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Environmental pollution evaluation of steel plants for achieving sustainable development; case study: khorasan steel complex of Iran

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Abstract

Today, advanced industries have a significant impact on growth and development in the societies. However, the construction and operation of these industries will lead to changes in the environment of adjacent areas. Given the importance of this industry and its growth in developing countries such as Iran, to reach the ultimate goal, which is to achieve sustainable development, communities requires the consideration of all environmental aspects of industrial projects. Khorasan Steel Complex is located in Neyshabour plain in the North East of Iran that is one of the most populated plains in Khorasan Razavi Province. This Complex with an annual production of approximately 2 million tons of steel, air pollutants, wastewater, solid wastes such as slag and dust from furnaces, has the ability of affecting the adjacent environment. In this study, according to different production units of Khorasan Steel Complex and emissions created by each unit, environmental impacts of complex activities have been investigated. Among all the environmental impacts of the complex, the most negative effects can be mentioned as air pollution, excessive consumption of ground water in the area with poor water sources and the high volume of dumped slag.

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Introduction

Iron is known as the most widely used metal in the world. Among the metal alloys, steel is accounted for the highest proportion of production. Iran, with an annual production of about 13.5 million tons of steel, has acquired fifteenth place of steel production in the world and first place in the Middle East (World Steel Association, 2014). Steel Industry due to the potential ability of contamination, enters irreversible loss on environmental resources while today, the ultimate goal of protecting the environment is achieving sustainable development in harmony with the principles of environmental protection and economic programs to prevent degradation and depletion of renewable and non-renewable resources. In this regard many environmental impacts studies have been done on steel plants (Cannon**,** 1974) such as Respiratory problems (Pope 3rd**,** 1989).Therefore, in this study, the effects of activities of the Khorasan Steel Complex on the affected environments (including: physical- chemical, biological, social- economical and cultural environments), after describing the Steel Complex units, are discussed separately.

Materials and methods

Khorasan Steel Complex is located in the west of Neyshabour plain in the central part of the Khorasan Razavi Province, northeast of Iran. The Complex is at a distance of 15 kilometers of the North West of historical city of Neyshabur. The land area of Complex is about 1,400 hectares with a geographic location ranging of 58° 42″ E longitude and N 36°21″ latitude (Fig. 1). Khorasan Steel Complex has launched in 2001, with about 2 million tons of steel production per year in the country has been placed as the fourth largest steel manufacturer of Iran (Iranian Steel Market, 2014). The Complex is equipped with Electric Arc Furnace, therefore it has the ability to use iron ore and iron scrap at the same time. Khorasan Steel Complex consists of 16 different units that the nine units including wagon returning, accumulation and withdrawals, direct reduction, cold briquetting, scrap, raw materials transportation, smelting, continuous casting and rolling are the main units and the other seven ones are considered as ancillary and support units. Continue on, major units of the Complex have been studied with regard to environmental contaminants, which they produce.

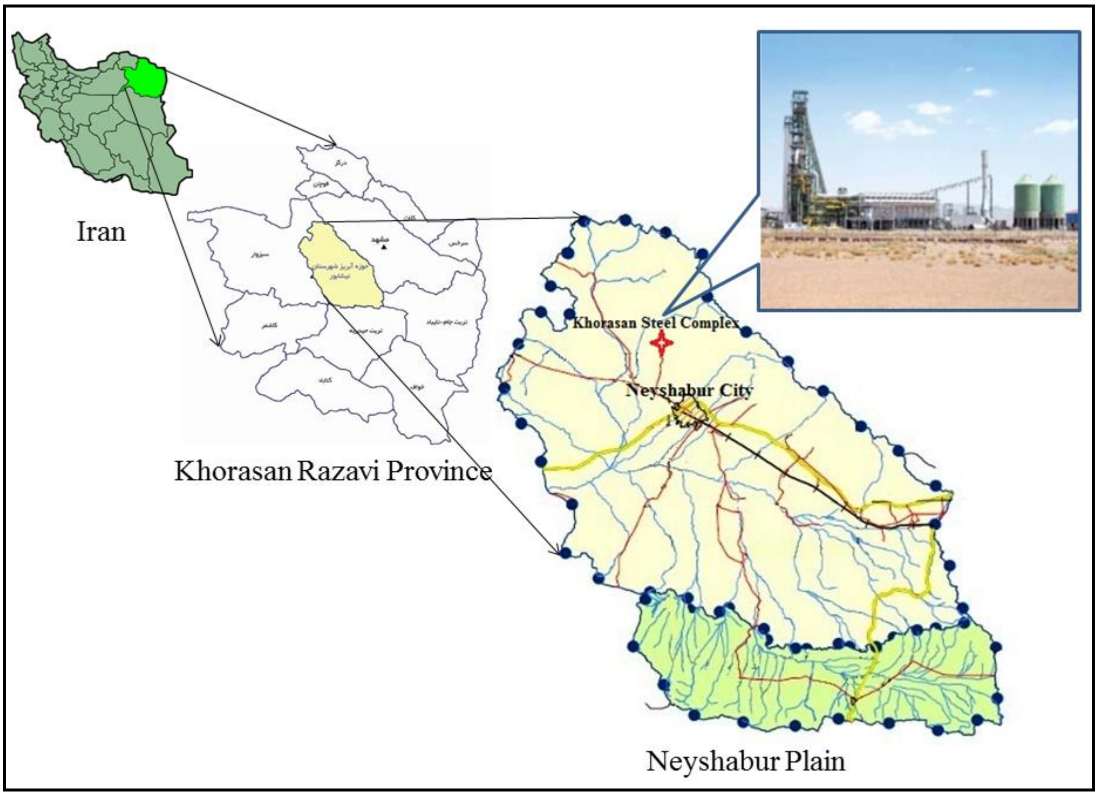


Fig. 1 Geographical Location of Khorasan Steel Complex

Discussion

Wagon return and accumulation- withdrawals units

Iron ore pellets entering to the Complex through road transport by truck and a single internal railway station to the Wagon Returning Unit with a capacity of about 900 tons per hour (18 wagons per hour). Iron pellets after discharging are transported by conveyor belt to the area of accumulation and withdrawals. Ore wagons sent back from the wagon return unit to accumulation unit would accumulate with the stacker machine with capacity of 800 tons per hour.

In the withdrawals unit, pellets are taken with reclaimer machine with a capacity of 550 tons per hour for sending by conveyor belt to reservoir (Day Bin) of daily intake. Environmental effects of two mentioned units' activities are shown in Fig. 2.

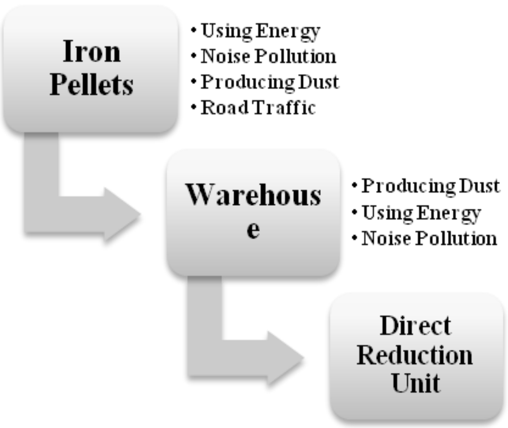


Fig. 2 Environmental Effects of Wagon Return and Accumulation- Withdrawals Units

Direct Reduction Unit

Pellets carried from daily storage reservoirs, after entry into direct reduction furnace with Midrex method, in vicinity of reducing gases (Co, H2) and 760 ° C temperature, lost their oxygen. Sponge iron produced at the bottom of the furnace, is transported by conveyor belt to a storage silos with a capacity of 7,000 ton of sponge iron. Sponge iron produced in this phase has all of the initial impurities of iron ore has. Environmental effects of this unit are shown is Fig. 3.

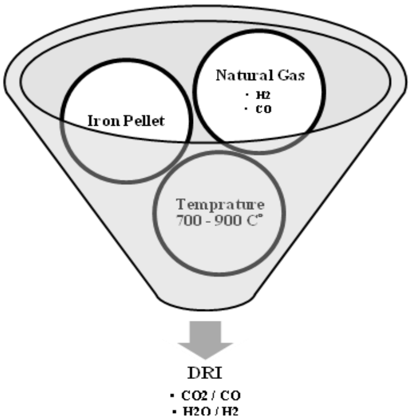


Fig. 3 Environmental Effects of Direct Reduction Unit

Cold Briquetting Unit

Sponge iron fines produced by direct reduction, have a high tendency to oxidation. With the sponge iron fines briquetting, its special surface reduced thus the sponge iron is more resistant against oxidation.

In the Complex, by using the sponge iron fines and additives such as adhesives, the sponge iron turn into compact and portable pieces that are appropriate to recharge the Electric Arc Furnace. Environmental effects of this unit are shown in Fig. 4.

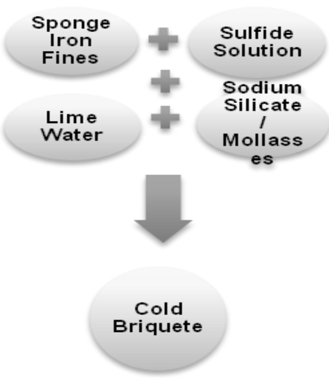


Fig. 4 Environmental Effects of Cold Briquetting Unit

Scrap Unit

All different types of scrap are graded due to specific weight (heavy and light) and according to the degree of impurity then are kept in specific allocated locations. Scraps are carried by three of the crane ceilings to bucket of scrap and next are transferred for melting operations. This unit produces noise and uses energy.

Raw Materials Transportation Unit

This unit was created for preparation and storage of smelter additives and given to equipped mechanical vehicles and conveyor belts, carrying additives to furnace is very fast and accurate and the entire process is done automatically.

Smelting Unit

Sponge iron stored in storage silos is transported by conveyor belts and metal scrap is carrying by vehicles to the furnace. All the materials using electricity (ampere power transformer 120 MW) in the 110-ton electric arc furnaces (AC) are converted to the molten. In this section, various types of additives added to the molten steel so that the desired properties can emerge. Thermal parameters and technical specifications of liquid steel produced in electric arc furnace, set after transferring to the ladle furnace. Environmental effects of smelting unit are shown in Fig. 5.

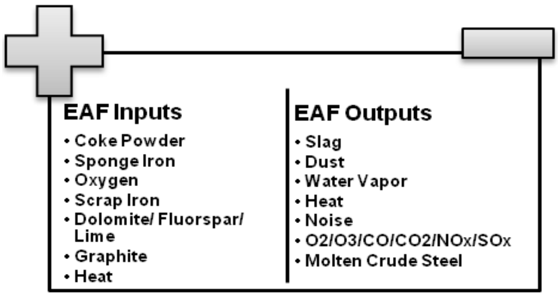


Fig. 5 Environmental Effects of Smelting Unit

Casting unit

In this unit, molten steel serves for casting, using a 6-line continuous casting, produce steel billet in different standards and different sections. To maintain the temperature to reach the rolled steel unit, electrical and thermal energy is required that will result producing combustion gases.

Rolling Unit

After billet production in casting unit, after charging the billets in preheated oven to reach the desired temperature (1100-1200 °C), with passing through 20 racks rollers which are installed vertically and horizontally in one direction, billets are converted into a variety of steel products. For heating billets, natural gas is used.

Results

To assess the environmental impacts of Khorasan Steel Complex, attempts have been done to classify the different environments, which are affected by the activity of this complex. Therefore, different pollutants that produced in the Complex, are discussed separately for potential of affecting on physical- chemical, Biological, social- economical and cultural environments.

Impacts on the quantity and quality of water resources

The construction of the complex in its current location has been affected runoff route and drainage patterns within the complex area. According to this point, shortage of seasonal surface waters for agricultural lands located in downstream of the plant is important since the Neyshabour plain climate is semi-arid and there are no permanent rivers around the complex. Currently, Khorasan Steel Complex needed water is provided through three wells with a total flow rate of 100 liters per second. Due to the large volume of water needed for the Complex and using of good water quality groundwater, it is expected to see further decrease in the water table in the aquifer. In result of the fact that for every ton of steel produced about 5 liters of water are needed (Farhang, 1970) and according to the production capacity of the plant, the annual consumption of water in the plant is about 10 million liters of water. Another effect of this Complex is affecting the regulations of water resources. Given the importance of the industry in the development and growth of the country, it is possible that because of complex over-discharging of underground aquifers, not just a decrease in the water table happens but also decrease in the available water used by local farmers is possible. In addition to the items listed in the water supply level, can be noted that the changes in wastewater qualities are different and are mentioned in Table 1.

Table 1. Wastewater Quality Changes in Complex

Water characteristics	Source
High tempereture	Direct Reduction/ EAF/ Rolling
Heavy Metal Content	Rolling/ Casting
pH change	Acid washing/ Casting/ Rolling
Ammonia/ Nitrogen	Direct Reduction/ Rolling
Cyanide	Direct Reduction/ Rolling
Phenol	Direct Reduction// Rolling
Oil and Hydrocarbons content	Rolling/ Casting
Turbidity	Rolling/ Acid Washing/ Casting
Disolve Solids	Direct Reduction/ Casting/ Rolling

Water used in the complex that has lost its quality is transferred to the treatment unit to recovery and finally, are used in green spaces irrigation. These kinds of waters have the potential of contaminating the adjacent groundwater and surface water resources and soils.

Sampling for Heavy metals in ground water resources of upstream and downstream of complex has been done (Hosseinpour *et al.*, 2014) and the results are shown in Table. 2.

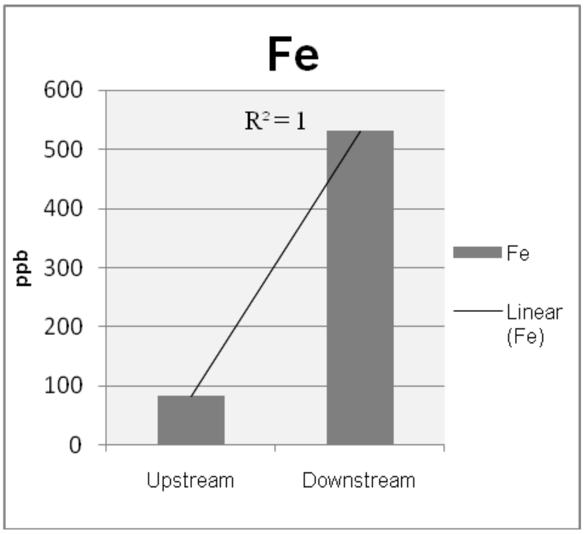
Table 2. Heavy Metal Content of Groundwater Resources of Khorasan Steel complex

Ppb	Fe	Zn	Cu	Pb	Cd	As	Cr	Ni
WHO Standard	300	5000	1000	100	5	20	50	20
Upstream	83	6.2	2.0	1.19	0.23	4.03	4.32	1.6
Downstream	531	8.3	9.90	1.59	1.12	5.41	25.88	2.36

According to short time of the complex activity, only very less changing in ground water resources has been assessed. Changes for elements including Ni, Cr, As, Cd, Pb, Cu, Zn, and Fe are shown in Fig. 6.

Impacts on air quality

In the steel production process, air pollutants in both solid particle and gaseous pollutants are generated. These particles have mostly a variety of heavy metals (Cansaran-Duman, *et al.*, 2011). The largest sources of dusts emissions in the Complex are raw materials transportation, outdoor material handling, direct reduction and smelting and eventually all are dispersed in space by the wind.



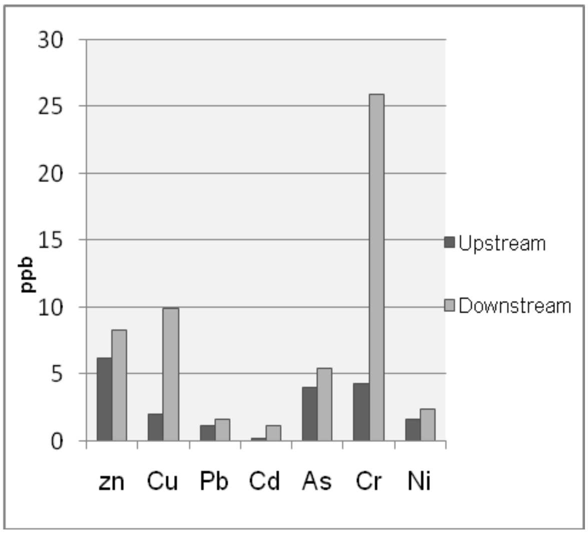


Fig. 6 Comparison of Heavy metal content of Upstream and Downstream

Gaseous pollutants generated in the production of steel are given in Table.3 (Monavari, 2001). The most important one among all the gases, is sulfur dioxide because at high concentrations would causes acid rain. In addition, the carbon monoxide gas poisoning of workers is very dangerous (Schueneman *et al.*, 1963).

Table 3. Gases and Dust Production at Various Stages of Steel Production

Air characteristics	Per ton	Source
High tempereture Water Vapor		Direct Reduction/ EAF/ Casting
NOx	2.5-3 m^3	Direct Reduction/ EAF/ Casting/ Rolling
SOx	4-13 m^3	Direct Reduction/ EAF/ Casting/ Rolling
CO	800-1000 m^3	Direct Reduction/ EAF/ Casting/ Rolling
CO2	45-50 m^3	Direct Reduction/ EAF/ Casting/ Rolling
H2S		Direct Reduction/ EAF/ Casting/ Rolling
HF		Rolling/ EAF/ Casting
HCl		Rolling/ EAF/ Casting
Oil and Hydrocarbons		EAF/ Casting
O3		EAF
Heavy Metal Dust	100-120 Kg	Direct Reduction/ EAF/ Casting
VOC		EAF
PAHs		EAF
Lime and Silica Dust		EAF/ Transportation

Some studies showed that dioxins and PCBs emitted by steel plants could accumulate in the body of people living around these facilities. Although iron and steel industry and waste incinerators contribute to global air pollution, it appears that they significantly increase the exposure of residents to persistent pollutants like dioxins only when high emission levels are coupled with a regular consumption of locally produced food (Sébastien Fierens *et al.*, 2007). Air quality in residential areas near steel plants may influence cardiovascular physiology (Liu *et al.*, 2014).

Impacts on soil quality

Soil quality of adjacent regions to the steel plants depends on several factors. Among all the factors such as water and solid wastes, which affect the soil quality, one can mention are the exhausted gases containing heavy metals of complex influence on the surrounding soils (Dragovi *et al.*, 2014). In addition, the output of the plant wastewater that are used for irrigation of green spaces or are discharged in sub-streams, can affect the quality of the soil. Metal analysis of soil samples in surrounding the slag and dust depots showed that these wastes could increase metal concentrations to several times in soils in some cases. In addition to heavy metals, pH of soils due to the presence of limestone, dolomite and magnesia in the slag were affected and showed a dramatic increase. Soil samples taken from the slag and dust surrounding depots are shown in Table.4. In all soil samples, metals are enriched in comparing to the background values.

Table 4. Heavy Metal Content of Soils around the Complex

Ppm	Fe	Zn	Cu	Pb	Cd	As	Cr	Ni
Soil Adjacent to Dust	34000	1150	50	130	11.5	8.3	88	36
Soil Adjacent to Slag	48800	7980	200	906	19.5	10.5	163	150
Background Soil	1920	48	9	7	0.25	6.0	20	19

Noise pollution

Noise is generated at various stages of Khorasan Steel Complex. From transport of raw materials to furnaces working and unloading of the products, noise pollution is available. Total produced sound in addition to disrupting the Complex staff health, would cause noise pollution in the adjacent residential areas. In Abghuy village, located at 2 km upstream of the complex, phenomenon of noise pollution after the hours of administrative time, due to the complex circadian activity, is more evident. It is important to note that many animal species that are found around the complex in result of the noise pollution of the area would scape. Noise pollution is of utmost importance for the staff in the smelting unit, which based on available information, are at greatest risk. Noise pollution caused by steel production in various sectors are shown in Table. 5 (International Labor Organization, 2005).

Table 5. Noise Pollution Caused by Steel Production

Source	Control room	Production hall	Separation of Mold	Discharge of raw materials	Main Door
Sound levels dB(A)	90-99	80-100	72-96	72-81	60-66

Use of energy resources

Steel Plants are considered as major consumers of energy. Currently, more than 10% of the world's energy is consumed in the steel industry (Monavari, 2001). The electrical energy required to melt a ton of metal scrap and bring the temperature from 25 °C to 1650 °C, is about 389 KWh. However, the loss of energy happens due to cooling systems, slag and gas emissions therefore, only about 57% of it is used for melting. Therefore, to melt a ton of scrap requires approximately 700 kilowatt per hour of energy (Tohidi, 1992). Considering the annual production capacity of Khorasan Steel Complex which is about 2 million tons of crude steel, the annul electrical energy required in the plant is over one billion and four hundred million kilowatt per hour. However, the other sources of energy such as coal and natural gas are used in the complex and make this industry so expensive (Soheili, 2010).

Using of resources and raw materials

From the beginning of steelmaking, raw materials that are used in the steel industry units are various and the most important ones are Iron ore, water, limestone, manganese, fluorine, refractory soil (soil angelic and sticky), dolomite, coal tar, Ferro alloys, quartzite, casting sand, iron scrap, aluminum, bentonite, melting materials and graphite electrode. In addition, the steel industry is a major consumer of electrical energy and fuels, including natural gas and coal. For producing one ton of steel about 1.66 tons of iron ore is required (Farhang, 1970) that according to the annual production capacity of Khorasan Steel Complex, 2 million tons of steel, about 3 million and 320 thousand tons of iron ore is needed for complex in a year.

Solid waste production

Generally significant amounts of furnace slag, coke crumbs, coal tar, crude, Cauldron butts, broken brick, industrial sludge, waste lime and unmelted scrap generate in steel plant during production which eventually depot in the complex area. Slag and furnace dust produced at Khorasan Steel Complex were analyzed and the results indicate that these materials are enriched of heavy metals (Hosseinpour *et al.*, 2014). The results of heavy metals of furnace dust and slag analysis are presented in Table. 6.

Table 6. Heavy Metal Content of Dust and Slag

ppm	Pb	Cu	Zn	Fe	Cd	As	Cr	Ni
Slag	52	31	117	> 10%	0.28	3.7	142	23
Dust	1182	331	14198	> 10%	21.7	17.3	157	40

During steelmaking in electric arc furnace, 10 to 15 kg of dust is generated per ton of steel product. In USA, EAF dust is listed by the Environmental Protection Agency (EPA) as hazardous waste under the Resources Conservation and Recovery Act (RCRA). Recent EPA regulations require EAF dust before being dumped, to be treated thermally or chemically to remove or stabilize the leachable toxic metals such as zinc, cadmium and lead; However the Khorasan Steel Complex dusts are dumped in precinct directly after accumulation and collection. The location of the slag and dust depots relative to the Khorasan Steel Complex is shown in Fig. 7.

Biological environment

Impacts on plants

Plants can affect from direct impacts of the steel project by soil removal or construction of a new access road. For the Khorasan Steel Complex in a total about 15 km of road and boulevard have been made outside and inside the site. Indirect impacts on plants can be caused by contamination of water, soil, air. Even pH changes can affect the plants, such as increasing in pH by slag's waste waters, something that is very common in soils of Neyshabour plain. Studies of trees nearby steel plants with much activities background have shown the absorbed heavy metals in their annual growth rings (MacDonald *et al.*, 2011).

Fig. 7 Khorasan Steel Complex location and Dumped Dust and Slag

Impacts on animals

The most important impact for animals near steel plants is noise pollution. In addition, some animal species in result of losing their habitat will die or inevitably will leave for finding new habitats and sanctuaries. According to the absence of permanent river adjacent to the Complex, there is no anxiety about aquatic organisms.

Impacts on health of staff

Steel plants are potentially dangerous work places that causing health and safety risks to the staff.

Harmful environmental factors such as high temperature, producing intense noise, emissions, vapors and particle pollutants, infrared radiation, hazardous materials, including acids and the risk associated with high electricity voltage are the most important factors that reduces the safety factor and individuals health. In addition, possible presence of radioactive materials in scrap and raw materials can expose staff (Sofilic *et al*; 2004). Studies have showed that ^{40}K and ^{137}Cs will be concentrated in dust, ^{226}Ra and ^{238}U will be mainly distributed between dust and slag but their presence in steel cannot be excluded. ^{226}Ra and ^{238}U in steel, slag and dust mainly come from fluorspar and bauxite. ^{232}Th was not detected in raw materials and steel scrap but it was concentrated in slag and dust during the technological process. In addition to safety problems, Electric and magnetic fields (EMF) are invisible lines of force emitted by and surrounding any electrical device (e.g. power lines and electrical equipment). Electric fields are produced by voltage and increase in strength as the voltage increases. Electric fields are shielded by materials that conduct electricity and other materials such as trees and building materials but Magnetic fields pass through most materials and are difficult to shield. Both electric and magnetic fields decrease rapidly with distance. Electric Arc Furnaces are a treat to the workers so there is public and scientific concern over the potential health effects associated with exposure to EMF (Prevention Handbook, 1998). The allowed magnetic field for EAF is presented in Table. 7 (Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields, 1998).

Table 7. Allowed magnetic field for Electric Arc furnaces

Description	Maximum allowed field intensity	Maximum field Intensity
Electric Arc Furnaces	30 μT	100 μT from source field

Social- economical environment

Khorasan Steel Complex have been created over 5,000 direct and indirect jobs. Therefore, according to the migration and increased population, many changes have been done to the social and economical environments, including: higher income levels, increase in health care, welfare and education, traffic, extraction of groundwater, wastewater production, land use change and real estate prices rise.

Cultural environment

Cultural environments may vary due to entrance of immigrants to the area, which have different cultures. In addition, with the presence of professionals in different majors, new generation of experts could be appear between local people. Increased incomes could change the local people culture.

Conclusions

Khorasan Steel Complex is in the thirteenth year of its operation. The complex, by using Electric Arc Furnace has the ability of using both scrap iron and sponge iron as raw material for steel production with the capability of 2 million ton a year. Due to location of the complex in a populated plain of Khorasan Razavi Province, environmental impacts of this Complex are very important. Base on the information and the studies, this Complex has three main environmental impacts. First discharging too much water of the ground water resources in the area that ground water is unique water sources. The second is about distributing of heavy metals in soils that is caused by slag and dust dumps and also emission gases. Moreover, the last point is the exposure of 4 million ton of not modified slag and dust in the Complex area.

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