A STUDY OF GROUNDWATER CONTAMINATION BY THE LEACHING OF FLY ASH IN VICINITY OF GURU GOBIND SINGH THERMAL POWER PLANT, ROPAR (PUNJAB)

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CERTIFICATE

This is to certify that **Mr. Satyendra Choudhry Roll No. 601101024** has worked on this thesis report entitled **"A Study of Groundwater contamination by the leaching of fly ash in vicinity of Guru Gobind Singh Thermal Power Plant, Ropar (Punjab)"** as a partial fulfillment for award of the degree of Master of Technology (EST). I certify that the matter embodied in this report is of the candidate's own record and not submitted to any other university in any part or full form for the award of such kind of a degree.

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Declaration

I, the undersigned, hereby declare that the research work presented in the M.Tech thesis entitled "**A Study of Groundwater contamination by leaching of fly ash in vicinity of Guru Gobind Singh Thermal Power Plant, Ropar (Punjab)**" has been carried out by me under the supervision and guidance of **Dr. Susheel Mittal** (Senior Professor, School of Chemistry and Biochemistry) and **Dr. Anita Rajor** (Assistant Professor, School of Energy and Environment). Thapar University, Patiala. Further, I declare that the matter presented in this thesis has not been submitted in part or full, to this or any other University/Institute for any degree or diploma.

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Abstract

In the present study, contamination of groundwater in the vicinity of Guru Gobind Singh super thermal power plant Ropar (Punjab) was investigated. Coal combustion results in huge amounts of fly ash from which metals can originate and migrate to groundwater and pollute it. Fifty groundwater samples were collected from the hand pumps in an area nearby the power plant in equally from downwind and upwind sides to determining physico chemical parameters and metals contents in groundwater. pH and other physico chemical parameters of the water were analysed. AAS and ICP-MS were used to determine the metal contents. The results were compared with the WHO and IS standards for drinking water quality. The results revealed that iron concentration was higher in most of the samples collected from the downwind side. Zinc concentration was within WHO guidelines value, but higher in downwind side. Lead concentration was also higher in downwind side and at some places the concentration of lead was higher than the WHO guideline value. The concentration of chromium was also higher than the WHO standard in samples collected from downwind side as compere to upwind side. Concentration of uranium was also determined and results showed that uranium concentration was higher in downwind side and the maximum concentration was 0.05 ppm which was more than 3 times higher from WHO recommended value. In upwind side the value of uranium was below the detection limit in most of the samples. The finding of this study supported with wind roses drawn for the duration of the study period revealed that fly ash generated from coal based power plants are one of the main source of heavy metals in the groundwater in the area of in the vicinity of downwind side of the power plants.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1 Introduction

1.1 Pollution

Pollution is the introduction of a contaminant into the environment. It is created mostly by human actions, but can also be a result of natural disasters. Pollution has a detrimental effect on any living organism in an environment, making it virtually impossible to sustain life. Pollution harms the Earth's environment and its inhabitants in many ways. The three main types of pollution are: Soil Pollution, Air Pollution and Water Pollution**.**

(a) Soil Pollution

Soil pollution refers to any physical and chemical change in the soil that adversely affects the growth of the plants and other organisms. It originates from waste dumping. Use of agrochemicals including fertilizer and pesticides, processing of petroleum products and release of heavy metals, etc. It affects all the components of ecosystem as the pollution tend to move in lakes, ponds and rivers, percolates into groundwater and enter into atmosphere**.**

(b) Air Pollution

Air pollution is the alteration of atmosphere chemistry by air pollutant from natural and anthropogenic sources. The emission of SO_2 from volcanoes, O_3 from lighting, particulates and CO_2 from natural occurring fire, etc., Anthropogenic source of air pollutants are from both mobile(the transport vehicles) and stationary sources (eg., power plant , industry etc.) Air pollution is a complex problem because numerous chemical substance are involves, which occurs in all three states, gaseous, liquid and solid.

(c) Water Pollution

Water pollution can be defined as any unfavourable change in physical, chemical and biological properties of water that makes it harmful to human and others life forms. Human actions reduce the use of water as a source. A water source may be fit for navigation and fishing, but not for irrigation or drinking which requires pure water. Examples of polluted water include acid mine drainage water, raw sewage –laden waters that enter in the river, turbid domestic waters full of detergents containing phosphate, the rust-colour, opaque water of a lake, full of toxic metals, a highly nutrient rich village pond water, the heated water from the cooling tower of an electric-generating plant and of the lake contaminated with asbestos fibres. Thus water pollution is common in all the regions of the world; the magnitude and the type of pollutants may vary. Water pollution may divide into two categories: surface water pollution and ground water pollution.

(i) Surface water pollution

Surface water is usually rain water that collects in surface water bodies, like oceans, lakes, or streams. Another source of surface water is groundwater that discharges to the surface from springs. Surface water pollution occurs when hazardous substances come into contact and either dissolve or physically mix with the water. Because of the close relationship between sediments and surface water, contaminated sediments are often considered part of surface water contamination. Sediments include the sand and soils on the bottom of an ocean, lake, or stream.

(ii) Groundwater pollution

Groundwater quality comprises the physical, chemical, and biological qualities. Temperature, turbidity, colour, taste, and odour make up the list of physical water quality parameters. Since most ground water is colourless, odourless, and without specific taste, we are typically most concerned with its chemical and biological qualities. Although spring water or groundwater products are often sold as “pure,” their water quality is different from that of pure water. Human activities can alter the natural composition of groundwater through the disposal or dissemination of chemicals and microbial matter at the land surface and into soils, or through injection of wastes directly into ground water. Groundwater pollution (or groundwater contamination) is defined as an undesirable change in groundwater quality resulting from human activities.

Heavy metals are considered to be very dangerous pollutants to groundwater. They are known to cause serious human health problems as many heavy metals are carcinogenic and also damage the environment **(Tamasi et al., 2004).** There are two sources of metals: Natural and Anthropogenic. Natural sources include decay of rocks and earth layers that contain metal compounds and fossil fuels and volcanic eruptions **(Goodarzi and Muki, 2000).** Anthropogenic sources which pollute the groundwater are mainly combustion of fossil fuels, mining and smelting operations, processing and manufacturing industries and waste disposal including dumping, release of domestic waste and scrap metal handling **(Brown and Peak, 2005)**. Combustion of coal in coal base power plants and other sectors is also one of the most important processes which has great potential pollution to the environment and groundwater as fly ash contain many heavy metals **(Sandroni and Clare, 2003).**

1.2 Coal-fired power plants as a source of pollution

In order to fulfil the future world energy demand, all energy resources may need to be utilised. Despite the efforts and the commitment for renewable power to account for a significant share of the total electricity supply, coal is still one of the most important electricity producing fuels. With growing energy demand, many industrialised and developing countries will continue to rely on coal for power generation in the decades to come. There are a significant numbers of thermal power plants around the world and new plants are put into operation very quickly. All these power plants brought along serious environmental imbalance due to the dumping of industrial wastes. The main impact factors over the environment of the thermal power plants that operate on fossil fuels are as follows: greenhouse gas emissions, use of natural resources, wastewater, storage of solid waste, noise. The environmental impacts should be understood also from the local population point of view. Pollutant emissions in air, soil and water have serious consequences over human health. Depending on the location of the coal mine that supplies the power plant the coal may have different properties such as heating value, moisture and mineral content resulting in different residue upon combustion. The properties of the resulted ash are a function of several factors. Beside the coal source there are other important factors that influence its properties as follows: boiler unit, loading and firing conditions, storage and handling methods. Variations may occur from ash properties point of view not only between different power plants but within a single power plant too.

(a) What is fly ash?

Fly ash is a by-product of the coal-combustion process in thermal power plants**.** The amount of fly ash generated in a thermal power plant depends upon two factors—the ash content of the coal and the type of boiler used. About 20 percent of the non-combustible components of the coal are converted into bottom ash and 80 percent into fly ash **(Agarwal et al., 1996).** Fly ash is carried up the chimney stack along with the combustion gas and is captured by an electrostatic precipitator**.** Together with bottom ash removed

Table 1: Composition of fly ash

s.no	Components	Composition in percentage		
		Bituminous	Subbituminous	Lignite
1	SiO_2	20-60	40-60	15-45
2	Al_2O_2	5-35	20-30	20-25
3	Fe_2O_3	10-40	4-10	4-15
4	CaO	1-12	5-30	15-40
5	LOI	0-15	0-3	0-5

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from the bottom of the furnace is jointly known as coal ash. Fly ash consists of finely divided particles with sizes ranging from 120 micron to less than 5 micron.

Table 2: Different elements present in fly ash and their concentration

Elements	Concentration
1) B , Ba ,Cu , Mn, Sr	100-1000 Mg/kg of ash
2) As, Cr, Mo, Ni, U , Th, Zn, La ,pb	10-1000 Mg/kg of ash
3) Cd, Ga , Sb, Se , Ti, V	1-10 Mg/kg of ash
4) Hg	1 mg/ kg of ash

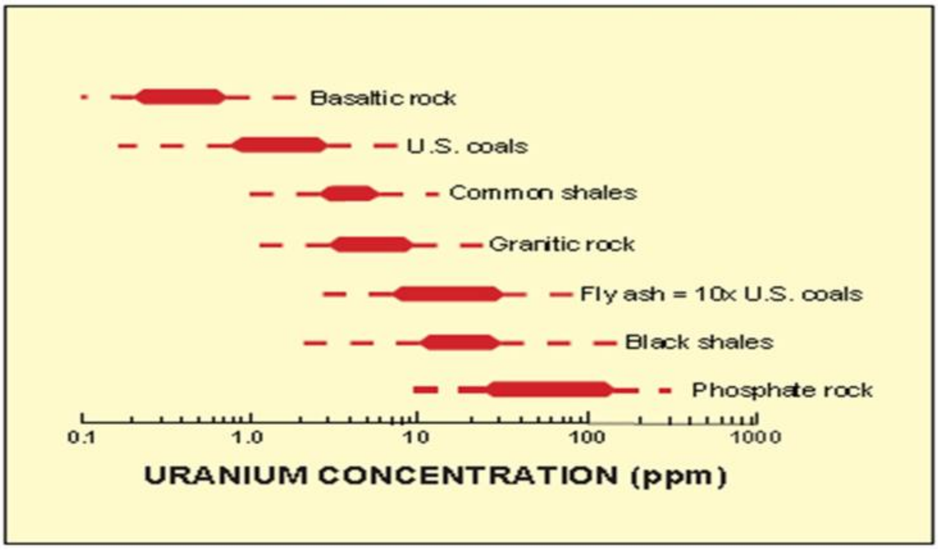
Journal of CAII (coal ash institute of India) volume – x October 2010

It is composed of oxides of iron, silicon, aluminium, magnesium, calcium, sodium and potassium Fly ash contains environmental toxic elements like barium, arsenic, beryllium, cadmium, boron, chromium, copper, cobalt, fluorine, lead, manganese, nickel, selenium, strontium, vanadium, thallium, zinc and radioactive elements.

The quantities of trace elements change according to the type of coal burnt to form fly ash. In fact, for bituminous coal, with the exception of boron, trace element quantities are similar to trace element quantities in uncontaminated soils.

Fly ashes are classified into two types by **ASTM C618**: Class C fly ash and Class F fly ash. The major difference between these classes of fly ash is the quantity of calcium, alumina, silica, and iron content in the fly ash. Chemical properties of the ash are largely influenced by the chemical content of the coal which is burned (i.e. lignite, bituminous, and anthracite). Fly ash contains many toxic metals like; As, Cr, Cd, Ni Zn, Hg, and radioactive elements like uranium and thorium. Radionuclides which are normally found in the coals get enriched into the ashes after burn up. The concentration of most radioactive elements in solid combustion wastes were approximately 5–10 times the concentration in the original coal. A 1,000 MW coal-burning power plant could have an uncontrolled release of as much as 5.2 metric tons per year of uranium and 12.8 metric tons per year of thorium.

Figure 1: Typical range of uranium concentration in coal, fly ash, and a variety of common rocks



U.S. Geological Survey Fact Sheet FS-163-97 (October, 1997)

In order to accurately to predict the mobility of radioactive elements during the coal fuel-cycle, it is important to determine the concentration, distribution, and form of radioactive elements in coal and fly ash. Thorium in coal is contained mostly in common phosphate minerals such as monazite or apatite. In contrast, uranium is found in both the mineral and organic fractions of coal. Some uranium may be added slowly over geologic time because organic matter can extract dissolved uranium from ground water. During coal combustion most of the uranium, thorium, and their decay products are released from the original coal matrix and are distributed between the gas phase and solid combustion products. The partitioning between gas and solid is controlled by the volatility and chemistry of the individual elements. After burning the coal less volatile elements such as thorium, uranium, and the majority of their decay products are almost entirely retained in the coal fly ash. Although particle emission control device like electrostatic precipitator in power stations may reach high retention efficiency, considerable amounts of fine fly ash particles are still emitted from the stack to the atmosphere because of the high rate of coal consumption. The collection efficiencies of pollution control devices are significantly lower for particles less than 10 μm in diameter, with the greatest penetration for ultra-fine particles of 0.1–1 μm diameter **(Senior et al., 2000).** It is observed that the fly ash from thermal power plant falls out upto a large distances from the plant. Heavy amount of fly ash has been observed to be falling even upto distance 3 to 4 km. it has been reported that the fallout rates of fly ash at the thermal power plant at Korba in Madhya Pradesh state as high as 300 -550 t/km^2/month in the vicinity of the the plant, about 130-550 t/km^2/month at the distance of about 2.5 km and about 60-450 t/km^2/month at the distance of about 4 km. The disposal of fly ash is considered a potential source of contamination due to the enrichment and surface association of trace elements in the ash particles (**Choi et al ., 2002**). The disposal of coal fly ash in ash pond subjects heavy metals rich materials to conditions that may result in further sequestration of the metals or to their release to the environment **(Lokeshappa, Dikshit., 2011).**

The release and transport of trace metals from coal fly ash material in the wet storage in the ash ponds is also an area of environmental concern **(Kim,2003).** The major potential impacts of fly ash disposal in ash pond are leaching of potentially toxic substances into soils, surface water and groundwater **(Praharaj et al., 2002).** The soluble salt content in ashes is closely related to the coal properties and the age of the fly ash and also to the pH and other environmental conditions **(Jankowski et al., 2006).** These solid residues (fly ash) can be leached in higher concentrations than drinking water standards and can cause contamination in drinking water sources and have negative effects on human health and on plants (**Mehara et al., 1998**). Indian thermal power plants produce about 150 million tons fly ash annually and it will reach to 200 million tons per year in near future **(Jamwal,2003).**

The problem of pollution from coal fired power station and birth defects are global. Births defects have increased by 40% from 2001 to 2006 as coal fired power stations have increased to supply more than two thirds of china's energy. Columbia University centre for children's Environmental Health showed that pollution from coal fired power station caused birth defects in China. It is reported that people living in the vicinity of a power plant has 1 to 50 percent more chances of cancer as compare to other people. In America there are high levels of birth defects of children born to parents living near to coal fired power plants. As well as pollution from uranium people are contaminated by mercury which causes birth defects such as stunted brain and body growth .This fly ash is also leached into the ground water and contaminates the ground water resources. So there is a need to predict the impact of fly ash on ground water resources. The present study is carried out near the Guru Gobind Singh super thermal power plant in Ropar, Punjab. This plant has six units of 210 MW each with total capacity of 1260MW, and total coal consumption of this is 17000 MT par day and generates 18 to 20 lakh metric tonnes solid waste in each year. This solid waste is disposed in nearby areas and about 750 acre area cover by fly ash. The power plant also emits fly ash from the chimney. This fly ash is spared over the long distance by wind and fall down on fields, on road and in the houses of local peoples and creates many health problems for local population. Many heavy metals like, may leached out from fly ash which are very dangerous groundwater pollutants and make the water unfit to consumed by human activities and other purposes. So it is very important to find out the impact of the fly ash emitted by the chimney of power plant and solid waste (coal ash) generated by the plant on the ground water near by the area of plant.

Coal fired power plants are very important source of metals to the environment. In addition to gases and fly ash emitted from these plants, the solid waste (known as the bottom ash) is a major source for metals. Bottom ash is considered a very important source of metals to groundwater **(Santoyo and Surendra, 2000).** Fly ash is heterogeneous in nature as the elements are not evenly distributed throughout. After the combustion of coal volatile elements such as As, B, Hg, Cl, Cr, Se, U, Th are condense on the surface of the fly ash particles, and forming compounds with a high solubility and essentially combined with Ca and these metal concentrated into fly ash. This results to increases the possibility of leaching of many metals **(Kukier et al., 2003).** Fine particles of fly ash, contains a significant amount of readily leachable elements **(Iyer, 2002).** Surface associated elements are therefore more susceptible to leaching in an aqueous environment. Elements which are associated with the surface of fly ash is generally found in the composition of a typical fly ash leachate. **(Dudas, 1981; Querol et al., 2001).** The extent to which trace elements are leached depends on the concentration in fly ash, mode of occurrence in the feed coal, the combustion conditions, and many processes like sorption/desorption, redox conditions and, most importantly, the pH. The trace element mobility in water is heavily pH-dependent **(de Groot, 1989).**

In coal arsenic is found in association with As-bearing pyrite **(Finkelman, 1995),** when the coals is combusted, arsenic bearing pyrite is decomposed and gives rise to a dominant surface association of arsenic in the fly ash. Leaching of Arsenic is mainly controlled by the pH as arsenic is an oxyanionic species, and maximum solubility of arsenic is found in the range of pH 7- 11. **Finkelman, 1995** found that antimony is associated with sulphides along with the pyrite**.** These compounds decompose in the coal combustion and liberate Sb as volatile species **Miravet et al., (2006)** observed that antimony leached at very acidic condition,while alkaline pH values resulted in poor extraction efficiencies. According to **Fruchter et al., 1990** the leachability of barium from fly ash did not much more depend on pH but is rather controlled by the ubiquitous Ca against which it competes for sulphate. If ca is present in large amounts in a solution it would promote the precipitation of more insoluble sulphate, more likely co-precipitated as $(Ba,Sr)SO_4$ than as $BaSO_4$ or $SrSO_4$**.** The observation of **Querol et al.,2001** support that boron is susceptible to quick leaching, despite the high ionic loads in initial leachates. Boron Co-precipitates with $CaCO_3$ under alkaline conditions **(Iwashita et al., 2005),** but this Co-precipitation does not occur in acidic-natured fly ash

(Jankowski et al., 2006). In Fly ash ,cadmium is associated with surface and it shows very low leaching in neutral and alkaline conditions **(Fruchter et al., 1990)** while values for acidic fly ash from Australia equate to 0.1 mg/kg at pH 4 **(Jankowski et al., 2004; Ward et al., 2009).** In acidic conditions, cadmium may leach out from fly ash. It was also noted that the leaching of fly ash is affected by the presence of chorine in fly ash High chloride contents enhance Cd solubility in higher pH values as a result of complexation processes that enhance the mobility **(Jones, 1995).** Hexavalent oxidation state of Chromium is potentially carcinogenic and highly soluble in aqueous media **(Huggins and Huffman, 2004),** whereas trivalent Cr (III) is not as much harmful as hexavalent and it is also less soluble. Most of hexavalent chromium reduced to trivalent as the coal is combusted (**Huggins et al., 1999). Dubikova et al., 2006** also reported the mobility of chromium species depends on pH of medium and the mobility increases with rise in the pH and show lower leaching at near neutral pH (0.02 mg/kg) and increase at high pH (around 5 mg/kg) . Hexavalent chromium (VI) has been determined in fly ash leachate, constituting up to 88% of the total chromium leached where lime flue gas scrubbing was employed, and up to 79% without such scrubbing **(Lecuyer et al., 1996)**. Earlier studies, however, indicated that all soluble chromium leached from fly ash under acidic conditions (<pH4.8) was present solely as chromium (III) **(Rai and Szelmecka 1990)**.

Cesium is very less leached in a solution and is released typically of 0.02 mg/kg for EU fly ash **(Moreno et al., 2005).** High Ca fly ash may display higher leachable concentrations of Cs (0.2 mg/kg), due to enrichment in readily soluble alkali metal-bearing salts, primarily sulphates **(Izquierdo et al., 2011).**

Piekos and Paslawska (1998) found that the leaching of fluorides from coal ash is increased with the decreasing particle size of ash and they also demonstrated that around 60 mg/kg Fluorine are leachable in water at a high L/S ratio (100 L/kg)**.** In most of the cases, the scientist suggested that Fluorine leaching is not of great concern in fly ash. **Kim et al.,(2003**) reported the iron leached less than 1000 mg/kg at pH=1.2 from 32 US fly ash samples leaching of iron decreased at neutral and alkaline pH, at neural pH the concentration of iron in a solution were below the detection limit **(Kim et al., 2003; Moreno et al., 2005)**. The concentrating of mercury is about 1mg/kg in fly ash, the elemental Hg is extremely volatile and released during combustion. The leaching of mercury form fly ash extremely low **(Nathan et al., 1999).** Mercury is a toxic element; small releases would trigger a regulatory response. However, it is also observed that Hg leaching is not of major environmental concern in coal fly ash. Lead associated with sulphides in coal and in fly ash it found in the association with surface **(Spears and Martinez-Tarrazona, 2004). Warren and Dudas** (**1988**) found that lead is probably associated with the internal glassy matrix of fly ash. The leaching of lead from fly ash is slightly increased in acidic conditions **(Jones, 1995).** The mobility of lead is controlled by the precipitation of phosphate minerals, which are highly insoluble over a wide pH range. Combustion of coal is the one of the major source of Selenium in the environment as this metal is the most strongly enriched element in coal (**Dubikova et al., 2006).** It was also observed that Selenite and selenite compounds are relatively mobile and highly soluble compared to other metalates (**Cornelis et al., 2008).**Selenium shows a complex pH-dependent leaching behaviour. Thorium is not in soluble phase in fly ash. The similar other studies suggest that Thorium is likely to be adsorbed or co-precipitated by oxhydroxides. Thorium is being poorly leached from EU alkaline fly ash **(Moreno et al., 2005).** The leaching behaviour of Uranium is studied by (**Warren, 1988**) in a Canadian fly ash and he found that uranium was partitioned approximately equally between the readily soluble and relatively insoluble phases of the ash particles. According to **Spears, (2004)** surface association of uranium in fly ash is very important**.** (**Querol et al.,1996)** conducted a test and found that U in fly ash is readily exchangeable, but not water soluble. Little U was released from EU fly ash with water **(Moreno et al., 2005).** Some uranyl-bearing phases could be controlling the leaching under acidic pH conditions, while with raising the pH, the solubility of carbonate complexes is also increased **(Warren 1988). Querol et al.,(1996)** studied that occurrence in coal plays a critical role in the behaviour of Zn in ash. In many water-based leaching tests Extractable proportions is obtained from Australian and EU alkaline fly ashes consistently ranged between 0.02 and 0.2% **(Moreno et al., 2005; Ward et al., 2003). Jones, (1995)** found that the formation of strong complexes in the presence of chloride may also increase Zn solubility**.**

(Fulekar and Dave 1985) studied coal-fired power plant of Delhi and found that fly ash contains a significant amount of arsenic which is potentially toxic if present in a soluble form. The eco toxicological studies reported to date deal with the effects of fly ash after its release from a holding pond. Fly ash has negatively charged surface area. Preliminary investigations have shown that its alkaline nature may mitigate acid mine drainage (AMD) by neutralizing pH and adsorbing positively charged metal ions **(Jackson, 1993).** Metal content associated with fly ash discharges vary widely in power plants evaluated at the Savannah River Project, in South Carolina, and the Glen Lyn Power plant in Virginia **(Cherry et al., 1976).** High aquatic concentrations on an annual basis were found released from a fly ash pond of a coal-fired fossil fuel power plant into a stream or swamp receiving system at the SRP during the 1970**.** These elevated elemental concentrations persisted in the water column and became incorporated into the sediment and then were bio accumulated by various benthic macro invertebrates **(Guthrie et al., 1986).** The study was conducted at the river Yamuna power plant site in Delhi, India compared plankton assemblages upstream and downstream of the fly ash effluent **(Walia and Mehra 1998)**. In a study done at the Thermal Power Station by (**Singh et al., 2004)** it was found that the leaching study of coal ashes over a 300 day period showed that especially Ca, Na, K, Fe, Pb and Cd leached at significant concentration levels.

Toxics like heavy metals can leach out of poorly controlled piles into storm runoff or leak from disposal sites into aquatic habitat and valued freshwater resources. In addition to solid coal combustion wastes, coal combustion produces air emissions that can contaminate water when they are washed out of the atmosphere by rain or other precipitation, eventually to join surface water resources or recharge groundwater. The presence of bottom ash deposits derived from coal combustion processes in a power plant could be a major source of metallic pollutants. Metals such as (Na, K, Ca, Ba, Al, Mg, Fe, Cu, Zn, Pb, Cd, Cr, V, and Ni) can have their origin from bottom ash. These metals may migrate to groundwater aquifers and pollute them resulting in a harmful effects to the environment and public health **(Özturk and Yilmaz, 1999).**

The amounts of trace elements released from fly ash into solution, and the rates of release, depend on three factors the total concentration of elements in the solid phases, the distribution of elements in the fly ash particles, and any incorporation of the elements into secondary solids. Minor elements present in soluble phases will be dissolved through congruent dissolution reactions. The alkaline-earth elements present on particle surfaces will be initially dissolved rapidly and pass into solution, but later, with increasing pH and element concentration, may re-precipitated to form secondary solids that are more stable during fly ash-water interaction (**Eary et al., 1990)**.

Jankowski et al., (2005) performed batch leaching tests on fly ashes collected from four Australian power stations. The behaviour of As, B, Mo and Se was investigated to obtain data on their potential for mobilisation during fly ash–water interactions. The most mobile of the four elements leached were Mo from alkaline fly ashes and B from acidic fly ashes. Arsenic concentration increased with time in leachate solutions from acidic and alkaline fly ashes

The impact of fly and bottom ash disposal ponds on groundwater quality was investigated at the coal-fired Columbia Power Plant at Portage, Wis. Analyses were performed for 16 major and minor elements, pH and conductivity. Data for a 3-yr monitoring program established the existence of large B, Na and SO_4 plumes in the groundwater system surrounding the ash disposal area. Substantial amounts of B, Na and SO_4 were present in the plume and portions were discharged into an adjacent wetland as the plumes moved with groundwater flow. Movement into the groundwater of heavy metals such as Cu and Zn was not observed and their concentrations are likely attenuated in the pond **(Chesters and Andren 1987)**

(Demirak et al., 2005) studied the presence of trace metals such as Hg, Pb, As, Cd, Cu, Fe, Mn, and Zn in groundwater samples obtained from three wells, an ash-pond and drinking water located near the Yatagan thermal power plant, Turkey. As, Hg, Cu, and Zn contents of the groundwater were lower than those reported in the European Economic Community and WHO guidelines The mean concentrations of Fe and Pb in groundwater of well 1 (0.5,0.037 mg/kg),well 2 (0.98, 0.069 mg/kg), and well 3 (1.315, 0.06 mg/kg) were higher than those reported in WHO guidelines. **Yadav et al., (2010)** studied near the Suratgarh Super Thermal Power, Rajasthan in India and the chemical analysis of the water samples collected from tube wells near the ash ponds revealed pH (8.7). The enrichment of some elements above WHO guidelines for drinking water denotes significant contamination of the groundwater from the toxic elements leached from the ash pile.

A Study assessed the impact of an Anpara and Renusgar coal-based thermal power plants (India) on drinking water sources. In this work, the concentration of trace metals such as Pb, Cd, Ni, and As in groundwater samples obtained from hand pumps located near these power plants were measured. The concentration levels of all the studied heavy metals in groundwater were found to be higher than the maximum acceptable limits of World Health Organization for drinking water **(Agrawal et al., 2011).** The Farakka Super Thermal Power Plant (STPP) operating in the state of West Bengal in India is another source of arsenic contamination in the nearby area. The analysis of fly ash deposited in the fly ash disposal ponds indicates arsenic content of the order of 400-500 µg/g. The ash generated from thermal plant finds its way into open environment i.e., air, water and soil from atmospheric precipitation, spillage from pipelines carrying fly ash slurry to ash ponds and from decanted water of ash pond. It contaminates groundwater due to seepage and mixing of fly ash into surface and subsurface water **(Jain,1998)**

At Vijayawada thermal power station, Andhra Pradesh, ground water quality monitored has been deteriorated due to the presence of fly ash ions (macro and micro such as Fe, Ca, Mg etc.) which were leached out from the ash up to some extent. The contamination is likely to increase in the case of toxic and other ions with the passage of time **(Suresh et al., 1998). Praharaj et al., (2002)** has reported that groundwater close to the ash pond in Angul, Orissa is highly contaminated with Fe, Ba, Cu, Mn, S, Pb, V, and Zn. This is due to very high leachability of many trace elements from fly ash by the infiltrating rainwater. leaching of elements from coal fly ash by rainwater produced concentrations of As in the leachate up to 260µg/L. This concentration is 26 times the United States Environmental Protection Agency (US EPA) limit and the WHO recommended value for drinking water**.**

Walia et al., (1997) studied the near Indraprastha Thermal power station situated at west side of river Yamuna. They tested physio-chemical parameters at three sites. One is fly ash pond, second one was non contaminated area of river, and third one was contaminated area of river and reported higher concentration of several elements in Yamuna.

A study was conducted in and around the ash disposal sites of Kolaghat Thermal Power Plant in West Bengal. The high concentration of the toxics (As, Al, Li, As, Zn, Ag, Sb, Si, Mo, Ba, Rb, Se, Pb) in the water samples implies significant input from the ash pile due to leaching **(Mandal et al., 2007)**. Ground water test conducted at Motera ash pond site and other surrounding areas near the Sabarmati thermal power station near Ahmedabad, recorded fluoride content of over 1.85 ppm as against the permissible limits of 0.6 ppm to 1.2 ppm**. (Misra, Leena ;1997)** .

Mehnert et al., (1996) in their study reported that the potentially toxic elements Ag, As, B, Ba, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se, and Zn can be leached to groundwater from fly ash. The leaching effects and groundwater status in regard to an increased level of As, Hg, Pb, Cd, Ni, and Cr were also observed by another worker in context of fly ash**. Fytianos and Tsaniklidi (1998)** studied that those metals generally found to leach to the greatest extent were Cd, Cr, and Pb. Simultaneously; it was observed that the coal fly ash has the potential to release trace elements into soil, surface water, and groundwater. The disposal of coal fly ash can result in releases of leached metals into soils, surface, and groundwater. Most of these elements are able to accumulate in soils and sediment **(Kim and Kazonich, 1999)**

In a report, **Research Communication (2005)** it is mentioned about the danger thermal plants pose to natural water sources: The enrichment of some elements (Al, Fe, As and Mn) above WHO guidelines for drinking water denotes significant contamination of the groundwater from the toxic elements leached from the ash pile. All ground water in the region around thermal power plants, where the fly-ash ponds are not properly controlled are vulnerable to metal contamination due to waste disposal and leachate percolation. **Electric Power Research Institute, USA (2006)** (EPRI) tested leachate liquid collected from wells, ponds or seeps at coal ash dump, 29 coal ash landfills and ponds and found hexavalent chromium at hundreds of times the proposed California drinking water goal at 15 coal ash disposal sites. The Nevada Department of Environmental Protection determined that coal ash contamination from impoundments at the Reid Gardner Generating Station spread from the dump site and found arsenic as high as 31 times the federal drinking water standard in an off-site well. Arsenic levels in onsite groundwater exceed federal drinking water standards by 73 times. Groundwater wells indicate arsenic pollution consistently over 10 times the federal drinking water standard during the past three years, with a maximum concentration of 26 times the drinking water standard. Other pollutants in the groundwater from coal ash include fluoride and manganese.

Goodarzi and Muki (2000) studied the possibility of metal leaching from coal seams to groundwater in the Sydney Basin, Nova Scotia, Canada. They analyzed 25 drinking water samples collected from various locations in the Sydney area to determine the concentrations of 7 major elements (Na, K, Al, Ca, Mg, Fe and Zn) and 13 trace elements (Mn, As, Ba, Be, B, Cd, Cr, Co, Cu, Ni, Pb, Se and V). Most samples have slightly elevated concentrations of Cu and Zn but within the recommended guidelines. Water samples were found to have low concentrations of all other elements determined. **Tamasi et al., (2003)** studied trace elements levels in drinking water in Siena and Grosseto districts, South Tuscany, Italy. The concentration of Fe in eight samples was higher than the MAC. The concentration of As in one sample was higher than the MAC and lower than the MAC, but relatively high in the rest of the samples.

Costa and Rydin (2000) studied the concentrations of four metals (As, Hg, Pb and Zn) in the soil and groundwater in Estarreja, Portugal. Estarreja is a power plant area. They found that some sample are exceeding the higher limit prescribed by WHO. **Giuma et al., (2005)** collected forty groundwater samples from water wells nearby Soma power plant in order to evaluate the effect of the power plant and the ash piles on the groundwater. They found that Fe concentrations in 12 wells were higher than the WHO, the Turkish and EC guidelines and Zn concentrations in 5 wells were higher than the EC guidelines. Zn concentrations were not higher than the Turkish guidelines. Pb concentrations in 8 wells were high but not higher than the guidelines. The other anthropogenic elements were within the guidelines **Khan et al., (2005)** recorded Elevated concentration of heavy metals (i.e. Pb, Cr, Hg, Cd, Fe, Cu, Ni, Co, Zn and Mn) in untreated wastewater discharged from mine pits, flyash ponds. This study revealed that some of the more toxic metals (Hg, Cr, and Co) exceed the maximum acceptable limits for irrigation. A study was done by **Deshmukh et al., (2012)** in the sub-watershed surrounding the ash ponds in the vicinity of Koradi near Nagpur in Maharashtra, India. Results indicates that the sulphate concentration was very high (1,000 mg/L) in samples close to the ash pond and in its downstream direction. The fluoride concentration exceeded the BIS limits in one sample.

Dubey et al., (2011) reported the source and origin of anthropogenic arsenic contamination in the parts Delhi with special emphasis on the Yamuna flood plains. The study revealed that arsenic concentration was well beyond the safe limits set by WHO. Analysis of samples collected extensively along Yamuna flood plains showed that more than 55% had arsenic contamination beyond the WHO limits of 10 ppb. The maximum value of arsenic in coal and fly ash from Rajghat coal based thermal power plant contained 200 and 3200 ppb. **Nalawade et.al., (2012)** investigated the underground and surface water samples from the surrounding areas of fly ash dumping site near Parli Thermal Power Station in India . The heavy metal pollution index (HPI) of the underground and surface water samples showed that, concentration of certain heavy metals was above permissible limit. The heavy metals like As, Hg and Zn showed highest concentration. The heavy metal pollution index indicated that leaching of fly ash contaminates the groundwater as well as surface water. **Bhat et al., (2012)** carried out a study to assess the contamination of water sources in Yellur and surrounding villages closer to a thermal power plant in Udupi district, Karnataka State, India. This study indicated that the well, stream and pond water within the core zone was contaminated with heavy metals and the levels were higher than the maximum acceptable limits of the stipulated drinking water guidelines. Physico chemical analysis showed, Turbidity, TDS, Chlorides, Sodium, Potassium and Hardness of samples of core zone were exceeding the maximum permissible limits of WHO drinking water guidelines. **Sarode et al. (2010)** analysed the ground water samples in the vicinity of ash dumping sites of Bhusawal Thermal Power Plant in India for heavy metal concentrations and results obtained were compared with Indian and WHO permissible limits. The concentrations of Ni and Pb were slightly higher than WHO permissible limits but below the Indian standards. The concentration of Cu was within the WHO permissible limits but slightly higher than Indian Standards.

Beqa et al .,(2005) examined the influence of ash disposal site of thermo electric power plants of Kosovo A in ground water quality. They found that heavy metals and sulphate ion, moves the fastest in groundwater and it serves to follow the influence of the ash dump site of the underground water quality. The variability of their concentration indicates the emphatic changes of the water quality to compare with the initial zero. The hydro mix disposal of the ash with water, contain a considerable amount of sulphates which contribute in ground water pollution of this area. For all water wells under impact zone of the ash disposal site characterizes with high mineralization.

Monica and Violeta (2008) carried a study in the proximity of the Arad thermal power plant Arad city (Romania). This investigation revealed that pH, chlorides, sulphates, heavy metals in drillings well was exceeded from accepted limit. A field investigation at Damoda abandoned open cast mine, filled with pond ash of Chandrapura thermal power plant in India revealed that concentration of manganese in ground water beneath the ash filled mine has been found very high (maximum up to 6.0 mg/L). But its migration to a long distance has not been seen (**Prasad, Mondal., 2009**). A study carried by **Khan et al., (2012)** at around the Singrauli coal field, district Singrauli, Madhya pradesh, India the physico chemical analysis showed alkaline nature of water, soft to moderately soft, TDS and total alkalinity exceeded the desirable limit. Sulphate and potassium exceeded in limit at some locations, whereas sodium and chloride show higher values. The minor ions like copper and zinc show values within desirable limits whereas iron, cobalt, and chromium showed higher values than the desirable limits which deteriorated the quality of water.

Alper B**aba el al., (2003)** carried a study to determine the effect of Yatagan Thermal Power plant and its waste disposal on surface and ground water. The results of chemical analyses showed that the concentration of $SO2^{-4}$, Ca^{2+}, Pb^{2+}, Cd^{2+}, Sb^{2+} exceeded the Turkish Drinking Water limits, the U.S. EPA maximum allowable limits and WHO. **Pathak, Khatri; (2012)** carried a study to analysed the radioactive element mainly uranium in water samples collected from Guru Nanak Dev Thermal Plant, Bathinda and Suratgarh Super Thermal Power Station, Suratgarh. Uranium concentrations in water were analyzed near the two thermal plants. The uranium concentration was in the range of 0.769ppb to 76.499ppb. It is relevant to indicate that the EPAs prescribe 30 ppb as a standard for uranium in drinking water. Sewerage water of Guru Nanak Dev Thermal Plant, Bathinda has maximum uranium that is 76.499 ppb or 0.076mg/l. and about 20% sample exceed the permissible limit recommended by the WHO for drinking water. The mean uranium concentration for the control water sample was negligible, which is lower compared with the observed uranium concentration in water samples collected near the both thermal plants

In **2011,** the **Bhaba Atomic Research Center, India** released a study that reported a high uranium concentration in Bathinda and its peripheral area near two coal-fired power plants. The report noted that high levels of uranium were found in the groundwater supply. The study also stated that: "Ashes produced in thermal power plants may contain high levels of natural radioactivity and constitute a potential health hazard to the power plant personnel and to the population living in the vicinity, due to fly-ash releases, fly-ash depositions and fly-ash industrial utilization

Chapter 3 Lacunae & Objectives

Lacunae

1. Roopnagar has a super thermal power plant with the total capacity of power generation1260MW and total coal consumed is 17000 MT per day. There is no report of groundwater analysis in the target area.
2. To study the effect of fly ash generated from thermal power plant on ground water quality, analysis of groundwater in upwind side and downwind side from the thermal power plant is planned this type of analysis has not been carried out in Punjab and in fact very few studies have been carried throughout the world.
3. Source and composition of coal used in power plant of Roopnagar is similar to coal which is used in thermal power plant of Bathinda which is well known for groundwater pollution with heavy metals. So, analysis of groundwater of Roopnagar is planned to be carried out

Objectives

1. Characterisation of groundwater quality in the vicinity of thermal power plant.
2. Comparative study of groundwater quality between upwind side and downwind side and also upstream side and downstream side.

Chapter 4 Materials and methodology

4.1 Area of study

Study site, the prestigious project of Guru Gobind Singh Super Thermal power Station is situated Near Village Ghanauli on Chandigarh/Ropar Nangal Road 12 km from Ropar 55 km from Chandigarh (between the north latitude 30°-32' and 31°-24' and east longitude 76°-18' and 76°-55). GGS STPP is a coal based thermal power station having six units of 210 MW each with total capacity of 1260MW. The coal requirement for this plant is 17000 MT per day and is being transported from the coal fields of Bihar, West Bengal and Madhya Pradesh from more than 50 sources called collieries. Distance of these sources is between 1417 km and 1560 km. The requirement of water for the plant is 750 cusecs (cubic meters of water per second) and raw water is drawn from from Nangal Hydel Channel directly through open channel and MS pipe and is collected in raw water reservoir. The dykes, where fly ash is disposed is spread over an area of 750 acres the ash disposal rate of 18 to 20 lakh metric tonnes per year by the plant 4 lakh metric tonnes of fly ash is lifted by the ACC and Ambuja (both cement companies) every year.

4.2 Characterizations of groundwater samples from different sites

The various water quality parameters were studied and their tests will be carried out. Experimental investigations were performed as per APHA 2005 for analyses of pH, Total Dissolve Solid (TDS), Alkalinity, Chloride, Total Hardness, Calcium, Magnesium, trace metals.

(1) **Alkalinity:** Alkalinity of water is the capacity to neutralise acids. Alkalinity of natural waters may be attributed to presence of salts of weak acids such as bicarbonates phosphates, silicates and borates, which induce buffer capacity and resists the lowering of pH. Alkalinity present in a water sample was determined by titration method. The water sample was titrated with standard acid to phenolphthalein end point and then continuing the titration to methyl orange end point.

(2) **Hardness:** Hardness was originally defined as the soap consuming capacity of water. This soap consuming capacity is mainly due to the presence of calcium and magnesium ions in the water; these react with the sodium salts of long chain fatty acid present in the soap to form insoluble scums of Ca and Mg saps having no detergent value. other metal

ions such as those of Fe, Mn, Al, Ba react in the same way and so could be referred to as hardness, but natural waters rarely contains more than traces of these metals. Hardness of water was determined with the help on titration method. The water sample was titrated by EDTA solution and use Eriochrome Black –T as indicator.

(3) **Chlorides:** Chloride, in the form of chloride ion is one of the major inorganic anion in water. In potable water, salty taste produced by chloride concentration is variable and depends on the chemical composition of water. In water samples the concentration of chlorides may be determine by argentometric method. In this method the water sample was titrated by standard silver nitrate (0.00141 N) solution by using potassium chromate indicator.

(4) **TDS (total dissolve solids):** TDS refers to total amount of total dissolved solids in a water samples

(5) **Sulphate:** The sulphate ion is one of the major anions occurring in natural waters. It is of importance in public water supplies because of its cathartic effects. Sulphate may determine by gravimetric method. According to this method sulphate is precipitated in a hydrochloric acid (HCl) solution as barium sulphate by addition of barium chloride. The precipitate was carried out near the boiling temperature, after a period of digestion the precipitate was filtered , washed with water until free of Cl, ignited or dried and weighted as $BaSO_4$

(6) **Heavy metals:** Generally heavy metal is not found in nature ground water but due many anthropogenic activities heavy metals may leached into groundwater and pollutes it. The presence of heavy metals is very dangerous to human consumption. The concentration of heavy metals in water sample is determined with the help of instruments like AAS and ICPMS.

(7) **Uranium:** Uranium is a radioactive element. It presence in water is very harmful as uranium is a carcinogenic metals. It may be leached into the groundwater by both anthropogenic activities and by some natural process. The concentration of uranium was determined by the help of a instrument named ICPMS.

Table 3: WHO permissible limits for drinking water

Parameters	Permissible value
pH	6.5-8.5
chloride	200 mg/lt
Sulphate	200 mg /lt
TDS	500 mg/lt
Alkalinity	200 mg/lt
Hardness	300 mg/lt
Fe	0.03 mg/lt
Cr	0.05 mg/lt
Zn	5 mg/lt
U	0.015 mg/lt
Pb	0.01 mg/lt

Chapter 5 Result and discussion

This chapter presents results of the study conducted and discussion on results. The thermal power plants brought serious environmental imbalance due to generating industrial waste.

5.1 Climatic conditions and hydrology of area of study

The plant is located in district Roopnager within an average annual rain fall of about 775.6 mm. Relative humidity is high, averaging about 70 percent during monsoon The district receives normal annual rainfall of 855 mm, which was spread over 41 days. 78% of the annual rainfall is contributed by southwest monsoon. The climate of the district can be classified as tropical steppe hot and semi-arid type, and groundwater occurs under phreatic condition in the shallow aquifers of Quaternary alluvium deposits, Inter Montane valley and Kandi formation while groundwater occurs under leaky confined to confined conditions in the deeper aquifers of alluvium. In the case of unconfined aquifers, the depth to water level varies from 2.7 to 10.3 m during pre-monsoon and 2.1 to 11.6 m during post-monsoon. Groundwater flow is towards south and south eastern direction whereas in the south eastern part of the district, the groundwater flow is in the south and south western direction. The water table elevation is highest near the hills and lowest in the south eastern part, which in turns reflects the topographic gradient. The hydraulic gradient is steeper near the hills and gentles near the plains, and the wind direction is dominated to west south.

5.2 Sampling sites and sampling

After collecting the information about the local climatic condition and hydrology, the samples was collected from different villages; Duburji, Ranjeetpura Chakdera, Lodimajra, Gonimajra, Rawalmajra, Lohghar fidhe, Ghanouli, Awankot. All the samples are collected from both upwind side and downwind side and the downstream direction of groundwater flow. Samples were taken from the hand pumps. Information about depth of the hand pumps and installation year was also collected from households. All samples were collected in clean plastic bottles. Samples were stored in cold room in acidic conditions for metals analysis.

Figure 2: Location of sampling sites (villages) in the vicinity of GGS thermal power plant, Ropar district.

5.3 Characterization of water from upwind and downwind side

Laboratory tests were performed for determining the effect of fly ash leaching on groundwater quality. For this purpose, different parameters was analysed like; pH, total dissolve solid, alkalinity, chloride, sulphate, heavy metals and uranium for groundwater sample from both upwind and downwind sides and also for downstream and upstream side. After analysed the metals concentration in fly ash leachate (table 4) the metals concentration was detected by AAS and ICPMS.

Table 4: Metal concentration in fly ash leachate

	Metals	Concentration in mg/lt
1	Iron (Fe)	29
2	Lead (Pb)	0.60
3	Chromium (Cr)	0.40
4	Nickel (Ni)	0.10

The pH was found to be between 7.8 to 8.5 with an average pH was 8.2 in downwind side and 7.7 for the upwind side. The pH levels were reported to be between 5.8 to 10.5 at Bokaro Thermal Power Station **Singh et al., (1999)**. pH of water at all station was almost neutral. According to WHO low pH is likely to give rise to off take and promote the corrosion. The limit is 6.5 to 8.5. So all the sample are under limit. The total hardness was found to be 374 mg/lt in downwind side and 325 mg/lt in the upwind side. All samples had high concentration of dissolved solids in both sides but the concentration was slightly higher in the downwind side. The total dissolved solid (TDS) was found as minimum 500 mg/lt and maximum 800 mg/lt with an average concentration of 630 mg/lt in downwind side and 562 in upwind side. In downwind side the chloride concentration was found to be 82 mg/lt and 42 mg/lt in the upwind side. Alkalinity is the measure of the water samples ability to neutralize hydrogen ions. The result showed that alkalinity was also higher in downwind side. The alkalinity was found to be 278 mg/lt for downwind side and 219 mg/lt for upwind side. In water samples iron might be present in true solution, in a colloidal state that may be peptized by organic matter, in inorganic or organic matter or in relatively coarse suspended particles. The excess iron affects organ function, presumably by direct toxic effect. Excessive iron stores exceed the body's capacity to chelate iron and free iron accumulates. This unbound iron promotes

Table 5: chemical analysis of ground water sample from upwind and downwind sides of GGS thermal power plant, Ropar.

Sr. No.	Parameters	Values of different Physico-chemical parameters									WHO limits
		Downwind side					Upwind side				
		Doburji	Lodi Majra	Gunu Majra	Lohghar Fidde	Rawal Majra	Ranjeetpura	Chak dera	Ghanouli	Awankot	
1	pH	7.8	8.36	8.25	8.28	8.56	8.14	7.42	8.2	7.4	6.5-8.5
2	Hardness (mg/lt)	354	390	388	385	351	280	326	318	376	300 mg/lt
3	Alkalinity (mg/lt)	246	320	260.4	285	246	237.4	228	261.8	249	200 mg/lt
4	TDS (mg/lt)	778	660	552	618	544	506	570.8	596	578	500 mg/lt
5	Chlorides (mg/lt)	66.6	83.8	108	92	61.8	31	48.4	35.6	54	200 mg/lt
6	Sulphate (mg/lt)	145	165	130	210	128	100	210	120	100	200 mg /lt

free radical formation in cells resulting in membrane lipid per oxidation and cellular injury. The iron concentration was found to be 0.084 ppm to 0.04 ppm in downwind side. The concentration was higher than the WHO recommended limit for drinking water and in upwind side the concentration of 0.045 to 0.024 ppm is somewhere closer to the upper imits. Iron concentrations close to 1 ppm were also reported in most places near the ash ponds at Kolaghat Thermal Power Station, West Bengal **(Mandal and Sengupta, 2005)**.

Low-Level exposure to chromium can irritate the skin and cause ulceration. Long-term exposure can cause kidney and liver damage, and damage to circulatory and nerve tissue. Chromium often accumulates in aquatic life. The concentration of chromium in downwind side was found in the range of 0.056 to 0.035 ppm and in upwind side it was 0.041 to 0.023 ppm. The WHO recommended limit for Cr in drinking water is 0.05ppm/lt. The concentration of lead in downwind side was 0.023 to 0.001 ppm which was higher than WHO recommended limit (0.01 ppm) at some sites and 0.001 to 0.005 ppm in upwind side. Lead is known to cause serious conditions such as anemia, brain damage and kidney failure. And, because of size and charge similarities, lead can substitute for calcium and accumuated in bones; children are especially susceptible to this effect. **Aggarwal et al., (2011)** also carried a study at Anpara and Renusgar coal-based thermal power plants (India). They observed that lowest concentration of Pb was 0.2 ± 0.02 mg/L which is 20 times higher, and the maximum concentration 1.28± 0.01 mg/L was 128 times higher than WHO recommended limit for drinking water. Zinc is a trace element that is essential for human health. But too much zinc can still cause serious health problems, such as stomach cramps, skin irritations, vomiting, nausea and anaemia. Very high levels of zinc can damage the pancreas and disturb the protein metabolism, and cause arteriosclerosis. The concentration of Zinc in downwind side was to be found 0.8 to 04 ppm and in upwind side it was 0.4 to 0.09 ppm. The concentration of Zn was within the WHO permissible limits but it was higher in downwind side as compare with upwind side.

The results of uranium concentration levels in groundwater samples are quite interesting when their level are compared in the groundwater samples collected from locations on downwind side to those in the upwind side. Wind rose for the month January, February, March, April (figure 3 to 6) indicated that most of the occasions the wind direction had been from east to west. Hence, sampling sites like Dubuji, Lodimajra, Gonimajra, Lohghar Fidde and Rawal Majra were identified as downwind sites and Ranjeetpura, Chakdera, Ghanouli, Awankot, ect as the upwind sides. Multiple samples were taken from each sampling site and

Table 6: Metal content in groundwater samples from upwind and downwind side of the GGS thermal power plant, Roper

S.no	Metals	Location of sampling									WHO limits
		Downwind side					Upwind side				
		Doburji	Lodi Majra	Gunu Majra	Lohghar fidde	Rawal Majra	Ranjeetpura	Chak - dera	Ghanouli	Awankot	
1	Fe (PPM)	0.06	0.08	0.08	0.07	0.04	0.045	0.024	0.030	0.025	0.03 mg/lt
2	Cr (PPM)	0.035	0.047	0.04	0.056	0.03	0.023	0.02	0.01	0.02	0.05 mg/lt
3	Pb (PPM)	0.01	0.013	0.022	0.015	0.001	0.001	0.005	0.007	.004	0.01 mg/lt
4	Zn (PPM)	0.56	0.78	0.81	0.65	0.41	0.087	0.04	0.3	0.09	5 mg/lt

characterised for different water quality parameters like pH, hardness, alkalinity, total dissolved solid, chloride, sulphate, and some heavy metals. Among heavy metals iron, chromium, lead, zinc, and uranium were studied.

Uranium is a naturally occurring metal, which is widespread in nature. It is present in the ocean and certain types of soils and rocks, especially granite. Natural uranium is also released into the environment from various activities such as the use of phosphate fertilisers, mining, and combustion from coal and other fuels. Coal is composed of organic matter, but inorganic matter in coal are minerals and trace elements. Some trace elements in coal are naturally radioactive. These elements include uranium (U), thorium (Th) and their decay products. The combustion of coal results in the release of radioactive elements in the environment. When coal is burned into fly ash, uranium and thorium are concentrated up to 10 times their original concentration in fly ash. The major part of the uranium (99%) escapes from the chimney, while the rest remains in the bottom ash. Fly ash escapes from the stacks of coal-fired power plants in 1-3 % of the total coal ash.

Table 7: Concentration of uranium in coal for some major countries

Sr. no	Country	Concentration of U in ppm
1	Australia	0.01-4.5
2	Brazil	2.7-19
3	Canada	0.2-7.2
4	China	0.16-21
5	Germany West	less than 1 – 13
6	India	1.1-3.6
7	New Zealand	0.015-0.46
8	South Africa	1.2- 7.3
9	Turkey	1.4-6.4
10	UK	1.1- 3.0

(Swaine,1990)

Table 8: uranium content in groundwater samples from upwind and downwind sides of GGS thermal power plant Ropar.

Sr no	Concentration of uranium in ppm								WHO limits	IS limits
	Downwind side				Upwind side					
	Location	Minimum value	Maximum value	Average value	Location	Minimum value	Maximum value	Average Value		
1	Doburji	0.02	0.03	0.028 ±0.002	Ranjeetpura	0.0	0.2	0.02 ±0.001	0.015	0.030
2	Lodi Majra	0.01	0.02	0.025 ±0.001	Chak -dera	0.0	0.0	0.0		
3	Gunu Majra	0.01	0.03	0.025 ±0.002	Ghanouli	0.0	0.02	0.021 ±0.001		
4	Lohghar Fidde	0.03	0.05	0.044 ±0.003	Awankot	0.0	0.01	0.002 ±0.001		
5	Rawal Majra	0.02	0.04	0.030 ±0.002	Others	0.0	0.1	0.005 ±0.001		

Table 9: uranium concentration in all 50 samples from upwind and downwind sides of GGS thermal power plant, Ropar

Sr.no	Concentration of uranium in groundwater (ppm)									
	Downwind side					Upwind side				
1	0.03	0.01	0.02	0.0	0.02	0.0	0.0	0.0	0.0	0.0
2	0.0	0.03	0.03	0.02	0.02	0.0	0.01	0.01	0.01	0.0
3	0.02	0.04	0.02	0.03	0.02	0.0	0.02	0.0	0.0	0.02
4	0.01	0.03	0.03	0.04	0.05	0.01	0.0	0.02	0.0	0.0
5	0.01	0.03	0.01	0.02	0.03	0.02	0.0	0.02	0.0	0.02

The fly ash spreads over long distances due to wind and deposits in the fields and roads. Uranium from the fly ash leached into the groundwater and contaminates soil and water. In the downwind side, the maximum value of uranium was 0.05 ppm (out of 25 samples). From this group of samples the concentration of uranium in 18 samples was higher than WHO recommended limit of 0.015 ppm. In the upwind site, the concentration of uranium was very low and below the detection limit in 15 samples out of 25 samples. Only 5 samples have uranium concentration higher than 0.015 ppm. These samples were collected from villages Ranjeetpura and Ghanouli situated closer to dump site and power plant. **Singh et.al (2008)** also conducted a study and found that the maximum concentration of uranium was 0.04 ppm in the Lohghar fidde village. WHO had recommended 15 μg $l^{-1}$of uranium in water as safe limit, whereas United States EPA had recently recommended 30 μg l^{-1} of uranium in water as the safe limit for drinking water. All the results shows that the chimney of power plant emits large amount of fly ash which contains fine particles of many elements that are spread over a long distance with the help of wind and the leached out into the ground water. Metals are also leached into groundwater from the fly ash dumping site. It causes contamination in groundwater and reduces the quality of potable water.

A comparison of the data (table 6) of metal concentration in the downwind side and upwind side shows that the metal iron, chromium, lead, zinc are higher than in upwind side indicating a strong influence of the dumping site and spread of fly ash from the chimney of G.G.S Thermal power plant. Although the contamination levels of metals not exceeding WHO limits except for iron in downwind side, yet clearly indicate influence of fly ash on groundwater quality. The study concentration levels of uranium in groundwater samples (table 8) are of special interest because of its potential carcinogenic nature. Distirclly higher concentration levels of uranium in the sampling sites of downwind side supports the hypothesis that fly ash is responsible for deteriorating the groundwater quality particularly, with regards to uranium contamination levels.

Figure 3: Wind rose of district Ropar for January 2013

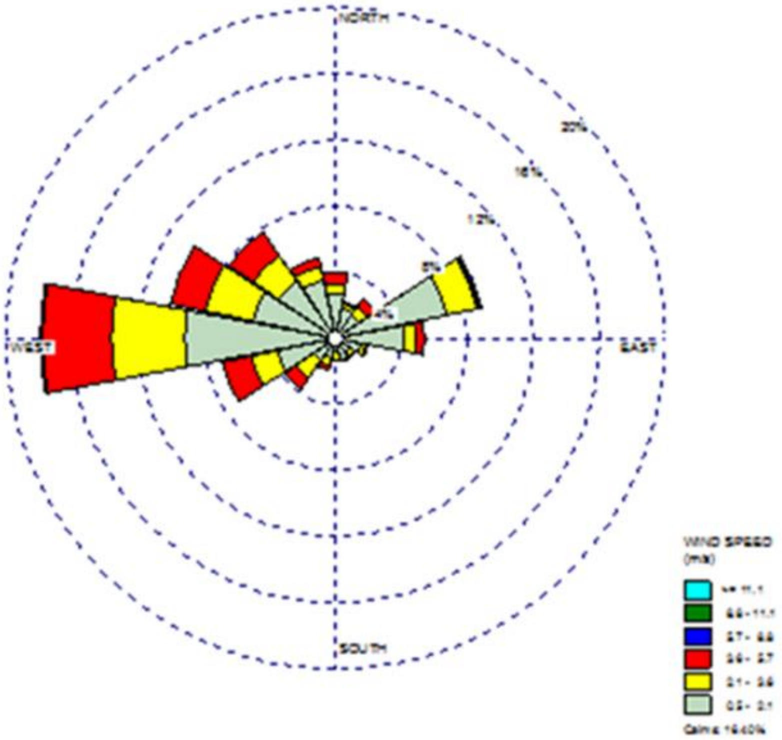


Figure 4: Wind rose of district Ropar for February 2013

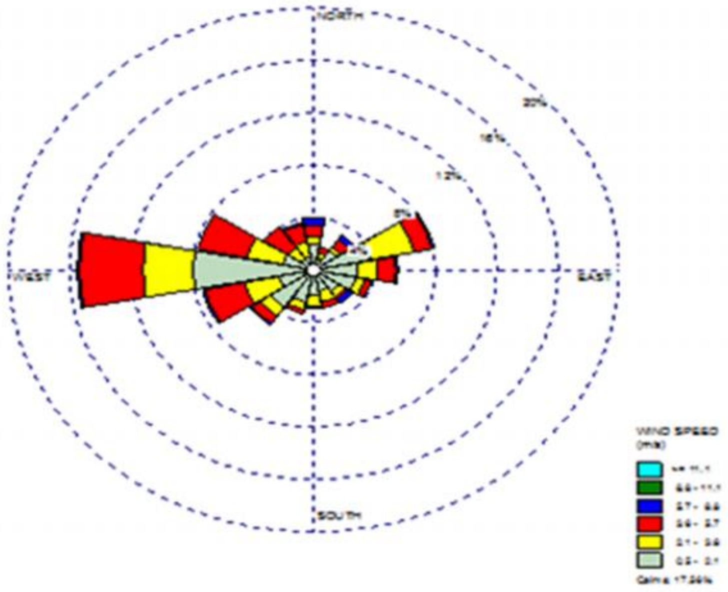


Figure 5: Wind rose of district Ropar for March 2013

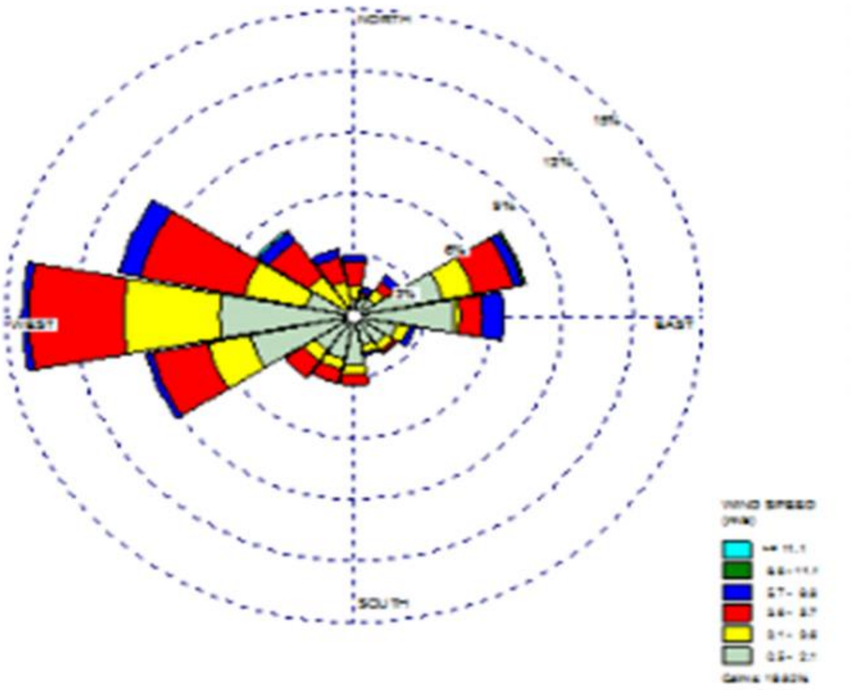
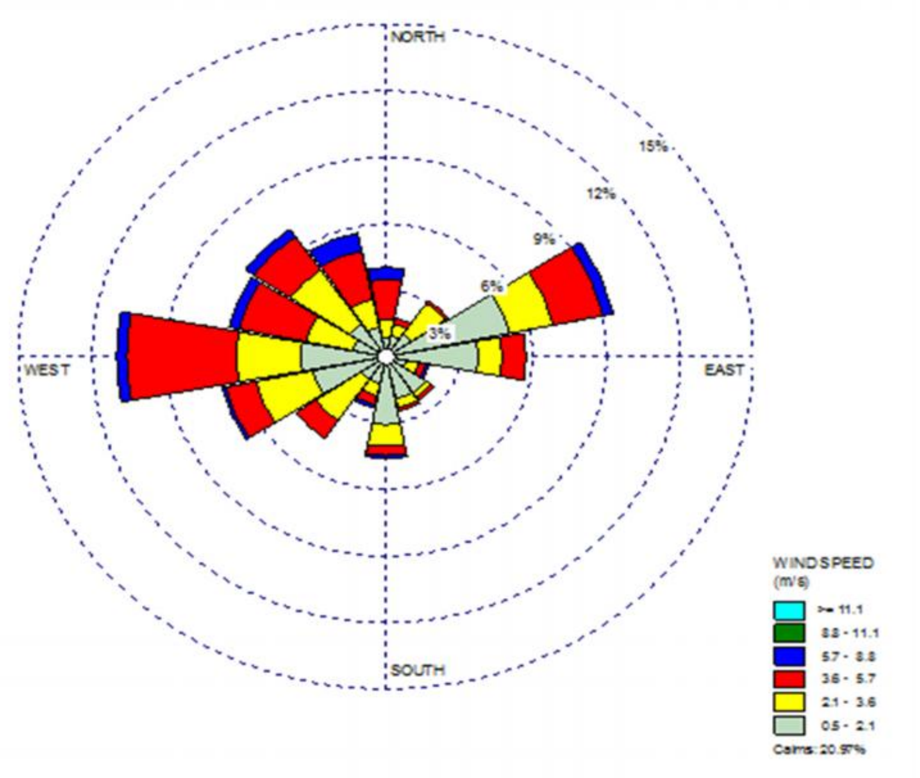


Figure 6: Wind rose of district Ropar for April 2013



Chapter 6 Conclusion

In this study, fifty groundwater samples were collected from different villages in the vicinity of Guru Gobind Singh super thermal power plant in order to evaluate the effect of the power plant and the ash piles on the groundwater quality. The results showed that not only fly ash dumping site, but also fly ash emitted from the chimney of power plant has an adverse effect on groundwater quality in the vicinity of thermal power plant. Samples were collected from hand pumps in sampling bottles and different physico chemical parameters were analysed. The concentrations of metals were determined with the instruments like; AAS and ICPMS. The results of this study revealed that metal concentration was high in downwind side of thermal power plant as compared to upwind side. Concentration of Fe in most of the samples collected from downwind side were higher than the WHO guidelines value and Zn concentration was within the limits on both sides as recommended by WHO but the concentration was higher the downwind side as compare to the upwind side. Lead is also leaching out from fly ash as lead concentration was high in downwind side and at some places the value of lead concentration was exceeded from the WHO recommended value. Chromium was also higher in all samples collected from downwind side as compared to upwind side and in some samples the concentration of chromium was higher than the recommended value. Concentration of uranium was also determined and results showed that uranium concentration was higher in downwind side and the maximum concentration was 0.05 ppm which was more than 3 times WHO recommended value. In the upwind side the value of uranium was below the detection limit in most of the samples. Chemical analysis also showed that the pH, hardness, alkalinity, chloride, TDS were also higher in downwind side (also downstream side). From the results, it can be concluded that the metals present in coal fly ash migrate into groundwater and pollute it and contribute to degradation of land, water and air. So, there is a need to change in land use pattern and to adapt new methods for fly ash utilization**.** The countries like Germany, UK, Denmark and Netherlands utilize fly ash up to 70% in construction material but in India its utilization is less near 15%. Use of fly ash in agriculture provides a feasible alternative for its safe disposal and improves soil environment and crops production. However, a judicious amendment strategy has to be developed to abate the land and water pollution from the heavy metals presents in it.

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