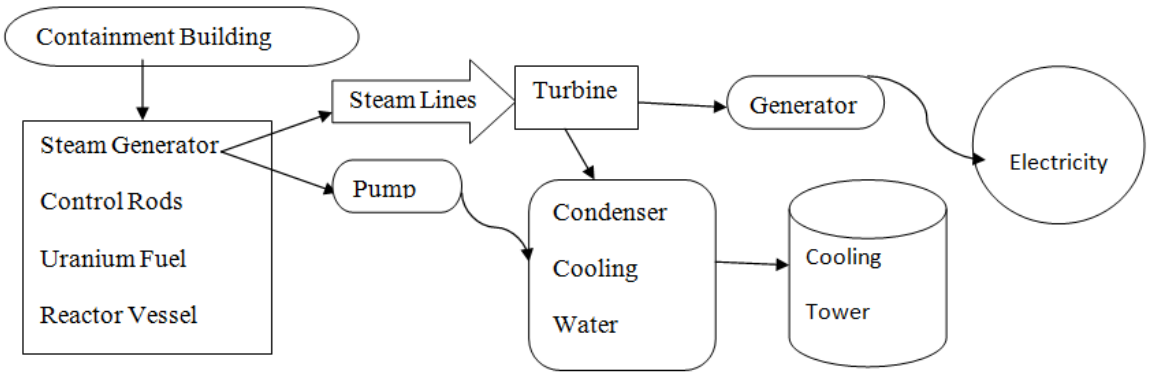

Figure 2: Typical Structure of a Nuclear Power Plant to produce Energy (Nuclear Reactor)

Generally, fuel rods contain uranium pellet and produce neutrons by fissionable nuclei and chain reactions start. Unlike nuclear bomb, the reaction in nuclear plant can be stopped by control rods which are made of boron or cadmium. The control rods control chain reaction's speed by absorbing neutrons. Moreover, the control rods are pushed into the reactor and slow down the nuclear reaction. By the time of full rods insertion, the chain reaction stops (Nuclear Reactor, 2011). However, the fission by products never stops to produce heat. The danger of nuclear reactor starts from this situation that the control rod fails and the cooling tower can explode. If the heat is not cooled down, the reactor can be damaged.

3.3 TYPES OF NUCLEAR STRUCTURE AND TECHNOLOGY

There are also several designs of nuclear power plants specifically, Pressurized Water Reactor (PWR), Pressurized Heavy Water Reactor (PHWR), Boiling Water Reactors (BWR), Fast Breeder Reactor (FBR), and High temperature gas cooled reactors (HTGR). Among them, Pressurized Water Reactor and Boiling Water Reactor are in great use as seen in fig. 3. There are slight differences in different designs. For instance, steam has direct contact to rotate turbine in BWR plant, PWR has closed system, FBR has a core of plutonium is covered by rods of uranium-238, and many others (Cameco Corp, 2012).

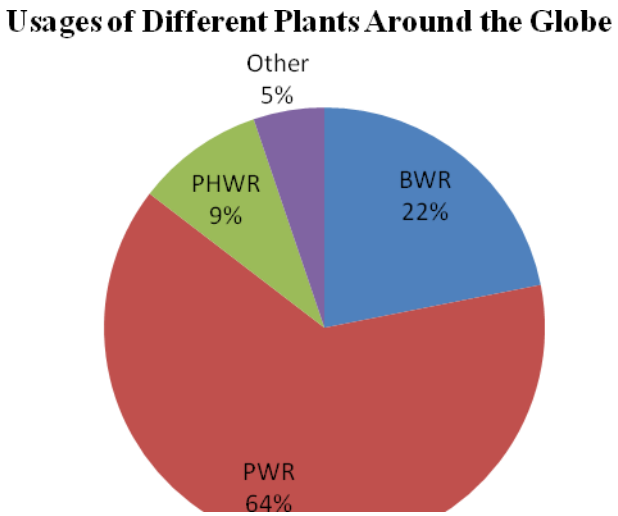

Figure 3: Different Methods of producing Electricity in different percentages (Cameco Corp, 2012).

3.4 BANGLADESH NUCLEAR POWER PLANT STRUCTURE:

Rooppur Power Plant is designed for producing 2000 MW from two unit of power plant (IAEA, 2013). The Bangladesh government has signed with the Russian Government to construct power plant VVER-1000. This plant design was developed in Rosatom in Russia in 1970. This design is also built at Monakovo in Nizhny Novogorod in Central European Russia to produce 1200 MW in VVER=1200. This design is also aviable in Iran [Busher], Bulgaria [Belene], and India [Kudankulam]. In Russian language, VVER is Voda Voda Energo Reactor [in English, Water-Water Power Reactor] which works similar to PWR (shown in figure 4). In Bangladesh context, for water coolant and steam generation, the lake and nearby river water will be used to generate electricity in Rooppur Power Plant. According to International Nuclear Safety, the strength and limitations of the reactors are described below:

3.4.1 Principal Strength (INSP, 2004):

- Steel-lined, pre-stressed, large-volume concrete containment structure, similar in function to Western nuclear plants.
- Improved model comparing to VVER-440 and V213 Reactors

- Uses of four coolant loops and horizontal Steam Generators (shown in figure 4)
- Improved coolant and control rods
- High purifying capacity of primary coolant and water-chemistry control

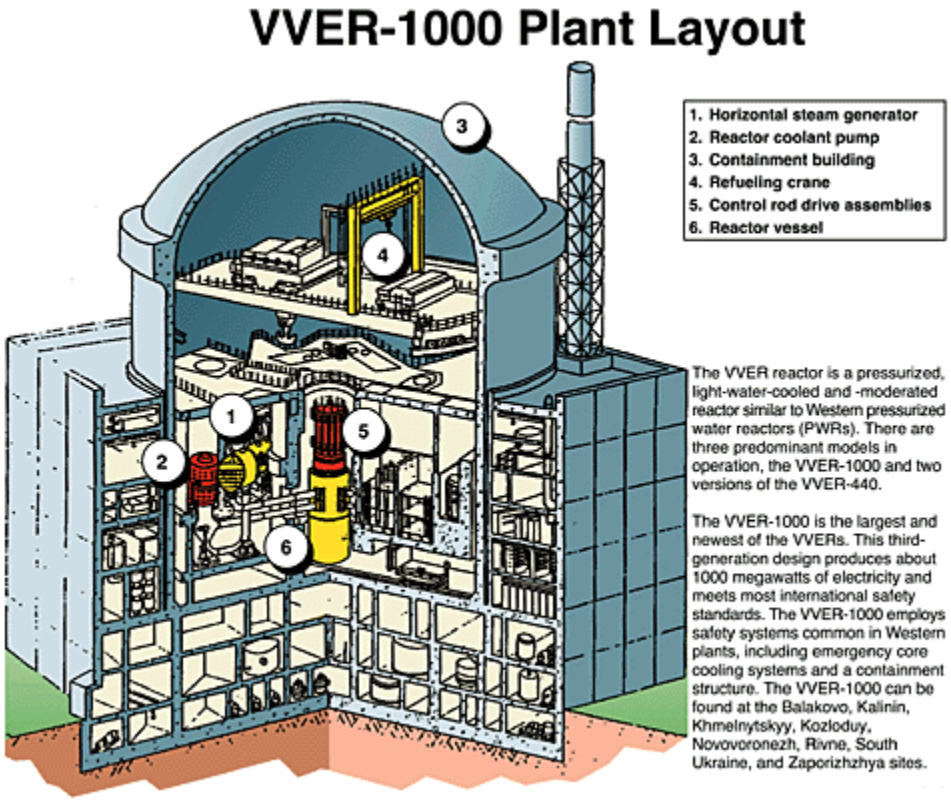

Figure 4: The structure of VVER-1000 used in Chernobyl Power Plant (INSP, 2004)

3.4.2 Principal insufficiency (INSP, 2004):

- Wiring of Emergency Electrical System and Reactor protection does not meet West Standard.
- Since control and safety functions are interconnected that control system may be failed to prevent operation of safety system.
- Fire-protection is not improved from earlier VVER models
- According to US standards, quality control, design and construction are still deficient.
- Protection measures comparing to VVER-440 and V213 models did not change into US standards.
- Operating and Emergency procedures greatly vary from Western Standards

- High power densities and the volume of primary and secondary systems are less stable reactor

3.5 RECENT VIEWS ON RNPP

There are hopes, supports and financial assistances for Rooppur Nuclear Power Plant constructions. However, there are also concerns for construction of Nuclear power plant. Different authors' views and analysis considering on pros and cons of Nuclear power plant are described below:

International Atomic Energy Agency (IAEA) reviewed Bangladesh Integrated Work Plan for nuclear power infrastructure development. IAEA also attended the ceremony at the RNPP site and congratulated the president of Bangladesh for Nuclear construction. IAEA will be assisting for the development of nuclear power for the infrastructure of safety, secured, responsible and sustainable project (IAEA, 2013). The IAEA's assistances and supports to establish the RNPP implies that Bangladesh can start producing electricity as the RNPP projects meet the requirements of IAEA.

Some people living in Rooppur are excited about nuclear power plant in the region because it will assist them to obtain electricity access which will eventually help them in economic development. Moreover, they believe that NPP will also help them increasing employment opportunities to overcome unemployment (Rasel, 2013). However, the awareness of nuclear reactor and being skilled workers were not seen yet.

The chairperson of Bangladesh Atomic Energy Commission, Abu Sayeed Mohammad Feroz stated that nuclear power plant is an eco-friendly and cost-effective energy option for producing electricity. He added that since NPP does not emit carbon-dioxide, acid rain and ozone layer depletion will be reduced for global warming and climate change. He also mentioned Russian State Atomic Energy Commission (RosAtom) will build, operate, and provide fuel to the plant by taking the radioactive waste back to Russia (Rasel, 2013). It seems that the establishment of RNPP does have stronger opinions and potential to be built and to produce a clean energy for Bangladesh. On the other hand, there are many concerns for building nuclear reactor in Bangladesh as well.

Though Russian govt. helps for building RNPP and proposes to plant VVER-1000. This reactor design is outdated, discarded and unsafe reactor. Since there is no such expertise or skilled manpower from Bangladesh for working with this high technology, Bangladesh may face difficulties for immediate cases and safety purposes. Due to current political instabilities, Bangladesh authorities keep changing their legal implications for licensing regime (VOICE for JUSTICE World, 2013). The government of Bangladesh and corruption in the management can be a problematic issue as there is a necessity to take wise decision to consult and confront with the nuclear expertise for any kind of changes in the reactor.

It has been revealed that Russia denied for the agreement of radioactive waste disposal in their areas. Moreover, the author in *BD News* said that Nuclear Explosion is inevitable in Bangladesh and the govt. should rethink for constructing RNPP (VOICE for JUSTICE World, 2013). Therefore, it implies that there still some contradictory which is a concern to build nuclear plant in Bangladesh in terms of operating the reactor, safety issues and management issues.

3.6 NUCLEAR ACCIDENTS IN HISTORIES:

3.6.1 USA:

In 1979, a nuclear accident occurred at Three Mile Island nuclear power reactor near Harrisburg, Pennsylvania, USA. The power plant was pressurized water reactor like VVER-1000 to produce 800MW energy. This reactor is failed due to melting down of reactor core and the loss of coolant. To produce 800 MW energy, around 78 ton uranium [one of raw materials] need to be taken in the reactors (Nuclear Development, 2011). Moreover, the radioactive materials were started to have leakage from the coolant tower. Therefore, data of affected area from the Three Mile Island is used in the calculation to estimate for Bangladesh Power Plant. Although there was no direct fatalities and loss due to emergency evacuation, the radioactive exploded gas was released into atmosphere. For this reason, people nearby can have radioactive radiation in them. It is estimated that each person can carry 2 mrem of radioactive dose in them and 100=125 mrem can be seen per year (USNRC, 2013).

3.6.2 Russia:

The Chernobyl reactor RBMK-1000 which is high power channel type nuclear plant was failed in 1986. Because of this manmade disaster, there were instant 31 deaths at the instant and

tremendous fatalities. Furthermore, an instant evacuation of all residences was around 18 miles. Moreover, all the children also were evacuated from 100 miles from the villages (Hinrichs and Kleinbach, 2006). Currently, the cancer effect of radioactive materials in the Northern Hemisphere [towards Europe] increases around 0.003% and the residences in the Northern Hemisphere can have deaths about 150,000 (Petryna, 2002). This energy production from this reactor and affected area from this manmade disaster was used to estimate affected area in Bangladesh plant.

3.6.3 Japan:

Japan Daiichi Fukushima plant was one of the massive nuclear accidents in histories due to natural disasters such as earthquake and Tsunami. Though there was no direct loss of deaths, 100,000 people were evacuated at the instant from 20-40km area (BBC, 2011). Therefore, these three different accidents were used in predicting a probable risk area in Bangladesh plant.

4. Methodology of the Assessment

The methodology is divided into three parts of calculation such as past accidents' data analysis, estimation of Bangladesh Risk Zone by statistical analysis, and calculation of risk area by Lagrange Interpolation Formula for unequal intervals in Matlab Program that are described in following sections below:

4.1 HISTORICAL NUCLEAR PLANT ACCIDENTS ANALYSIS:

Topography, amount of water used in coolant tower of reactors, produced radioactive wastes, wind speed, and weather are the main parameters for dispersing radioactive gases and materials. These parameters are very essential to consider in calculating the exploded [radioactive materials concentration] risk area. For example, 10 kiloton of explosive can have explosion in 5 to 20 km from the base line or plant area. Depending upon material of ground such as rock, dry or soft rock, there can have depth of 17 m and diameter of 75 m for dispersion in the landscape. If the wind speed is higher enough, the area of nuclear explosion can be varied (Garwin, 2010).

There are important tools that are helpful for calculating and monitoring radioactive materials When nuclear reactors are exploded, the also shake the earth crust like earthquake.

Using seismograph, nuclear blast also can be determined similarly earthquakes by seismic waves (citation: stuff). Moreover, various gauge stations at several point sources nearby the nuclear plant can also monitor radioactive materials in soil and water bodies. The atmospheric emissions can also be monitored by different stations. The International Monitoring System (IMS) and Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) work with collaboration to monitor various radioactive emissions from Nuclear power plant or any radioactive or noble gas emissions.

Currently, they have 254 of the monitoring stations and 10 of the radionuclide laboratories have been certified. The Comprehensive Nuclear-Test-Ban Treaty monitors and measures radioactive particles with 80 stations and 16 laboratories. These monitoring stations can measure very tiny which is even less than 0.1 g molecule from the atmosphere (CTBTO, 2012). In order to measure the atmospheric emissions, IMS and CTBTO consolidate data from seismological, radionuclide, hydroacoustic and infrasound stations. The organizations will provide emissions data to those countries which are signed and ratified by the organizations. For Bangladesh, the govt. has also signed and ratified at the air monitoring organization respectively in 1996 and 2000. The figure 5 shows static air quality stations but the interactive map with higher resolutions shows three categorized countries such as signatory states, ratifying states and non-signatory states which is GIS map.

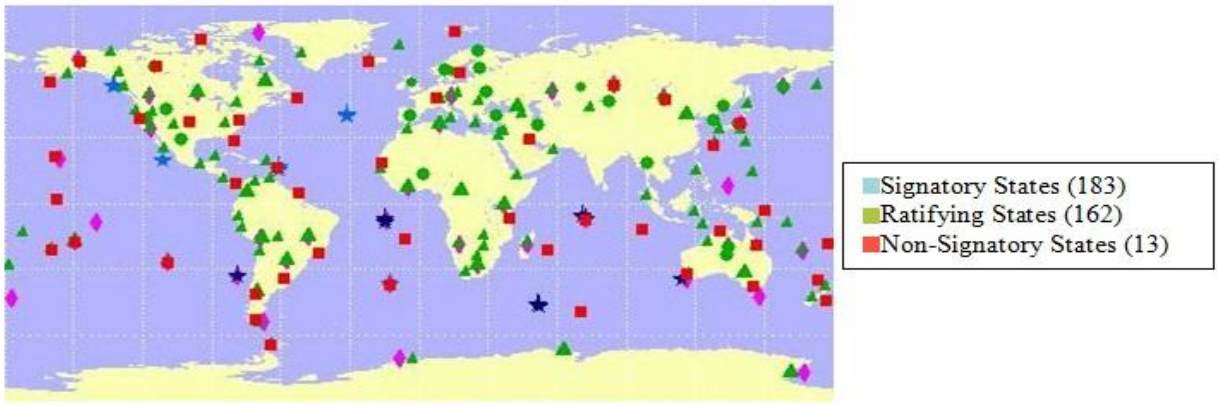

Figure 5: Static Map for Air Quality Stations of Radioactive Emissions in the World (CTBTO, 2012)

In histories of nuclear accidents, Russia and Japan nuclear accidents and tremendous explosions have affected the regions very adversely. When a nuclear accident happens, the probable risk area is measured by various sampling. To measure radioactive emissions in the topography and atmosphere, the most risk area is measured and quantified by air sampling and monitoring. Air monitoring can be assessed by two ways such as direct effluent and environmental surveillance. Direct effluent or point source radioactive air sampling is simply calculated at the exhaust point or source point. Environmental surveillance is conducted from the fugitive pathway. There are several monitoring stations are located for monitoring and sampling. To understand the radioactive materials' dispersion in particular areas, soil sampling is a way to calculate radioactive materials present in earth surface (Barnett, 2011). That is how by sampling in various points, we can predict a risk area which is exploded by poisonous radioactive materials by certain extent.

Chernobyl plants accidents in Russia For instance, after nuclear accidents at Pripyat town, in Russia, 110,000 residences were evacuated. The map of 30-km exclusion zone was the radius for people evacuation from the area. The figure 6 shows the places of 30-km exclusion zone. This figure is obtained by various gauge stations that calculated by soil samples with various concentration. The calculated area with 30 km radius in Pripyat Russia had no lives due to extreme concentration of radioactive materials. Later on, the contaminated place was started to clean by the nuclear expertise (Petryna, 1996). Thus, the Russian nuclear accident provides an idea to estimate approximate risk zone if there is any reactor leakage or nuclear accidents happen.

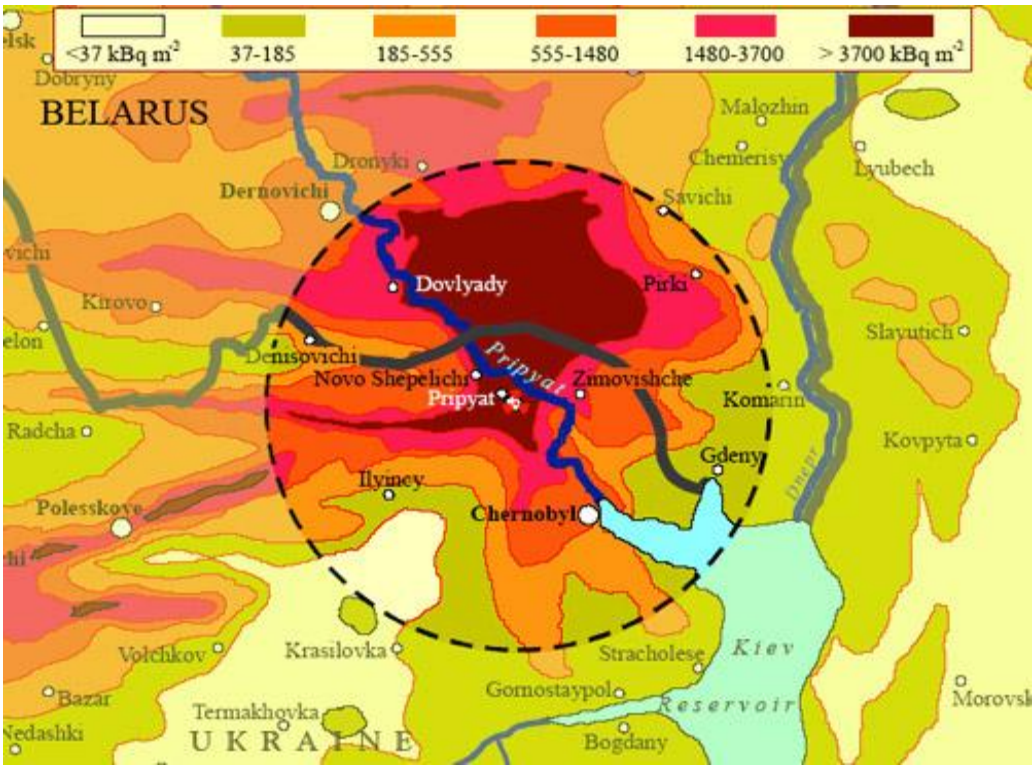

Figure 6: 30-km Exclusion Zone in Chernobyl Nuclear Accidents: the no safe zone (Petryna, 1996).

The Japan Fukushima Plant was exploded by an extreme tsunami and earthquake with respectively 60 m rise of seawater and 9 magnitudes of earthquakes. After the explosion of nuclear plant by natural disasters, the Japan expertise also evacuates people from Daichi Nuclear Reactor after explosion within 35 to 40km area. Moreover, the presence of radioactive materials right after the accident in the air is calculated by Takasaki monitoring network and the radioactive emissions spread to northern hemisphere (Preparatory Commission, 2011). The dispersion of radioactive materials from Daichi Nuclear Power Plant is shown in figure 7. The atmospheric dispersion is more concerned since the radioactive materials with certain concentration can travel miles and miles by certain wind speeds. Similarly, the Three Mile Island nuclear accident in the USA also had very adverse effects in 10-20 miles of areas (Three Mile Island, 2010).

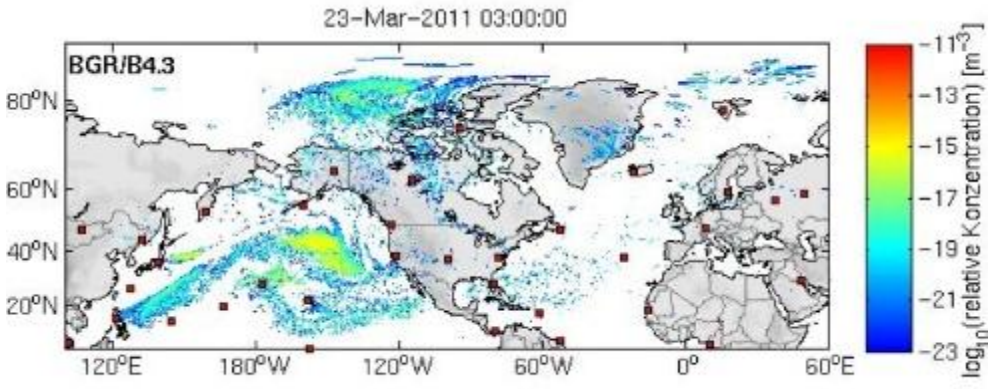

Figure 7: Dispersion of Radioactive Emissions from Japan Nuclear Plant, (Source: *German Federal Institute for Geosciences and Natural Resources)* (Preparatory Commission, 2011)

After observing three major nuclear accidents and analyzing the risk areas, these data were used to calculate a risk area in Bangladesh Plant and is estimated by statistical and mathematical relationships. Since before any explosions happen and without having environmental samples (soil or water), the calculated area will not be possible to predict very accurately. However, with this massive information of past nuclear accidents, we can estimate by analyzing a relationship between energy production and exploded area, amount of Uranium used and exploded area. The calculation was carried out in excel and found a linear relation to predict for Bangladesh Plant exploded area by comparing with Russia, Japan, and USA. Moreover, the same information was used to calculate the area in Matlab programming by Lagrange Interpolation Formula for Unequal intervals.

4.2 DATA CALCULATION BY MATLAB:

The number of data sets in calculating the results of probable exploded area is in the table.

Table 4: data sets for exploded area calculations

Country	Energy Production (MW)	area (Km)	Amount of used Uranium (Ton)
Japan	2719	25	80
Russia	1000	30	75
USA	880	20	82

The matlab program to estimate area was the following. By running into the software, we can numerically calculate the area for explosions. The Lagrange formula was used to calculate because the data below were unequal intervals.

Values for Energy Production in MW [x] and Exploded area in km [y]: (2719, 40), (1000, 30) and (880, 20) and Estimated for Bangladesh of 2000 MW energy production. Here N is the number of all x values.

With the same equation or program, amount of uranium used in ton and area of exploded in km is also determined with the (80, 40), (75, 30), and (82, 20) (Nuclear Development, 2011). Estimate for Bangladesh of 78 ton raw materials, we get a result that is shown in table 4.

```
N=input('\n Enter The Value of N:');
for i=1:N
   x(i)=input ('\n Enter the value of x:');
   y(i)=input('\nEnter the Value of y:');
end
Y_req=0;
fprintf('\n Enter the value of x for which y to be calculated');
X_req=input('Must be less than the last and first x value');
for i=1:N
   p=1;
   q=1;
   for j=1:N
      if(j~=i)
         p=p*(X_req-x(j));
         q=q*(x(i)-x(j));
      end
   end
   Y_req=Y_req+(p/q)*y(i);
end
fprintf('\nWhen X = %f, then Y=%f', X_req, Y_req);
```

Since there was less number of data sets to for calculation, Lagrange formula is helpful to calculate and approximate a result with minimum three unequal values.

5. Result:

Statistical analysis of energy production and area of explosions provides an estimated area in Bangladesh Power Plant. The figure 7 implies when Bangladesh has 2000 MW energy production, the estimated area to be exploded around 25 km if there is any nuclear accident at the Rooppur plant.

Table 5: Estimation of Risk area in RNPP by analyzing from Historical Nuclear Accidents

Parameter	Lagrange Formula	Statistical Analysis
Energy Production	66.125km	25km
Used Uranium	46.28km	32km
Average Result:	42.125km	

The figure 8 shows how the amount of energy production co-relates to have affected areas and implies around 25km area would be affected by any nuclear radioactive materials. Since there is only three different countries data available for calculation, the result may be varied if there was more data and the gap between the straight line could have been more smooth and accurate.

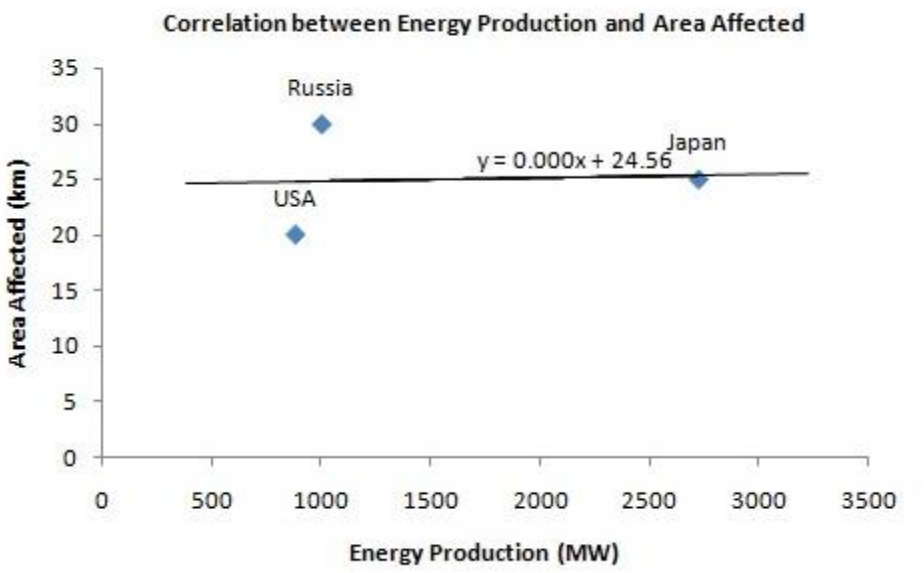

Figure 8: Estimation of Affected area from Amount of Energy Production from Proposed Rooppur Power Plant in Bangladesh Plant

Moreover, comparing raw material (uranium) used and the affected area also provide an estimated area of 32 km that might contain heavy concentrated radioactive materials (shown in figure 9). These graph also compared between three different countries so that the line we obtained would have been closer to each other and accurate if there was more data sets to compare (see also the table 4).

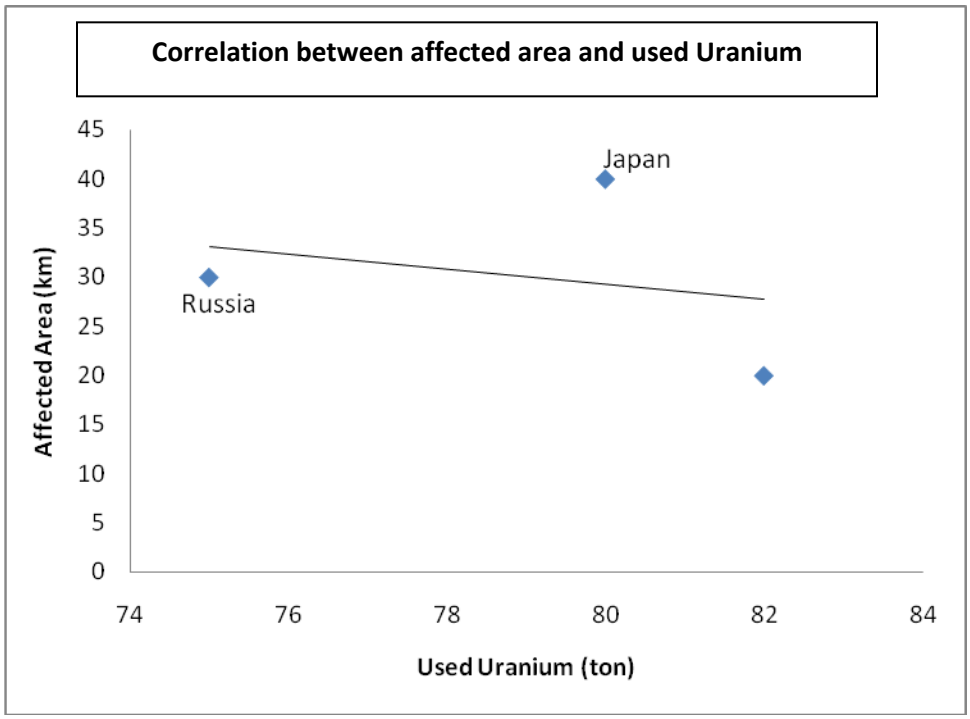

Figure 9: Estimation of Affected area from Amount of Used Uranium from Proposed Rooppur Power Plant in Bangladesh Plant

Moreover, the same data was calculated in Matlab program that provides following result 66.125 km when energy production is 2000 MW. Moreover, the result of raw material used is provided as 46.28 km. Having all the values from various parameters that are calculated in matlab and statistical analysis, the average area that can have radioactive explosions is 42 km (shown in figure 10).

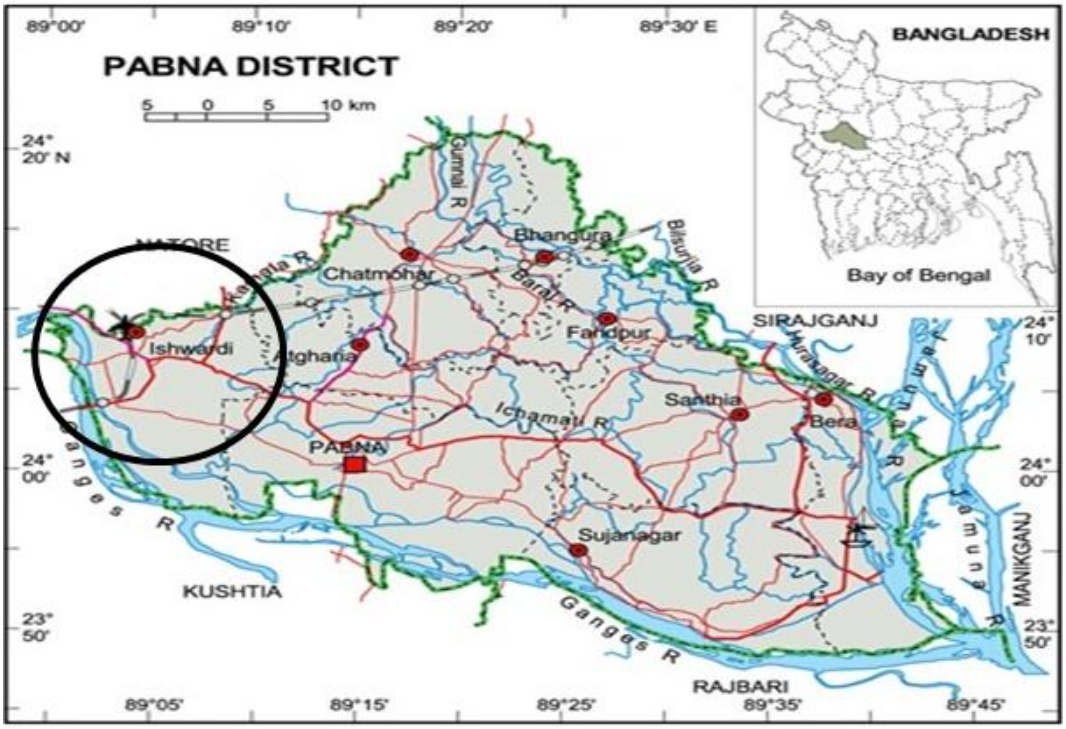

Figure 10: Estimated area by radioactive materials after any nuclear explosion and leakage at RNPP (Google Image)

To obtain more accurate and confined area, there are other parameters such as total amount of raw materials, technology types and capacity of cooling tower should be considered in assessment and calculation. The following figure (figure 11) shows a model that can be considered in creating a mathematical model to estimate a risk zone by any leakage or explosions happen at the proposed RNPP. The two most important aspects are environmental sampling and air monitoring system. The flow chart shows the parameters that play a significant role in calculation of confined area which might have the most concentrated amount of radioactive materials. For quantifying the area, GIS and GPS will be vital technology to monitor environmental sampling. Moreover, the study of seismograph and installing various gauge stations will also help to track the radioactive emissions in the landscape. On the other hand, the air monitoring system is useful to observe for monitoring the atmospheric emissions of radioactive materials. The air quality monitoring system merely utilizes the GIS and remote sensing technology to track the travel path of radioactive materials and provides images about the presence of radioactive materials in specified geology.

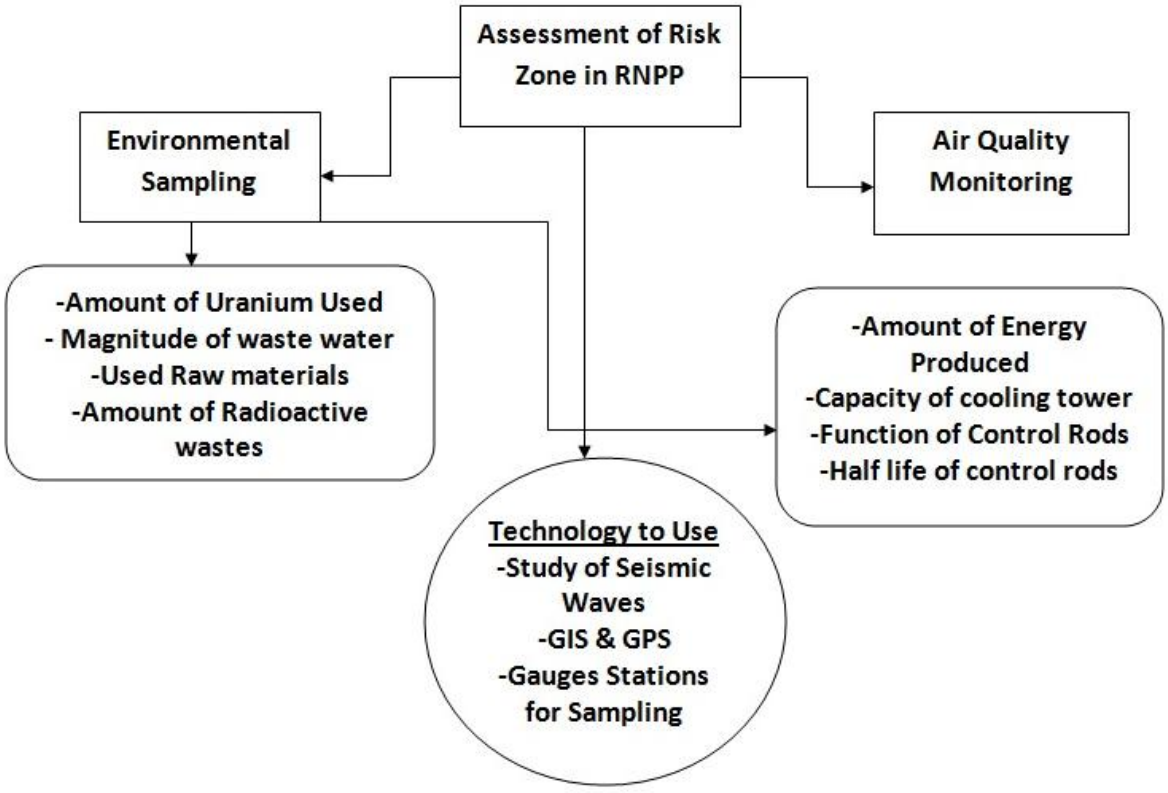

Figure 11: Mathematical model for the risk zone assessment in RNPP, Bangladesh

6. Discussion:

When nuclear explosion happens in Bangladesh Rooppur Power plant either natural disaster or machineries, the area can have concentrated around 40 km. The energy production and exploded area provide around 25 km area whereas the amount of uranium used shows 32 km in linear statistical calculation. The estimated area is reasonable to have occurred after nuclear power plant accidents. The result also shows a significant variation by Lagrange formula [66 and 46 km]. It implies that the variation happens because there are other significant parameters which are not considered while calculation. Since the dispersion of radioactive materials also depend on topography [soil and water bodies], the dispersion rate and travel path might be higher. This means the calculated risk zone is directly depending upon topography and soil type. Thus, there is Lalon Shah Bridge nearby the Rooppur plant and nearby places are floodplains. If somehow the radioactive wastes are drainage to these places and mixed with river water, the travel path and exploded area can extend even more than the predicted one.

Moreover, the amount of uranium used is calculated to estimate the risk zone. However, there are other radioactive materials that are used in nuclear power plant such as zirconium, plutonium, thorium, bentonit, indium, gadolinium and manganese. These materials also enhance the concentrations of radioactive emissions. When the concentration of radioactive material is increasing by other raw materials, the doses of radioactive waste also become higher. Finally, the cooling tower in Rooppur Power Plant is lake or river water which is more concerned for affected area by radioactive materials. Eventually, the exploded area can have heavy concentrated radioactive materials nearby RNPP with approximate radius 35km. As Bangladesh govt. will also enhance more reactors, the amount of energy production and used uranium will also account a lot for exploding and enhancing the risk area.

The atmospheric emissions of radioactive materials are not calculated since the Bangladesh is already ratified for International Monitoring System to monitor atmospheric dispersion. This can only be shown after any nuclear disaster happens. The relative wind speed, local weather pattern, and particular season will be responsible for atmospheric dispersion. The dispersion of radioactive wastes will be determined depending on the explosions size by using GIS and remote sensing. And the concentrated dose among citizens would be measured by medical tests.

7. Conclusion:

In conclusion, this is inevitable to construct nuclear power plant in Bangladesh since there is tremendous need of energy for economic development and comfortable lifestyles. Moreover, it is not such severe of having nuclear energy as there is France which is producing 70% of energy from many nuclear reactors. The most important aspect to consider is safety and security issues regardless political, expert workers, and weak technological supports. Nuclear energy is a clean energy choice to reduce climate change impacts by reducing Green House Gas emissions. The study found an estimated risk area would be around 20-km radius across the nuclear power plant. The preventive measurement by knowing a risk area will be helpful as preparatory management. Since Bangladesh is a small country with over-dens population, the country will be in great loss by any mistake happens. From various experiences such as Rana Plaza destruction, flyover broken down, and disaster management, this is a concern of providing emergency and immediate services to nuclear accidents by the expertise if there were not any preventive and mitigation

measures taken. By knowing the risk area, various preventive measures taken will be eventually very effective to reduce nuclear calamities.

8. Recommendation:

After analyzing the risk area, it is a serious concern for Bangladesh to construct and maintain a strong observation of Nuclear reactor. To monitor any changes in soil or water bodies, there should be frequent gauges stations to analyze nuclear explosion amount or even leakage and estimated area by seismic waves and to observe the presence of radioactive materials by sampling and monitoring stations. The experts to operate the power plant also need to be extra-alert all the time that the all machineries, cooling tower, cooling rods, and other important monitoring system are in right functions. In terms of land uses, the govt. should create a concrete and strong policy in this region. The estimated risk zone should not have strong and high rise infrastructure, industries, long term agriculture and less dense population's accommodation. Moreover, for security and safety purposes, any political uncertainties and hostility should not be an aspect for threatening general public life and eventually the international countries.

8.1 SUGGESTIONS OF FURTHERE WORK

Since there are less data available to obtain more accurate data, there are the other important parameters and data to consider and to explore for establishing a risk area. The areas of further studies are listed below:

- **Magnitude of waste water**
- **Used Raw materials**
- **Amount of Radioactive wastes**
- **Capacity of cooling tower**
- **Function of Control Rods**
- **Half life of control rods**

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9. References:

[1.] Banglapedia, 2014. Pabna District. Accessed from http://www.banglapedia.org/HT/P_0002.htm

[2.] BBC, 2011. "Japan earthquake: Explosion at Fukushima nuclear plant". *British Broadcasting Corporation*. Accessed from http://www.bbc.com/news/world-asia-pacific-12720219

[3.] BPDB. 2014. Bangladesh Power Development Board. Accessed from http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=150&Itemid

[4.] Barnett M (2011). "Concepts for Environmental Radioactive Air Sampling and Monitoring". Pacific Northwest National Laboratory: U.S. Department of Energy. *In Tech*. [pdf]

[5.] Cameco Corporation (2012). *Nuclear Science*. *http://www.cameco.com/uranium_101/uranium_science/nuclear_reactors/*

[6.] CTBTO, 2012. *Preparatory Commission for the comprehensive nuclear-test-ban-treaty organization*. Accessed from http://www.ctbto.org/specials/who-we-are/

[7.] Das U. (2012). The IAEA Energy Management School in Japan: Overview of Nuclear Power Program in Bangladesh. *Bangladesh Atomic Energy Commission*.

[8.] Garwin R (2010). "A Nuclear Explosion in a City or an Attack on a Nuclear Reactor". *National Academy of Engineering*. 40:2. https://www.nae.edu/Publications/Bridge/19804/19892.aspx

[9.] Hinrichs R and Kleinbach M. (2006). "Energy: Its Use and the Environment" *Thomson Learning Academic Resource Center*: Canada. 4th Edition. Print.

[10.] IAEA, 2013. "Progress in Building Bangladesh's Nuclear Infrastructure." Accessed from http://www.iaea.org/NuclearPower/News/2013/2013-10-11-inig.html

[11.] INSP, 2004. "The VVER-1000*" International Nuclear Safety*. Accessed from http://insp.pnnl.gov/-profiles-reactors-vver1000.htm

[12.] Kalam. M. A and Topu H. K (2012). Major Hurdle Crossed: *The Daily Star*. Published in 22, January, 2012

[13.] Layton J. (2006). "How do scientists determine if a nuclear blast has occurred?" 14 October 2006. *HowStuffWorks.com*. Accessed from <http://science.howstuffworks.com/nuclear-detection.htm>.

[14.] Nuclear Development, (2011). "A Preliminary Assessment of Raw Materials Inputs that would be Required for Rapid Growth in Nuclear Generating Capacity" *Nuclear Energy Agency and Organization for Economic Co-Operation and Development. [pdf]*

[15.] Nuclear Energy Institute, 2012. *http://www.nei.org/howitworks/electricpowergeneration/*

[16.] Nuclear Reactor, (2011). BENE - Better Environment with Nuclear Energy. Accessed from http://www.bene.ie/bene/Reactors.html

[17.] Pabna District. (2014). Banglapidia: Accessed from http://www.banglapedia.org/HT/P_0002.htm

[18.] Petryna A. (2002). "Life Exposed: Biological Citizens after Chernobyl". *Princeton University Press*: New Jersey. Print.

[19.] Rahman. K.M.R (2012). Bangladesh Experience in Self-Evaluation of Nuclear Infrastructure. *Bangladesh Atomic Energy Commission.*

[20.] Rashid. H. (2007). A Case for Nuclear Energy in Bangladesh: *The Daily Star*. Published 19 Nov, 2007.

[21.] Rasel R (2013). PM inaugurates Rooppur N-plant: *Dhaka Tribune*. Published in October 2, 2013.

[22.] Three Mile Island, 2010. Accessed from http://www.pahighways.com/features/threemileisland.html

[23.] Slivyak V. (2011). Nuclear Issues. Bellona. Accessed from http://bellona.org/news/nuclear-issues/2011-11-comment-russia-will-pay-for-export-nuke-plant-in-bangladesh-host-bangladeshi-nuclear-waste-all-for-the-cleansing-light-of-nuclear-power-no-doubt

[24.] United States Environmental Protection Agency (2012). http://www.epa.gov/cleanenergy/energy-and-you/affect/nuclear.html.

[25.] USNRC. (2013). "Background on the Three Mile Island Accident". *United States Nuclear Regulatory Commission.* Accessed from http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html#impact

[26.] Voice for Justice, (2013). "Concerns over the Safety and Economic Viability of the Proposed Rooppur Nuclear Power Plant (RNPP)": *Voice for Justice Organization*. Accessed from http://www.voiceforjustice.org/Nuclear%20Power%20Site%20final.htm

[27.] Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization. (2011). "Fukushima-related radioactive materials measured across entire Northern Hemisphere." ScienceDaily. ScienceDaily, 7 April 2011. www.sciencedaily.com/releases/2011/04/110407121343.htm>.