Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

First Approach of Environmental Impact Assessment of Cerro Prieto Geothermal Power Plant, BC Mexico.

Zayre González, Disraely González and Thomas Kretzschmar.

Center of Scientific Research and Higher Education at Ensenada, Baja California. Ensenada-Tijuana Road No. 3918, Playitas Zone, C. P. 22860, Ensenada, Baja California, Mexico.

zgonzale@cicese.mx, disraely@gmail.com, tkretzsc@cicese.mx

Keywords: Sustainability, rapid impact assessment matrix

ABSTRACT

The sustainable development is based on three main aspects: social, economic and environmental. However, the international institutions of energy believe that economic growth improves social and environmental aspects. Therefore, the sustainable indicators coming from these institutions are based on economic productivity.

The Environmental Impact Assessment (EIA) gives an overview of the environmental conditions that has prevailed in the Cerro Prieto geothermal power plant throughout its existence. The EIA is based on five criteria: importance of condition (A1), magnitude of change or effect (A2), permanence (B1), feasibility (B2) and cumulative (B3). The intention of B3 is to judge the sustainability of the condition and should not be confused with a permanent or irreversible situation.

This study presents the first stage of evaluation of the nature of sustainable development of the Cerro Prieto geothermal power plant in Mexico, based on the Rapid Impact Assessment Matrix (RIAM).

1. INTRODUCTION

The terms sustainable and renewable are often confused. With respect to geothermal energy, sustainability means the ability of the production system to sustain production levels over long periods (100´s of years). To consider the geothermal resource as a renewal source of energy, the extraction never should exceed the natural recharge of water in the aquifer. Being renewable, the restitution of geothermal resources (heat and fluid) will always take place, although sometimes at slow rates (Rybach, 2007).

Electric power generation from geothermal resources has been in effect for more than a hundred years. In 2012, the world capacity of installed electrical generation was more than 10 GW, which represents less than 0.5 % of the world electricity demand (Chamorro *et al.*, 2012).

1.1 Mexican Scenario

In general, the sustainability of the energetic sector in Mexico from 1990 and 2008 shows a decrease in global sustainability from 0.73 to 0.56 respectively, where 1 means full sustainability. This result is based on Mexican sustainability indicators such as: Autarky, Robustness, exports, oil income, investment, productivity, electrical distribution, coverage of basic energy needs, renewable energy sources and fossil fuels depletion (Sheinbaum-Pardo *et al.*, 2012).

Cerro Prieto Geothermal Field (CPGF)

This geothermal field is located in the Mexicali Valley, at the Mexican northeastern state of Baja California, 30 km south of the border with the United States. Cerro Prieto is a large high-temperature (280-350ºC), liquid-dominated field, contained in sedimentary rocks. Cerro Prieto began commercial operations in 1973; and in 2000 had 3 power plants with 9 operating units.

In the approximately 15-km^2 area under exploitation, more than 300 deep wells (1250–3550m) have been drilled. The geothermal field is operated by the Comisión Federal de Electricidad (CFE), which has divided the field into four zones: Cerro Prieto I (CPI) located in the west; Cerro Prieto II (CP II) to the southeast; Cerro Prieto III (CP III) toward the north, and CP IV east of CP III (Arellano *et al.*, 2011). The actual capacity of Cerro Prieto (CP) geothermal field is 520 MWe, because Units 1–4 are out of service since 2011 (Peralta *et al.*, 2013). The temporal and spatial distributions of anthropogenic subsidence in the Mexicali Valley are related to the extraction of geothermal fluids in the CPGF. The changes in subsidence spatial pattern and rate are correlated with the development of the CPGF. However, the spatial extent of the observed subsidence is controlled by faults.

It is expected that a future increase of extraction rate and field limits expansion, as proposed by Aguilar (2010), would likely lead to additional future subsidence. So the evaluation of geological and environmental hazard due to subsidence process is required for Mexicali Valley area (Sarychikhina *et al.*, 2011). Although a dispersion model, which was validated with environmental measurements, was applied to H_2S distribution near CPGF and criteria pollutants in the air, the results demonstrated that the concentrations never exceeded the Mexican air quality standards and the population's health seems to be unaffected (Peralta *et al*., 2013).

In this work the authors made a first approach of the assessment of Cerro Prieto geothermal power plant applying the Rapid Impact Assessment Matrix (RIAM). The RIAM is a semi quantitative method of Environmental Impact Assessment (EIA) to determine and analyze anthropogenic components and environmental impacts; to reveal the level and nature of the sustainable development of the geothermal power plant.

2. ENVIRONMENTAL REFERENCE DATA

The compilation of the environmental reference data is of primary importance to assess the impact on environment due to the screen activities. In order to make the assessment, the environmental conditions of Cerro Prieto geothermal power plant will be described.

2.1 Physical-Chemical components

All physical and chemical aspects of the environment surrounding the geothermal plant, including (non-biological) finite natural resources such as subsidence, seismicity, noise, air emissions, solid waste, geothermal fluids, erosion, water quality, air quality and soil quality.

2.1.1. Odor

Most notably hydrogen sulfide due to its characteristic odor at very low concentrations, it is heavier than air, flammable, colorless, toxic and with a characteristic odor of rotten eggs. O. Rosales at Cerro Prieto and the surrounding suburbs from 15 to 27 July 2010 indicated that concentrations exceed the odor threshold, which according to the World Health Organization, is 0.002 ppm and the highest measured concentration was 0.38 ppm. There is no Mexican environmental standard for this pollutant. H_2S emissions reach a dispersion of 10 km radius of the geothermal plant, this action will last the lifetime of the resource exploitation. It is reported that the emissions at Cerro Prieto are mitigated up to 50% with direct contact condensers and in the cooling tower, where the H_2S is oxidized and trapped (Gallegos-Ortega *et al.*, 2000).

2.1.2. Gaseous Emissions

The Cerro Prieto geothermal power plant discharges pollutants generated in the form of gases that contain: hydrogen sulfide, carbon dioxide, methane, propane, sulfur dioxide, oxides of nitrogen, hydrogen, argon and ammonia. The Mexican Secretary of Environment and Natural Resources (SEMARNAT) in their emission reports and the transfer of pollutants (RETC) from 2004 to 2012 determined an emission average of 10 400 ton/year of hydrogen sulfide (H_2S), 9 060 ton/year of methane (CH_4) and 450 500 ton/year of carbon dioxide (CO_2).

2.1.3. Groundwater Quality

In 2010, Moncada-Aguilar and coauthors*,* reported the chemical analysis of water wells at 4 m deep for the communities of Hidalgo, Nuevo Leon, Chimi and the Delta. The results showed that the concentration of the dominant cations is higher than the Colorado River water. Their relative concentration of sodium chloride is close to the concentration of the brine from the evaporation pond, therefore; these waters might have hydrothermal influence due to the high concentration of potassium (this cannot be conclusive because the measured elements are also present in fertilizers, and it is well known that in this region their use has been abused in the agriculture practices).

The application of large volumes of agrochemicals such as pesticides and insecticides (some of which have been banned in the United States and in other countries) in the agriculture of the region are important sources of water pollution from agricultural runoff into drains, canals and the Colorado River. The soil salinization in Mexicali Valley has been attributed to the excess use of water to irrigate fields due to the soluble salts in the irrigation waters (CFE, 2007).

2.1.4. Surface Water Quality

For the management of geothermal waste waters, consisting of surplus cooling towers and drains turbines (steam condensate), the network of canals is used to discharge them into the evaporation pond. Sanitary wastewater is transported to a wastewater treatment plant in the geothermal field (CFE, 2007). The magnitude of the effect on water is less than 10% of the existing resource in the region, it is considered that this action is regional, because the water used is obtained from outside the geothermal plant (CFE, 2007).

The Nuevo River is the most polluted in the Mexicali Valley. This river rises in the agricultural wastewater return, in the northern part of the valley, it crosses the urban area and heads to the USA. When this river is generated by wastewater from the irrigation district, it contains dissolved salts and agrochemicals, then it crosses the city receiving industrial and domestic wastewaters. As expected the water quality exceeds the maximum allowable limits for heavy metals, solvents, greases and oils. Since this water body flows north from Mexicali, Mexico and disembogues in the Salton Sea, USA, it is considered an international impact.

2.1.5. Air Quality

It is affected by the emission of condensable gases into the atmosphere, Peralta and collaborators from 15 to 27 July 2010 monitored at Cerro Prieto and the surrounding suburbs: ozone (O_3), nitrogen dioxide (NO_2), nitric oxide (NO), sulfur dioxide (SO_2), carbon monoxide (CO), methane (CH_4) and hydrocarbons at levels below the limits established in the Mexican Official Norms.

In the operation and maintenance of a geothermal power plant, the air quality will be affected by the periodical gases emissions in addition to those already present. The General Residence of Cerro Prieto, has an environmental protection program that ensures a chemical composition of 3% geothermal steam, 96% carbon dioxide, 3.5% hydrogen sulfide and 0.5% ammonia and other inert gases. Only hydrogen sulfide is continuously monitored, being the object of the program (CFE, 2007).

2.1.6. Wind

According to records of the weather station, in Cerro Prieto from December to May the prevailing winds are from the northeast, in other words, from continental winds of the USA; from June to November, the wind comes from southeast, namely from the Gulf of California.

2.1.7. Solid Waste

With respect to non-hazardous solid waste, there is an open dump near the geothermal power plant of Cerro Prieto.

2.1.8. Geothermal Fluids

In Cerro Prieto, the geothermal fluids are geothermal brine and water from the cooling tower; both are discharged to the evaporation pond. There are a potential risk of groundwater pollution (mainly the deep aquifers), if an accidental spill of geothermal brine occur.

2.1.9. Noise

During major maintenance of the geothermal power plant, noise is generated by sediment ablation for pipe cleaning, the operation of the plant and electrical substation. A reforestation program that aims to reduce noise levels in critical areas of the geothermal field. Silencers are used to reduce noise emissions to allowable levels.

It is considered that the generation of noise is a local problem. In the center there are only steam silencers in the system of regulation of power plants, but not in the areas venting steam at high pressure in steam pipes (Miranda-Herrera, 2008).

2.1.10. Soil Quality

Since the 1960's, in Mexicali, several factors have led to the problem of soil pollution, among which can be mentioned: the contamination from saline-brackish water delivered by the United States as part of the present share of the Water Treaty of 1944; intensification of agriculture and the use of agrochemicals in the irrigation district; growing volumes of wastewater derived from domestic and industrial use; the use of sewage on agricultural land, and finally the onset of subsurface exploration for the purpose of operating the Cerro Prieto geothermal power plant (Lázaro *et al.*, 2006).

As background to the problem of soil pollution generated by the Cerro Prieto geothermal power plant in 1986 the Mexican Secretary of Urban Development and Ecology (SEDUE), stated: "One of the main problems facing the soil resources in the study area is soil salinization. Added to this is having the effect produced by the vapor emanating of geothermal plants with a high concentration of sodium, potassium and lithium. These and the emissions of hydrogen sulfide and carbon dioxide; precipitated compounds that are naturally in the atmosphere, falling to the ground and increasing salinization problem that naturally exists in the Mexicali Valley; the case itself is serious" (SEDUE, 1986).

2.1.11. Impacts on Industrial Growth

The Cerro Prieto geothermal power plant contributes to the generation of electric energy in northern Baja California, the average annual growth in energy demand is 5.5% and CFE shall provide service to more than 850 000 new customers annually in 2007. The construction of new wells in the geothermal power plant will produce additional 800 GW annually, which eliminates the consumption of 1.5 million of domestic fuel oil per year.

2.2 Biological-Ecological components

Includes all biological aspects of the environment, including renewable natural resources, conservation of biodiversity, species interactions and pollution of the biosphere, such as flora, fauna, disease vectors, biodiversity, diversity and food chain.

2.2.1. Biota Impacts

The loss of natural refuges in the Delta of Colorado River due to the scarcity of water from Colorado River, in the evaporation pond of the geothermal power plant of Cerro Prieto, migratory and resident waterfowl has been observed (De Leon, 2007)

2.2.2. Habitat Damage

There is little damage to habitats; the evaporation pond has promoted the arrival and settlement of resident and migratory animals (De Leon 2007). These species could be affected by a sudden change in water quality or the reduction of the surface area of the evaporation pond.

2.2.3. Anti-aesthetic Impacts

The existing infrastructure combined with livestock population density and agricultural activities has significantly changed the landscape and a significant deterioration can be observed in the vegetation cover. As compensation, CFE reforested affected areas to minimize aesthetic impacts. (REFERENCE)

2.2.4. Dumping of the Industry

The permanent removal of geothermal fluid at elevated temperatures over time in the life of the geothermal power plant emanates heat and moisture to the atmosphere, creates a climate impact in the region and in the vicinity of the water evaporation with increasing temperature. Cerro Prieto in particular might be of significance, due to the 300 wells that are in operation, however no studies were found.

2.3 Sociological-Cultural components

Consider all aspects with the human environment, including social issues affecting individuals and communities, along with the cultural aspects, including conservation of cultural heritage and human development, such as water supply, loss of housing, employment, immigration, migration and changes in the landscape.

2.3.1. Public Acceptation

There are social groups that have complained about the presence of odors in the vicinity of the geo-thermal power plant in Cerro Prieto.

2.3.2. Culture

The closest ethnic group to the geothermal power plant of Cerro Prieto is "Cucapá" society whose economy is based on fishing, gardening, collecting and incipient agriculture.

2.3.3. Education

The CFE promotes environmental education campaigns and dissemination of the operation of the geothermal field. The low level of income and education of the population of the nearby suburbs to the geothermal power plant, limit the efficiency of energy saving programs.

2.3.4. Migration

On the growth of the textile industry in the city of Mexicali, residents of the surrounding areas to the geothermal power plant arrive to work by the demand for labor.

Other factors of migration to these areas include people travelling from inside of the country with intentions to illegally cross the border into the United States, and settle in the regions around the geothermal power plant (Noriega-Verdugo, 2005).

2.3.5. Work Opportunities

Recruitment of personnel required for the operation and maintenance of the geothermal power plant is primarily insular to the region. However, there are some non resident contracted staff who come to inhabit temporarily or permanently in nearby towns.

2.3.6. Public Health

Studies on this topic were not found, however, there is a need to recognize the health effects of hydrogen sulfide to prolonged passive exposure. Also important are the health effects from the population of Mexicali, due to air pollution from automobiles; this is a great issue in Mexicali urban areas, more so than in Mexico City.

2.3.7. Population Growth

For the year of 2005, 1.72% of the total population of the municipality of Mexicali was included in the towns surrounding the geothermal plant.

2.4 Economic-Operational components

Includes aspects to qualitatively identify the economic consequences of environmental, temporary and permanent change and the complexities of project management within the context of project activities, such as: loss of crops, fisheries, tourism, changes in land use, cost of operation and maintenance.

2.4.1. Work

The plant near the population works mainly in services and trade a portion of the population in industry (textile industry in Mexicali) and construction in agriculture, livestock and power (Noriega- Verdugo, 2005).

2.4.2. Public Services

With services that include neighboring cities to the geothermal power plant, the electrical service covers 96 % of households with piped water 64.1 %, with sewage service 56.9 %.

The geothermal power plant contributes to the electrical service at the regional and national level, promoting the quality of life of the inhabitants of the region so they will have an efficient and sufficient service.

2.4.3. Agriculture

Irrigated agriculture is mainly practiced in the region; current crops include: wheat, barley, cotton, alfalfa, oats, sesame, safflower, pumpkin, cucumber, pigweed, asparagus, watermelon, melon, corn, grapes, beans and nopal. In the growing season of 1999-2000, about 400 liters of pesticides were used in growing cotton, wheat, and alfalfa alone.

2.4.4. Recycling

The CFE auction the recycling materials so that companies or individuals can take advantage of them.

2.4.5. Cost of Community Health

About 71 % of the area near the geothermal plant has medical services, of which 85% are entitled to social insurance.

3. METHODOLOGY

The applied methodology of the Rapid Impact Assessment Matrix (RIAM) was adjusted from the developed methodology by Pastakia, 1998, adapted by Yousefi and collaborators, 2009 and modified by Phillips 2010.

3.1 The Rapid Impact Assessment Matrix

3.1.1. Scheme

The Rapid Impact Assessment Matrix (RIAM) method (Pastakia, 1998; Pastakia and Jensen, 1998) is based on a standard classification of the important valuation criteria. By this, semi-quantitative assessment for each of these criteria can be organized, providing an accurate and independent score for each condition (Pastakia and Jensen, 1998).

A score is assigned for each component of the defined criteria using the evaluation of the impact of screen activities against the environmental components. The essential assessment criteria is divided into two groups:

Criteria A that denotes the importance to the condition, and which can individually change the score obtained.

Criteria B that determines the impact value to the situation, but individually should not be capable of changing the score obtained.

The value determined for each of these sets of criteria is calculated by using a series of formulas. These formulas allow the qualifications of the individual components to be determined in a defined manner (Pastakia, 1998; Pastakia and Jensen, 1998). The scoring system is a simple product to determine the overall environmental score (ES) for each criteria being assessed, as shown below:

$$(a1)(a2) = aT(b1) + (b2) + (b3) = bT \quad (1)$$

$$(aT)(bT) = ES \quad (2)$$

Where (a1) and (a2) are the individual criteria scores for group (A); (b1) to (b3) are the individual criteria scores for group (B); aT is the result of multiplication of all (A) scores; bT is the result of summation of all (B) scores; ES is the assessment score for the condition.

Positive and negative impacts are represented by using scales that pass from negative to positive values through zero for the group (A) criteria. Zero consequently represents 'no-change' or 'no-importance' value. The use of zero in group (A) criteria allows for the ability to use a single criterion to isolate conditions which indicate no change or are unimportant to the analysis (Pastakia and Jensen, 1998).

A value of zero is avoided in the group (B) criteria, because if all group (B) criteria score zero, the final result of the ES will also be zero. This condition may occur even when the group (A) criteria show a condition of importance that should be recognized (Pastakia and Jensen, 1998). In order to avoid this situation, scales for group (B) criteria use '1'as the 'no-change/no-importance' score.

3.1.2. Assessment criteria

The criteria needs to be defined for both groups, aside from the fundamental conditions which may be influenced by change, as opposed to being related to a particular individual project Two principles must always be satisfied as long as possible to assign a number of criteria (Pastakia, 1998; Pastakia and Jensen, 1998):

1. The universality of the criterion, to allow it to be used in different EIAs.

2. The value of the criterion, which determines whether it should be treated as a Group (A) or Group (B) condition.

Consequently, only five criteria are used in the RIAM. Nevertheless, these five criteria represent the most important fundamental assessment conditions for all EIAs, and satisfy the principles set out above (Pastakia, 1998; Pastakia and Jensen, 1998). These criteria, together with their appropriate judgment scores are defined as follows:

I. Group (A) criteria. Importance of condition (a1): This is a measure of the condition's importance. It is assessed against the spatial boundaries or human interests that it affects (Pastakia, 1998). The scales are defined as:

4—important to national/international interests.
3—important to regional/national interests.
2—important to areas immediately outside the local condition.
1—important only to the local condition.
0—no importance.

Magnitude of change/effect (a2): Magnitude is defined as a measure of the scale of benefit/disbenefit of an impact or a condition:

+3—major positive benefit.

+2—significant improvement in status quo.
+1—improvement in status quo.
0—no change/status quo.
1—negative change to status quo.
2—significant negative disbenefit or change.
3—major disbenefit or change.
II. Group (B) criteria. Permanence (b1): This determines whether a condition is temporary or permanent. This therefore should be viewed only as a measure of the temporal status of the condition. The scoring for each condition is as follows:

1 No change/not applicable.
2 Temporary.
3 Permanent.

Reversibility (b2): This defines whether or not the condition can be changed. This consequently reflects the measure of the control over the effect of the condition. It should not it any way is related or confused with permanence. The scoring for each condition is as follows:

1 No change/not applicable.
2 Reversible.
3 Irreversible.

Cumulative (b3): This is a measure of the nature of the effect. Whether the effect will have a single direct impact, or whether there will be a cumulative effect over time, or a synergistic effect with other conditions. This criterion is a mechanism for evaluating the sustainability of a condition. It should not therefore be confused with a permanent/irreversible situation.

1 No change/not applicable.
2 Non-cumulative/single.
3 Cumulative/synergistic.

It is possible to change the cumulative component to one of synergism, if the condition warrens consideration of additive affects (Phillips, 2010).

3.1.3. Environmental components

The RIAM requires specific assessment components to be defined through a process of scoping; and these environmental components fall into one of four categories, which are defined as follows (Pastakia, 1998; Patakia and Jensen, 1998):

Physical/chemical (PC): This covers all physical and chemical aspects of the environment, including finite (non-biological) natural resources, and degradation of the physical environment by pollution.

Biological/ecological (BE): This covers all biological aspects of the environment, including renewable natural resources, conservation of biodiversity, species interactions, and pollution of the biosphere.

Sociological/cultural (SC): This covers all human aspects of the environment, including social issues affecting individuals and communities; together with cultural aspects, including conservation of heritage, and human development.

Economic/operational (EO): This seeks identify qualitatively the economic consequences of environmental change, both temporary and permanent, as well as the complexities of project management within the context of the project activities.

Using these four categories can be, in itself, provide a capable tool for EIA. However, each category can be further subdivided to identify specific environmental components in order to demonstrate the possible impacts (Pastakia and Jensen, 1998). Consequently, the degree of sensitivity and detail of the system can be controlled in the selection and definition process for these environmental components (Pastakia, 1998).

3.1.4. Evaluation

To use the evaluation system described, a matrix is produced for each project option. The matrix comprises of cells showing the criteria used, set against each defined component, whereby within each cell, the individual criteria scores are set down. From the formulas given for each ES number is calculated and recorded. Once the ES score is set into a range band (Table 1), which is $-108 \leq ES \leq 108$. The relevant scores are shown individually or grouped according to component type and presented in numeric form.

Table 1: Range bands used for RIAM, as proposed by Pastakia, 1998.

Environmental score	Range bands	Description of range band
+72 to +108	+E	Major positive change/impacts
+36 to +71	+D	Significant positive change/impacts
+19 to +35	+C	Moderately positive change/impacts
+10 to +18	+B	Positive change/impacts
+1 to +9	+A	Slightly positive change/impacts
0	N	No change/status quo/not applicable
-1 to -9	-A	Slightly negative change/impacts

-10 to -18	-B	Negative change/impacts
-19 to -35	-C	Moderately negative change/impacts
-36 to -71	-D	Significant negative change/impacts
-72 to -108	-E	Major negative change/impacts

To evaluate the sustainable development of the system E and H_{N1} has to be calculated.

$$E = \frac{\sum PC + \sum BE}{PC_{max} + BE_{max}} \quad (3) \qquad H_{N1} = \frac{(SC_{max} - \sum SC) + (EO_{max} - \sum EO)}{SC_{max} + EO_{max}} \quad (4)$$

With the values of E and H_{N1}, S can be calculated as:

$$S = E - H_{N1} \quad (5)$$

If E > H_{N1} then S > 0 and the system is sustainable and the level and nature of the sustainable development will be according to the next ranges of S values: 0.751-1 – very strong; 0.501-0.75 – strong; 0.251-0.5 - weak and 0.001-0.25 –very weak.

If E < H_{N1} then S < 0 and the system is not sustainable.

4. RESULTS

The RIAM required specific evaluation of the components, for this work four categories were set and the description was presented in section 2. Physical-Chemical (PC); Biological-Ecological (BE); Sociological-Cultural (SC) and Economical-Operational (EO).

In table 2 is presented the first approach of the RIAM applied to Cerro Prieto geothermal power plant.

Table 2: Description of components and the impact categories in the Cerro Prieto geothermal power plant.

Physical and Chemical Components (PC)		**ES**	**RB**	**A1**	**A2**	**B1**	**B2**	**B3**	**Relative ES**
PC1	Odors	-42	-D	2	-3	3	2	2	66
PC2	Gas Emissions	-28	-C	2	-2	3	2	2	80
PC3	Groundwater Quality	-36	-D	2	-2	3	3	3	72
PC4	Surface Water Quality	-64	-D	4	-2	3	2	3	44
PC5	Air Quality	-28	-C	2	-2	3	2	2	80
PC6	Wind	0	N	1	0	2	1	2	108
PC7	Solid Wastes	-7	-A	1	-1	2	2	3	101
PC8	Geothermal Fluids	0	N	2	0	3	2	3	108
PC9	Noise	0	N	1	0	3	2	2	108
PC11	Soil Quality	-14	-B	2	-1	2	2	3	94
PC12	Impacts for Increased Industrial Activity	-14	-B	2	-1	2	2	3	94
Biological and Ecological Components (BE)									
BE1	Impacts on Biota	24	C	4	1	2	2	2	132
BE2	Damage of Habitats	12	B	1	2	2	2	2	120
BE3	Anti-aesthetic Impact	6	A	1	1	2	2	2	114
BE4	Dumping of the Industry	-14	-B	2	-1	2	2	3	94
Sociological and Cultural Components (SC)									
SC1	Public acceptance	-24	-C	2	-2	3	2	1	84
SC2	Culture	0	N	1	0	1	1	1	108
SC3	Education	0	N	3	0	3	2	2	108
SC4	Migration	-36	-D	3	-2	2	2	2	72
SC5	Recreational Areas	4	A	1	1	1	1	2	112
SC6	Work Opportunities	12	B	2	1	2	2	2	120
SC7	Public Health	-32	-C	2	-2	3	2	3	76
SC8	Impact on Housing	16	B	2	1	3	2	3	124
SC9	Population Growth	18	B	1	2	3	3	3	126
SC10	Public safety	0	N	1	0	1	2	2	108
Economical and Operational Components (EO)									
EO1	Works	6	A	1	1	3	1	2	114
EO2	Public Services	6	A	1	1	3	1	2	114
EO3	Tourism	0	N	1	0	2	1	2	108
EO4	Agriculture	-36	-D	3	-2	2	1	3	72
EO5	Operation and Maintenance	6	A	1	1	3	1	2	114
EO6	Recycling	48	D	2	3	3	2	3	156
EO7	Traffic	-5	-A	1	-1	1	2	2	103
EO8	Loss of Property Value	-32	-C	2	-2	3	2	3	76
EO9	Cost of Community Health	-16	-B	2	-1	3	2	3	92

In the table 3 are the results of the ES totals and maximum potential scores for each category.

Table 3. Summary of the ES totals and potential maximum values for the Cerro Prieto geothermal power plant.

Component	Total
∑ PC	955
PC_{max}	2376
∑ BE	460
BE_{max}	864
∑ SC	1038
SC_{max}	2160
∑ EO	949
EO_{max}	1944

Using the equations 3 to 5, mentioned in the methodology to determine S, E and H_{N1}, the resulted values are:

$E = 0.437$
$H_{N1} = 0.516$
$S = - 0.079$

Thus, $E < H_{N1}$ and $S < 0$, then the system in not sustainable.

The principal reason of this unsustainability would seem to be that the proposed positive impacts of the socio-economic factors overshadow the negative impacts of the environmental factors. This means that there would be improved socio-economic quality of life of the local inhabitants, at expense of the environmental quality of the area.

This is the first approach of the environmental impact assessment of this geothermal power plant. The information used to obtain these results is from published material and application of the methodology proposed by Pastakia 1998 and modified by Phillips 2010.

The lack of the published data on environmental monitoring from the geothermal power plant of Cerro Prieto makes it difficult to apply this methodology; this might be a different scenario if the data was available for the population to consult. Additionally, this methodology is very general. For example, to evaluate public health in this particular case, the air pollution of the city caused by automobiles makes a negative number, even though the geothermal power plant has no direct impact in this parameter. Also, migration is present in the zone, but is not caused by the geothermal power plant; this social phenomenon is present because of other causes. To give another example: tourism in the surrounding areas is discouraged not because of the presence of the geothermal power plant, but because water scarcity and extreme weather conditions. Finally, the environmental detriment of the zone has been caused by factors such as decreased water from the Colorado River used by USA and Mexicali inhabitants, limiting the flow to the natural areas (Carrillo-Guerrero *et al.*, 2013; Murphy and Ellis 2014)

To have a most reliable RIAM, it is proposed to organize a discussion with different types of participants such as: experts that have worked in Cerro Prieto, experts that have worked to assess environmental impact, but have nothing to do with Cerro Prieto, postgraduate students that know Cerro Prieto but have not worked with environmental impact, and finally a group of postgraduate students that do not know Cerro Prieto and have not worked with environmental impact. This group will assign the qualification of the assessment and the result would be more precise.

4. CONCLUSIONS

The results of the first approach of the rapid environmental assessment of the geothermal power plant of Cerro Prieto, Mexico, revealed that the system is not sustainable, given the negative environmental impacts. Therefore, it is important and suitable that additional research is conducted in order to elucidate more data on the environmental aspects related to geothermal power production and the prevailing sustainable development considerations.

The RIAM methodology is a very helpful tool to make a rapid environmental assessment, however, the generality of the evaluation criteria makes it questionable in order to identify the direct responsible of a negative or a positive impact. In other words, when the geothermal power plant is direct responsible of a positive or negative impact and when other externalities are responsible.

6. ACKNOWLEDGEMENTS

The authors are grateful for the financial support of The Mexican Council of Science and Technology (CONACyT) and Mexican Secretary of Energy (SENER). Grant of CONACYT-SENER-Energetic Sustainability 2013-01/207032. Moreover, the financial assistance as part of the specific project P25 of the Mexican Center of Innovation in Geothermal Energy (CICESE *et al.*).

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