ENVIRONMENTAL CONCERNS FOR GEOTHERMAL DEVELOPMENT IN ETHIOPIA

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ABSTRACT

The Environmental Concerns of Geothermal Development in Ethiopia will fluctuate dependin primarily on the location and geological setting of the geothermal prospect. In Ethiopia the locatio of the high enthalpy geothermal fields with which this paper is mainly concerned are concentrated i the Main Ethiopian Rift (MER) and the Afar Depression of Ethiopia (AfDE). In the MER th Geological setting of the geothermal fields is near volcanic centres which act as heat sources whil in the AfDE it is along axial ranges, incipient spreading zones which also act as heat sources. Ther are also some geothermal fields associated with volcanic centres in southern Afar. Additionally t these, there will be further variation depending on the types of volcanic centres and axial ranges.

Discussing about Environmental Concerns of Geothermal Development in Ethiopia, this pape mainly refers to those geothermal projects where exploration for geothermal development has been conducted to some degree and with which exploration this author has been involved. Foremost in these explored geothermal areas are the Aluto-Langano Geothermal project, the Tendaho Geothermal project where exploration up to deep drilling has been conducted and in the case of the Aluto-langano Geothermal project a pilot geothermal power plant of 8.2MWe gross was installed, although not operational at present due to some technical troubles which are now under study and in the process of remedial. Then the other geothermal fields referred to are Northern Lake Abaya Geothermal Field, Corbetti Caldera Geothermal Field, Gedamssa Caldera Geothermal field and a number of fields in the Southern Afar Project.

The environmental considerations look into the environmental laws of Ethiopia, the physical environment, the biological environment and the human environment. Considering the initial environment, the high enthalpy geothermal development areas are remotely located and often barren, presently their neighborhood is typically devoid of settlements and also lacking in recreational or tourist facilities. Any Geothermal Development however should conform to the Environmental Policy of Ethiopia issued in 1997 as well as the Proclamation on the Establishment of Environmental Protection Organs, Environmental Impact Assessment (EIA) Proclamation and Environmental Pollution Control Proclamation all issued in 2002.

In the MER the physical environment consists of young rocks and young landform; the soil development is also at a young stage. The topography can vary from flat to mountainous due to volcanic edifices which are in part formed by rock and in part by loose and weak pyroclastic materials which can pose for erosion problems. However the rocks both hard and weak can be used as natural construction materials. The altitude can vary from about 1000 to over 2000 meters. The climate is variable with hot temperatures below the volcanic edifices and cool temperatures on top of the volcanic edifices. There is water available in nearby lakes and rivers in the case of Aluto-Langano, Northern Lake Abaya, Corbetti Caldera and Gadamssa Caldera Geothermal Fields, that can be used for drilling fluid and as part of the natural construction materials. The land-use land-cover is limited. The biological environment does not have abundance of flora and fauna. There are

ests excepting for bush and rare scattered wood mostly acacia trees. There can occur some fe but there are no concentrated wildlife habitats warranting national parks, wild life reserves e like at the moment, excepting at the Fantale Geothermal area where there is the Awash e National Park. Similarly there are no forest conservation areas. The air quality varies with ilities of H_2S smell near natural geothermal manifestations; noise also varies from quiet to nd very high sound levels from fumaroles and other hydrothermal discharges. Aesthetics also depending on the geological setting and topography although it is generally considered to be nd attractive.

AfDE, where geothermal resources occur the physical environment consists of even younger and younger land forms in relation to the MER. The land is rocky with lake and Aeolian ents covering most parts and with no or very little soil formation. The topography is very flat t at the axial ranges which are represented by ridges. The altitude is in the order of 300 to . The climate is hostile with very hot temperatures and very little rain. There are no rivers with wash and its tributaries being some Kilometers away from the geothermal development site. e is general lack of vegetation including grass due to the very low rainfall and the desert ition of the area. There is wild life consisting of Gazelle, Antelope, Ostrich, Wild Ass and thog. The Wild Ass and Ostrich population warrant some kind of a wild life reserve. The Wild is endemic to Ethiopia. Vegetation and wildlife are concentrated near areas of hydrothermal ifestations due to the availability of water there. But the geothermal development areas in opia do not coincide with the hydrothermal manifestation areas, being some kilometers away thus would not disturb the flora and fauna existing at the hydrothermal manifestation areas.

s means from the point of the Initial/existing Environment there is a relative ease of adverse ironmental impacts due to Geothermal Development as a result of the deficiency in human lement as well as the limited flora and fauna. There will not also be any loss of agricultural land there is no or limited land use.

e main concerns are then, Geothermal effluents, that is separated brines and non-condensable es including noxious odour emitted from cooling towers and gas ejectors as well as from other othermal facilities. There is a relatively high concentration of Sodium Bicarbonate (Na_2HCO_3) and dium chloride-sulphate for example in the Aluto-Langano Geothermal brine. Boron having a high pact on vegetation is also of concern. Arsenic which is poisonous is a risk and can pollute water odies. Among other pollutants to the water and soil are, Ammonia, carbon dioxide and saline bore aters. Among air pollutants are, Carbon Dioxide (CO_2) which has green house gas effect because it aps heat from the Sun that is reradiated by Earth; Hydrogen Sulphide (H_2S) which concentrates in ow areas is toxic; Ammonia (NH4), mercury, radioactive elements and rock dust should also be of concern. Silica precipitation on vegetation should also be of concern.

To mitigate all the above problems re-injection was found to be the best system in that it meant getting rid of the effluent quickly by putting it back into the ground. However this was not as easy as was said. Rather there were some uncertainties about re-injection at the beginning due to lack of researched data and there was fear that re-injection might cool the system, reduce the permeability, and so on. Thanks to continued research and growing use of re-injection as well as practical experience and knowledge in geothermal fields around the world, re-injection was found to reduce all the pollution concerns of geothermal development besides being advantageous in maintaining the reservoir pressures and thermally insulting from cold water incursions into the reservoir in some respects.

Thus pollution from separated brine after extraction of energy can be mitigated by means of injection back into the system. Similarly rejected condensate water can also be re-injec Sometimes this might have its own problems if the formation lacks permeability or there can oc clogging due to scaling. One can further solve these problems by injecting at higher pressures higher temperatures (although this can lead to loss of energy), as well as by chemical treatment prior settling of the effluent. If the geothermal setting allows it, discharging the effluents into alre saline lakes (as a result of natural hydrothermal discharge into them) and large rivers can gre reduce the impacts by bringing down the concentration of theses elements to ambient levels in case of large rivers and in the case of Saline Lakes by concentrating the extractable minerals l Soda ash which is now being mined in Lake Abiata would be of further economic benefit. Howe both these solutions of effluent disposal must be studied in detail for their impact on fish and ot aquatic animals.

Non-condensable gases like H_2S which pollute the air can be scrubbed before their escape to t atmosphere. It is also these days being considered for commercial extraction of some of the pollutants like for example using CO_2 for the manufacture of dry ice, carbonic acid and so o Similarly adequate ventilation inside the geothermal facilities will protect from poisoning by to gases like H_2S.

There will also be some environmental concerns due to the construction activity of the geotherm power plant including drilling and construction of buildings and access roads. Erosion, subsiden and settlement could also be a concern during construction and operation, since the foundations f geothermal installations can be accumulations of loose and weak pyroclastic ejecta coming from t volcanoes. The fresh ground water should be protected from mixing with the geothermal fluid. Th the engineering designs should look into mitigating these problems by including appropriate we construction with concentric casings to prevent mixing of geothermal water with fresh ground wate Blowouts and hydrothermal explosions can occur, thus the engineering designs should provide blo out prevention equipment. Geothermal areas are usually active seismic and volcanic zones. Thes and initiation of seismic shocks due to withdrawal of geothermal fluid should also be considered an the engineering designs should look into selection of appropriate acceleration factors for th geothermal facilities and buildings. Corrosion protection by selecting appropriate materials an paints should also be examined.

However, on the whole the impacts from the above will be small compared for example wit hydropower development where there are usually settlements of people and the hydropower scheme occupy very large areas causing displacement of very large numbers of people especially in the da site and the reservoir area plus the possibility of greater and more extensive physical environmen problems like erosion and subsidence.

Further the impacts from Geothermal Development would be mainly related to continuous production of steam and brine from geothermal wells and should be negligible and temporary when boreholes are opened only for testing purposes. Finally it is agreed by many that compared to other types of Thermal Plants, Geothermal Plants have relatively little effect on the environment. For example the amount of carbon dioxide released from geothermal plants, is in the range of 4 percent of the carbon dioxide released by an equivalent thermal plant fueled by coal or petroleum. Thus after allowing for the necessary mitigation measures discussed above Geothermal Development is an attractive energy source that is yet to be utilised fully, considering its large resource base compared to oil, coal and nuclear energy.

INTRODUCTION

Background

ermal energy resource is said to be only second to hydro-energy resource for generation of icity in Ethiopia. Both Geothermal Energy and Hydro-Energy are renewable resources that proved to be of practical value as energy sources yet to be fully utilized by mankind. They are based on water media. In the case of Geothermal, the water gets its energy from heat derived terrestrial sources usually magma chamber at shallow depth in the order of 5 to 10 kilometers. heat source can also be hot dry rock at shallower depth.

thermal resources have been used by man perhaps since pre-historic times and certainly in ric times by ancient civilizations like the Greeks and the Romans. Its use flourished with time, g used both for bathing, balneology (medicinal bathing) and also for bottled mineral drinking r. Besides these the other applications were direct heat uses like space heating, food processing, iculture, refrigeration and so on. In addition minerals and chemicals, like boric acid, sulphur, um and calcium chloride are extracted from geothermal resources.

first successful geothermal power plant for electricity generation was put into service in 1913, at derello, Italy. It was a 250 Kw_e power plant using geothermal steam. This was followed by New aland about fifty years later with the Installation of 192 Mw_e geothermal power plant using arated steam from superheated hot water ever-increasing the exploitation possibilities from steam hot water. United States of America was the next country to produce electricity from geothermal am. Other Countries like Japan, former USSR, Mexico, El-Salvador, Iceland and Turkey lowed. Lately developing countries like Philippines, Indonesia and China have joined in. In rica, Kenya had been the first country to generate electricity from geothermal energy. Ethiopia ned the club in 1996 by installing the first geothermal power plant of about 8.2Mwe gross.

ith the Coming of the African Rift Geothermal (ARGeo) Facility, It is believed that there will be xpansion of the Geothermal Development in Africa as a whole, particularly in East Africa and hiefly in Ethiopia and Kenya. In combination with this sound Environmental Management of the eothermal Resources at all stages of the Geothermal Development will further enhance the stainability of the use of this particular energy sector. This paper dwells on environmental ncerns for Geothermal Development in Ethiopia.

1.2 Objective

The objective of this paper is to broadly look into the environmental concerns of geothermal development in Ethiopia and to examine which aspects of geothermal development need to have environmental impacts attention and assessment.

2.0 NATURE OF THE RESOURCE AND GEOLOGICAL SETTING

2.1 Geothermal Occurrence

Geothermal comes from the Greek and means Earth-Heat. The earth is broadly divided into the core, mantle and crust. The temperature increases with depth and the heat is generated predominately by radioactive processes. The temperature of the mantle is in the order of 600°c while at the centre of the earth the temperature could reach about 6000°c. However to get this heat geothe development does not have to go to these depths. It is now well known that convection curre the mantle generate drifting of the continents and the phenomenon is known as plate tectonics. result there is magmatic up-flow and volcanism at the axis of the spreading zones with the cre of new crust at the surface, while at the other margin of the plate there is collision of the crusts subduction of the oceanic crust downwards under the continental crust due to the bigger densi the oceanic crust which later melts as it reaches to the high temperature depths and erupts t surface. There could also be transform zones, were instead of collision there is sliding of the against each other.

The plate margins are thus areas of magmatic, volcanic and seismic activity and are now recorded by volcanological and seismological observatories world wide. These processes brin Earth's Heat up to shallow depth during volcanic activity, in the form of buried remnant ma chambers and/or hot rock. This heat can be picked up by ground water circulating in the subsu and can further be transported and stored underground in a natural geothermal reservoir at sha depths in the order of 500m to 3000m where the geological conditions permit and it can be rea by deep drilling. Some of this fluid can also manifest itself at the surface as hot springs, fumar geysers and the like by migrating through fractures and faults from the geothermal reservoir an known as geothermal manifestation.

It is generally accepted that the ground water is of a meteoric origin and can be recha continuously by rain, making it renewable. The heat source/magma chamber is believed to hundreds of thousands of years before it cools. The geothermal resource is thus a naturally occur heated ground water that is renewable and temperatures can vary from above ambient to su heated in the order of 300°c and more. The lower temperature ranges are used for direct h purposes, like bathing, space heating, and the medium temperature ranges are used for dryin agriculture and mining and process heat in industry etc. while the higher temperature ranges a used mainly for electricity generation.

2.2 Geothermal Resource in Ethiopia

The geothermal Resources in Ethiopia are also related to plate tectonics. The main geother Resources of Ethiopia occur in the Ethiopian Rift, which is a result of extension tectonics. T Ethiopian Rift is divided into the main Ethiopian Rift (MER) and the Afar Depression of Ethio (AfDE). The MER is characterized by a graben represented by older essentially Northeast-Southw trending fault blocks and a newer active centre of NNE-SSW trending fault blocks and rift in structures and associated volcanism both basaltic and acidc known as the Wonji fault belt M (1971). The basaltic volcanism is fissural while the acidic volcanism is central forming volca edifices. The heat source is related to the volcanic centres as can be gathered from pres knowledge

The AfDE is an area of incipient spreading zone with accumulations of basaltic volcanism. Some the basalts are tholeitic in nature similar to the sea floor basalts. It is this volcanism and the remn buried magma chamber/dykes that supply the heat source for the geothermal energy.

The water recharge comes from rainfalls that originate on the highland plateaus west and east of Ethiopian Rift Valley as the rainfall within the rift is low and in the case of AfDE it is exceeded the evaporation, although there could be some infiltration from the rainfall in the MER in so places.

are several geothermal prospects in both the MER and AfDE. Some of these geothermal ts have been explored to varying degrees. A reconnaissance survey has covered the whole of iopian Rift. The exploration included airborne infra-red survey that showed practically all of thermal manifestation areas. After this results areas were selected for further studies and the ing table shows the geothermal prospect areas and the geothermal explorations and ment undertaken.

1: List of Geothermal Areas Showing Exploration and Development Activities taken

Geothermal Prospect	Explorations Undertaken					Development
1, Aluto - Langano	Geological	Geochemical	Geophysical	Shallow temperature gradient wells	Deep Exploratory Drilling	About 8.2Mw$_e$
2, Corbetti Caldera	,,	,,	,,	,,	-	-
3, Northern Lake Abya	,,	,,	,,	-	-	-
4, Gademssa Caldera	,,	,,	,,	Shallow temperature gradient wells	-	-
1, Tendaho	,,	,,	,,	Shallow temperature gradient wells	Deep Exploratory Drilling	-
2, Southern Afar	Geological	Geochemical	Geophysical	-	-	-

ddition to the above there were recently conducted geological and geochemical explorations in u Moye and Fantale-Dofan in the MER.

e endeavor of all the above explorations is to prove the existence of geothermal resources luding its quality and quantity with the ultimate aim of using the resources in electricity eration which needs exploitation of large quantities of geothermal fluids concurrently leading to vironmental impacts.

POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK ON ENVIRONMENT IN ETHIOPIA

lthough recently, there are environmental laws promulgated in Ethiopia to protect the environment. The following sections briefly point out the environmental policies, regulations, legal and dministrative framework existing regarding the environment in the country.

3.1 The Ethiopian Constitution

The constitution adopted on the 21st of August 1995 describes the concept of sustainable development and environmental rights, among others the right to development and the right to live in a clean and healthy environment.

3.2 Conservation Strategy of Ethiopia (CSE)

The Conservation Strategy of Ethiopia (CSE, 1996) which is a policy document recognizes t importance of incorporating environmental factors into development activities as an essent component of economic, social and cultural development.

3.3 National Policies

3.3.1 Environmental Policy of Ethiopia

The Environmental Policy of Ethiopia (EPE) (April 1997) goal is to improve and enhance the heal and quality of all Ethiopians and to promote sustainable social and economic development as well awareness of the essential linkage between environment and development. It also emphasizes th need for participation of the people and their organizations at all levels in environment management activities.

3.3.2 Sectoral Policies

Several sectoral policies are issued or in various stages of formulation. Of particular note are the following:

- The Water Resource Policy
- Wildlife Policy
- Forest Policy and Strategies
- National Population Policy
- National Policy of Women

Geothermal development should have a good interaction with any of these policies.

3.4 Environmental Framework Proclamations

The following three proclamations are currently issued by EPA:

- Proclamation on the establishment of Environmental Protection Organs
- Environmental Impact Assessment Proclamation and
- Environmental Pollution Control Proclamation

The first proclamation re-established the Federal Environmental protection Authority (EPA), as well as Sectoral and Regional Environmental Units and Agencies respectively. The Sectoral Environmental Units will be responsible for specific Sectoral Environmental Issues while the Regional Environmental Agencies will be responsible in their Region for environmental protection, regulation and monitoring as well as ensuring public participation in the decision making process among other things.

The second proclamation dealing with Environmental Impact Assessment states that projects should first be authorized by the EPA or the relevant Regional Environmental Agency. Licensing agencies should also ensure that projects have the proper authorization from the concerned environmental protection authorities. It also states that the environmental impacts of a project shall be assessed commensurate with its size, location, nature and cumulative effect with other concurrent impacts or phenomena, trans-regional effects, duration, reversibility or irreversibility or other related effects of the project.

The third proclamation dealing with Environmental Pollution Control is concerned with the right of each citizen to have a healthy environment, as well as on the obligation to protect the environment of the country. In keeping with this, regulations are set up to penalize any person violating the law.

environments are required to be cleaned and put right. Recycling measures are also ...ded where possible.

...nd Tenure, Expropriation and Compensation

... land ownership in Ethiopia is vested on the state, the constitution provides for tenure rights ...s for the leasing of use rights. In addition the constitution states for adequate compensation ... property as a result of state programs.

...y Geothermal Development in Ethiopia shall conform to the Environmental laws of Ethiopia ... require an Environmental Assessment (EA) commensurate with the size of the project and ...ity of the location. In addition Project Affected Persons (PAP)s need be adequately ...nsated and environmental impacts need to be mitigated to avoid, offset and/or reduce the ... impacts while at the same time enhancing the beneficial impacts.

... Multilateral Agreements

...ederal Democratic Republic of Ethiopia has ratified several International Conventions and ...cols as listed below:

- Convention Concerning the Protection of World Cultural and Natural Heritage, ratified 1972
- International Plant Protection Convention
- Convention on International in Endangered Species (CITES)
- Vienna Convention on Ozone Layer Protection (1990)
- Montreal Protocol for Substances Depleting the Ozone Layer (1990)
- United Convention on Law of the Sea
- Framework Convention on the law of the Sea
- Convention on Biological Diversity, ratified in 1994
- African Convention on the Conservation of Natural Resources
- Convention on Desertification, ratified in 1994
- Rio Convention on Biodiversity (1997)
- Framework Convention of United Nations on climate Change (1997)
- Convention on the Control of Transboundary Movement of Hazardous Substance

4.0 BRIEF DESCRIPTION OF THE PRESENT/EXISTING ENVIRONMENT

4.1 Physical Environment

4.1.1 Topography

The topography in the geothermal areas of MER is dominated by hilly terrain formed by volcanic edifices including fault scarps although the geothermal field could be limited to flat areas formed by volcanic depressions like calderas in the case of Corbetti & Gadamssa and summit depressions in the case of Aluto-Langano and escarpments in the case of Northern Lake Abaya Geothermal prospect. The area around the volcanoes is also usually flat. The topography in AfDE is generally flat with southern Afar being hilly including escarpments. The altitude can vary from about 1000 to over 2000 meters at the volcanic edifices in the MER and form about 300m to 500 meters in the AfDE.

4.1.2 Geology and soils

The geology in both MER and AfDE is dominated by young volcanic and sedimentary rocks. However it is not the intention here to cover all the geology in the Ethiopian Rift but rather to point out the general geology in the vicinity of the known geothermal areas The volcanic rocks consist of rhyolitic domes and/or fissural basalts while the sediments are lake sediments sometimes called volcano-sediments due to the large proportion of volcano-clastic material that deposited during pyroclastic eruptions into the lakes created by rifting and subsidence. The tectonics is dominated extension tectonics with fissures and faults. In Both the MER and the AfDE you find faults grabens of varying amplitude sometimes with enechelon displacements and rift in rift structures well as tilting of fault blocks. The fissures and faults have acted as passage ways for volca material that were eventually the heat sources for the geothermal energy resources.

The soils are young also and there are large areas of bare surface especially in the AfDE. It is again the intention to cover all the soils existing in the Ethiopian Rift valley. The attempt is describe in general terms the soils existing in the known geothermal prospect areas according to t Geomorphology and Soils Map of Ethiopia (1983). Thus In the AfDE, in the area of the Tenda Geothermal prospect, the dominant soils are orthic solonchaks with sodic characteristics while in t southern Afar Geothermal prospect areas the dominant soils are Lithosols, Eutric Regosols (lithi Vitric Andosols (lithic) and eutric fluvisols,

In the MER the soils in the Gadamssa Caldera Geothermal Prospect area are Molic Andisols a Eutric Fluvisols and those in the Aluto-Langano Geothermal area are lithosols while those in t Corbetti Caldera Geothermal Prospect Area are mollic Andisols and Lithosols and those of Norhte Lake Abaya Geothermal Prospect areas are Chromic Vertisols and Lithosols.

4.1.3 Land Use/land Cover

According to the Land Use/Land Cover Map of Ethiopia the Rift is generally exposed rock, salt fla and exposed land and soil surfaces. These can sometimes have scattered scrub and grass. There a also moderately cultivated lands and grass lands especially in the MER. Acacia trees which had bee dense in the past are now very sparse and are the dominant trees especially in the MER. The ri relatively becomes more vegetated as one goes southward and there also occur more moderatel cultivated lands. In the Rift valley there also exist agricultural lands limited to the Awash Valley flood plain and its tributaries. The waters of these rivers are used for irrigation and large farm mostly state owned have been developed, that cultivate sugarcane, cotton, fruits and to a lesser par grain and vegetables. There are also associated agro-industries like food processing and cotto ginning plants as well as settlements forming built up areas around the farms and the Agro-industries like sugar factories. Apart from these the Awash River valley consists of swamps and marshes as well as riverine forest. Similarly in the vicinity of the Northern Lake Abaya Geothermal prospect area there is the Bilate River and Agricultural Development that uses the water of the river for Irrigation. Around Zway Lake which is a fresh water lake, there is also agricultural development using its waters to irrigate flowers and vegetables.

4.1.4 Climate and Water Resources

The rainfall in the Ethiopian rift valley as a whole is low compared to the highlands and the plateau and it also decreases as one goes from the south to the North in the Rift Valley. Briefly, In the MER the Mean Annual Rainfall varies from about 900mm in the Northern Lake Abaya Geothermal prospect area to about 700mm in the Gadamssa Caldera Geothermal Prospect Area. While in the AfDE it varies from 500mm to 300mm in Southern Afar and less than 300mm in the Tendaho Geothermal Prospect area, according to FAO/UNDP-ETH/78/003. Also briefly the mean Annual temperature according to the National Atlas of Ethiopia (1988) in the MER varies from 20 to 25 °C and in the AfDE it varies from 25 to 30 °C in Southern Afar and it is more than 30°C in the Tendaho Area. Isolated temperatures values could be more than 45°C. Thus in Tendaho Area, desert climatic conditions exist and in Southern Afar the climatic conditions vary from desert to hot semi-arid while In the MER the climatic conditions are hot semi-arid. Regarding water Resources there are several fresh to saline lakes namely from North to south, Ziway, Langano, Abiata, Shala, Awasa and Abaya

R including one man-made Lake Koka. In the AfDE there are fresh water lakes near the order namely from North to South Lakes Gregori, Gamari, Afambo, Bario and Abhe. The ver crosses the MER and flows into the AfDE where it finally disappears into Lake Abe Ethiopian borders. The other important rivers found in the MER are Meki and Qatar o Lake Ziway, Bilate and Gidabo Rivers flowing into Lake Abaya.

e Geothermal Fluid

al fluids are saline fluids at high temperature in the order of 330° as evidenced by wells La-6. The geothermal fluid seen on the surface, coming as natural hydrothermal tions is mixed with shallow fresh ground water and as such is not characteristic of the deep al fluid in the reservoir. Nevertheless there had been conducted deep exploration drilling at hermal sites namely Aluto-Langano and Tendaho where productive wells have been red and thus it was possible to know the temperature and composition of the deep reservoir luto-Langano Geothermal field having the deepest drilled wells yet has relatively more uids than at Tendaho. Table 2 below shows the chemical composition and temperature of hal fluids from two of the productive wells LA-3 and LA-6, selected for their very high ures at Aluto-Langano Geothermal Field, taken from Meseret Teklemariam and Kibret (2001).

:Representative Chemical Composition Data (ppm) of Separated Water from Meseret ariam and Kibret Beyene (2001), Aluto-Langano Geothermal Field, Ethiopia

T °C	pH	Na	K	Ca	Mg	CO^3	HCO^3	Cl	SO_4	F	NO_3	HBO_2	SiO_2
320	9.3	1000	228	0.1	<0.1	242	1464	514	23	73.6	20.87	25.21	974
335	8.99	1170	303	0.1	<0.1	151	1423	787	177	75.2	26.47	49	907

n be observed in Table 2 above, the geothermal fluid is an alkali-bicarbonate-chloride fluid and dition there is also considerable composition of Sulphate in the case of LA-6. The total lved solids are in the order of 5000ppm. The pH is slightly on the alkaline side. The silica entration is also considerably high. Boron which is deleterious to plants is also present. Fluoride h attacks teeth is also high. Although not shown here on the chemical analysis one should ays be aware of Arsenic and mercury which are poisonous to man and animals.

le 3, below shows the chemical composition of gases from two (LA-3 and LA-6), of the uctive wells, selected for their very high temperatures at Aluto-Langano Geothermal Field also n from Meseret Teklemariam and Kibret Beyene (2001).

ble 3: Representative Gas Composition Data (mM/100M water) from Meseret Teklemariam and Kibret Beyene (2001), Aluto-Langano Geothermal Field, Ethiopia

Well	CO_2	H_2S	He	H_2	N_2	CH_4
LA-3	320	9.3	1000	228	0.1	<0.1
LA-6	335	8.99	1170	303	0.1	<0.1

As can be observed in the Table 3 above there are high concentrations of the green house gases like CO_2 There are also noxious gases like H_2S.

4.2 Biological Environment

4.2.1 Flora

The flora in the AfDE is scarce often being exposed rock, salt flats and exposed land and surfaces. There are though some scrub and grass around hydrothermal manifestations. In the M there occur open woodland consisting of acacia trees and some grass. Here also occur exposed r exposed land and soil surfaces. There are no forests as such.

4.2.2 Fauna

There are birds and wild animals at various localities of the Ethiopian Rift Valley. However Geothermal prospect areas proper are not inhabited except in AfDE where you frequently find life consisting of Ostriches, Wild Ass, Gazelle, Antelope, and Warthog and similarly in the Fa geothermal Prospect area in Southern Afar where there is the Awash National park, you find va wild animals mainly antelopes- Sala, Ambaraille, Agazen, Korke, Gazelle with few lions leopards. The Awash National Park which rests on 756 KM^2 received legal recognition in 1968 is reported to be home to 81 species of mammals and 453 bird species. According to the Ethio Herald of 11 Oct, 2006, there were about 9068 tourists that visited the park in the 2005/2006 fi year and the revenue for the Fiscal year was Birr 175,714 (about US$ 20, 000). And the numbe tourists visiting the park increased by about 3400 from the previous year but the revenue doub This shows that in the future the revenue from the park could be considerable and that is a remi that the geothermal development in the Fantale area should be carefully planned so as not to dist the Awash National Park. Further South near the Corbetti Caldera Geothermal Prospect there also antelopes (kudu, Tragelaphus imberbis.) in Senkale Park.

4.3 Socio Economic Environment

4.3.1 Population

The people living in the geothermal prospect areas of the Ethiopian Rift Valley consist predominantly the Afar people in the AfDE and in the MER are Oromo around Aluto-Langa Oromo and Sidama around Corbetti Caldera and Wolayita around Northern Lake Abaya.

4.3.2 Livelihood and Economic Activity

The Afar are predominantly pastoralists although this is fast changing with new initiatives taken both the federal and regional governments to introduce irrigated farming and farming in general. T Kereyu belonging to the Oromo are also chiefly pastoralists with some farming. Large herds Cattle, goats, sheep and camel are common sites in the Afar.

The pastoralists are always on the move in search of grass and vegetation for their animals and it possible that one way or the other there can occur an encounter with these people including th large herds of cattle. This needs to be given special thought during the environmental impa assessment to offset any impacts that might occur either way. The Sidama and Wolayita a predominantly farmers also with large component of livestock rearing.

Apart from these there are a large number of commercial farm and factory workers in settleme centered around large commercial farms and agro industries as well as towns and villages cateri for the large number of transport vehicles going to and forth from the port as well as the Southe Central and Northern parts of the country on the main highways. The lively hood of the town peop is shop keeping of various merchandise as well as running of hotels and restaurants. There are al people employed in cottage industries, garages and workshops in settlements and towns. The towns nts and agro-industries although in the rift are far away from the presently known al prospect areas to be affected by environmental impacts from geothermal development.

OTENTIAL ENVIRONMENTAL CONCERNS AND SUGESTIONS FOR MITIGATION

Physical Environment

Erosion and Land Subsidence

ossible that construction, especially land preparation (excavation, fill, waste disposal, ion of construction materials) and access road building could initiate erosion and land nce. Thus appropriate engineering design standards similar to those used in other ction activities like hydroelectric and road projects should be applied. Land subsidence due to rmal fluid extraction has been reported to occur in other geothermal areas thus proper ering considerations should be given including for extraction of construction materials. Re-ion can reduce subsidence due to geothermal fluid withdrawal.

Water Pollution

ic which is poisonous to man and animals can occur in geothermal fluids is a risk, and can te water bodies. Among other pollutants to the water and soil are, Ammonia, carbon dioxide saline bore waters. Boron having a high impact on vegetation is also of concern.

mitigate all the above problems re-injection was found to be the best system in that it meant ing rid of the effluent quickly by putting it back into the ground. However this was not as easy as said. Rather there were some uncertainties about re-injection at the beginning due to lack of arched data and there was fear that re-injection might cool the system, reduce the permeability, so on. Thanks to continued research and growing use of re-injection as well as practical erience and knowledge in geothermal fields around the world, re-injection was found to reduce the pollution concerns of geothermal development besides being advantageous in maintaining the ervoir pressures and thermally insulting from cold water incursions into the reservoir in some pects.

hus pollution from separated brine after extraction of energy can be mitigated by means of re-jection back into the system. Similarly rejected condensate water can also be re-injected. ometimes this might have its own problems if the formation lacks permeability or there can occur ogging due to scaling. One can further solve these problems by injecting at higher pressures and igher temperatures (although this can lead to loss of energy), as well as by chemical treatment and rior settling of the effluent. If the geothermal setting allows it, discharging the effluents into already aline lakes (as a result of natural hydrothermal discharge into them) and large rivers can greatly reduce the impacts by bringing down the concentration of theses elements to ambient levels in the case of large rivers and in the case of Saline Lakes by concentrating the extractable minerals like Soda ash which is now being mined in Lake Abiata would be of further economic benefit. However both these solutions of effluent disposal must be studied in detail for their impact on fish and other aquatic animals.

Non-condensable gases like H_2S which pollute the air can be scrubbed before their escape to the atmosphere. It is also these days being considered for commercial extraction of some of theses pollutants like for example using CO_2 for the manufacture of dry ice, carbonic acid, green house gas supply and so on. Similarly adequate ventilation inside the geothermal facilities will protect from toxic gases like H_2S.

Pollution of water bodies by discharging geothermal effluents into lakes and rivers shoul disallowed unless it has been shown that this will not have negative impacts. Similarly mixing c geothermal fluid with the ground water should be prohibited. This could be mitigated by good construction and completion. Discharging waste-water into ponds need protection against use o water by people and animals, this might mean constructing fences or putting a guard.

5.1.3 Air pollution

Among air pollutants are, Carbon Dioxide (CO_2) which has green house gas effect because it t heat from the Sun that is reradiated by Earth; Hydrogen Sulphide (H_2S) which concentrates in areas is toxic; Ammonia (NH4), mercury, radioactive elements and rock dust should also b concern. Silica precipitation on vegetation should also be of concern.

5.2 Biological Environment

5.2.1 Flora

It is rather tempting to say that there will be no environmental concerns regarding flora due to scarce vegetation including grass and the occurrence of vast areas of barren rock and soil surf especially in the AfDE. In spite of this any big trees encountered should be preserved and eff should be made to locate boreholes, pipeline routes as well as buildings away from trees vegetation especially endemic and endangered vegetation as much as possible.

5.2.2 Fauna

Some of the geothermal areas are close by to national parks like the Awash and Sinkile Parks in MER. There also exist wildlife in the Afde although there have not been delineated parks. I believed that there could be disturbance to wild animals during mobilization and demobilizatio well as setting up at well sites. It is likely that the animals could slowly get used to these activi although they may be scared away at the beginning. Thus wild animals should not be hunted their habitat should be preserved as much as possible. In addition wild life routes should not obstructed and if crossed by pipe line, the pipe line should be made to overpass by raising it ab ground or underpass by going underground along the crossing of the wildlife routes. It is belie that the geothermal facilities will not occupy large spaces and would generally be away from centers of the wild life habitat.

5.3 Socio Economic Environment

The geothermal areas in Ethiopia are generally uninhabited except for occasional pastoralists mov to the area or passing-by with their herds of cattle seasonally. To stop any damage being incurred the facilities and vice versa, fencing of the important facilities could be a simple and cost effect solution. In connection with this creating awareness regarding the geothermal development and use to the pastoralist community would be also useful.

6.0 ENVIRONMENTAL MANAGEMENT PLAN (EMP) AND MONITORING PROGRAM

Environmental management plan is an integral part of the EIA in order to mitigate Environmen impacts. A monitoring program is also required to see the response to mitigation measu undertaken. Monitoring is required to see if there are any changes, especially changes to chemis of geothermal fluids with continued exploitation of the geothermal resource.

CLUSION

nt of this presentation is not for an all out EIA but rather to point out which aspects of the ment are of concern. As pointed out the existing environment is not sensitive in that it is and does not have human settlement, Flora are also scarce, with no forests, although wild s can be encountered in nearby national parks. The main concerns are effluent disposal which achieved by reinjection. Geothermal as energy source is environmentally friendlier compared r energy sources especially fossil fuels.

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