Environmental Impacts of Iran Ferrosilicon Company and Mitigation Plans to Reduce the Adverse Effects

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***Abstract*—**Industries are one of the most significant sources of environmental pollution. Ferrosilicon company is one of the industries in Iran which requires a continues monitoring and environmental assessments. In general, each environmental assessment has three stages, namely; construction, operation and capacity development. Each of the stages must be assessed under physical, economic, social and biological environment. Based on the environmental assessments, a bored decision is made for the future trend of the factory.

The main objective of this study is to assess the impact of the ferroalloy on environment. This objective is important because it mandates the sustainability of the company and also provides a comprehensive solution to prevent the negative impacts of the industrial activities on the environment.

Iran Ferrosilicon Company is selected an industrial control for the study. This company is the first producer of silicon alloy in Iran, situated in Semnan province. And therefore it is selected as a control industrial hub for case presentation. The ferrosilicon company which is equipped with most advanced laboratories produces finest type of 75% ferrosilicon by annual capacity of 25,000 tons of ferroalloy production and 4000 tons of magnesium ferrosilicon annually. (IFC's laboratory is equipped base on standard 17025).

In recent years the company is aiming to increase its chain production rate to 50,000 ton per year. By capital planning of this aim and objective, the ferrosilicon company considers the important of environmental issues, and therefore includes environmental assessments in their future strategies in order to prevent harm to the environment. The management and the stakeholders associated with the company and the CEO are briefed about the environment impacts of the factory production and the managing committee has a special attention for the environmental issues. The company has consultation teams which consist of environmental experts whom assess and monitor the emission control online, on daily bases. The emission controls provide information to the local environmental department office. This procedure is carried on in order to eliminate potential harmful effects of ferrosilicon company contaminants of environment.

It is important to note, Ferrosilicon Company has been a pioneer in job production and business generation. The company believes by implementing a proper environmental protocol, the company can act as a role model for greener environment in industrial section. Also, it can still enhance its opportunities to be one of the countries successful business company.

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I. INTRODUCTION

Environment challenges are becoming increasingly important for all of us. It's understandable that there are several reasons for the increased attention given to environmental issues and there are growing concerns about the environmental situation and unwanted side-effects of human activities . The initial impacts are related to total energy use and different kinds of pollution which may result during the various stages in the production of materials.The production of ferroalloys and the environmental aspects of silicon have to be taken into account as a part of man-made pollution. Many companies implement waste management or environmental departments to empower potential cost savings and avoid wasting, but concept of sustainability requires much more. Ensuring that aspects of sustainability were considered within business processes must be followed by Environmental Impact Assessment (EIA) to improve decision making processes for sustainable or greener practices [1].

II. MATERIALS AND METHODS

A. Study area

Ferrosilicon Iran Co. (Public Joint Stock Company) was established as the first Ferro-silicon production plant in Iran in the province of Semnan in 1981, with an area of 50 hectares in the 11 km road of Semnan road of Damghan (opposite industrial town of Semnan. The production capacity of this plant has been 85 tons per day and annually 25,000 metric tons of ferrous silicon so far, regard to using the electric arc furnace.

As a case study this company has been selected which has a history of over 35 years in this business as the first producer of silicon alloys in Iran. "Iran Ferrosilicon Co", founded in 1981, and the boards are experts in the field of metal casting and melting, who are pioneer in producing standardized ferrosilicon. The production unit, using an arc furnace with daily production capacity of 85 tons and an annual capacity of 25,000 tons, which benefits of the most advanced laboratories and quality control service, for producing the finest type of

75% ferrosilicon in country. Also, 4,000 tons of magnesium ferrosilicon annually is producing which is competitively comparable to similar specimens in terms of quality.

Nowadays, due to the enhanced need for Ferroalloy Products in the country, an expansion plan is considered for boosting the production capacity of Ferrosilicon up to 50,000 tons a year. But its implementation can impose some environmental damages without preparing environmental basis and mitigation management plans.

Due to high quality products, this factory exports to European and Asian countries.Iran Ferrosilice Company (Joint stock company) has set up a series of safety, environment protective and health care systems based on ISO 9001 - 2000 ISO 14001 – 2004 OHSAS 18001 – 2007 under an Integrated Management System. Furthermore this company is a leader in quality management in ferroalloy industry, as the first holder of international certificate “Golden Eagle Award “of Europe 2010 for quality management and Winner of International Quality ERA award 2013.

B. Ferrosilicon Industry Products and Application

Ferro-silicon is an alloy of iron and silicon (Fe-Si) which is produced in electric arc furnaces and in various grades, including% 10 Fe-Si to 90% Fe-Si, which means the number, the amount of silicon Available in this ferroalloy. However, the grades required by the industry, especially the steel industry, are 70% Fe-Si and 75% Fe-Si. It should be noted that other elements such as, Al, P, S, C, Mn, Cr, Ti are commonly used in this compound, and usually most steelmakers require a lower percentage of aluminum to 2%.

For instance the specification of products from “Ferrosilicon Iran Co” is:

- Ferro Silicon is often used in the production of cast iron. It is also used in the production of semiconductor pure silicon in electrical industry and silicon copper in chemical industry. (Application : Deoxidizing factor in Steel Producing ,Grain Refiner for Ductile Cast Iron’s Casting and Alloying Element in Rich Silicon Steel Production).

Size (mm)	Chemical Analyze						
	Si	Al	Ca	C	P	S	Fe
	%	Max%					
10-60	72-78	2	1.2	0.1	0.04	0.01	Remaining Percentage
	73-78	1.5					
	74-78	1	0.2				
	74-78	0.5					
3-10	72-75	2	1.2				
0-3	70-72	2.5					

- Ferrosilicon Magnesium with Magnesium content of 6% - 6.5% is a basic foundry alloys used for the production of ductile cast iron. Magnesium content plays an important role in the produced alloy grades from dolomite ore. (Application : in producing Ductile Cast Iron).

Size(mm)	Chemical Analyze					
	Si	MM	Mg	Ca	Al	Fe
	%				Max %	
5-30	43-48	0.5-1	5-6.5	0.8-1.4	1.2	Remaining Percentage
5-15						
1-5						

- Microsilica Powder A byproduct of the production process of Ferrosilicon is Microsilica Powder or Silica fume. It is added to concrete mixes to improve compressive and bonding strength. Because of its chemical and physical properties. Until a few years ago, 6,000 psi concrete was considered to be high strength. (Application: In Construction Industries for Increasing Concrete Compression Strength, Corrosion and Electrical Resistance and Polymer Industries)

Physical Analyze					
Structure	Shape	Particle Size (μm)	Bulk Density (kg/m^3)	Specific Surface (m^2/g)	Specific Gravity (kg/m^3)
Amorphous	Spherical	< 40	200-300	14-20	400-600

Chemical Analyze							
SiO_2	Fe_2O_3	CaO	Al_2O_3	MgO	C	L.O.I	Moisture
Min %	Max %						
85	2	1.5	1	2	3	3.5	1

- As a whole, these products consume at steel and casting industry as an oxygen exhaust and regulator of the chemical composition according to the steel grade and when the melt is discharged from furnace to ceiling or during secondary metallurgical operations. Other applications are the casting industry as germination or in the producing of casting in the form of Ferrosilicon membrane as a non-destructive agent in dactyl cast iron and compact graphite cast iron. Micro silica powder is also a by-product in the process, which has application in housing to increase compressive strength, electrical resistance, corrosion resistance in polymer and refractories industries. In the concrete industry, due to the size of the micro silica powder particles, this product acts as a homogeneous filler for filling the pores surrounding the cement paste beads, obstructs permeable pores and improves the adhesion of concrete to steel.

III. Environmental Aspects in Ferrosilicon Production Industry

The main sources for pollution in the silicon process are:

• Electric energy system. A variety of environmental problems may arise from the electricity system.(e.g.C02)

• Reduction materials - coke, coal and woodchips. The carbon necessary for the reduction process will inevitably be converted to CO or C02 gas. Some minor elements in the ash will be found in the off-gas, slag or in the alloy

• Quartzite minerals. These silica sources normally contain minor elements besides the Si02. Some of these elements may be carried with the off-gas to the environment. Other elements will end up in the metal or slag.

The large amount of air sucked into the hot combustion zone in the furnace may produce nitrogen-bearing gases. Process emissions are often divided into three main categories, pollution to air, soil, and water. From the silicon process air pollution is probably most significant. On the other hand, an emission to the air may later convert to soil or water pollution. One example of this is sulfur dioxide (S02) in the off-gas, which will contribute to acid precipitation and consequently lead to water pollution. The most visible emission from the silicon process is the Si02 fume if there is no cleaning equipment. These are very small condensed particles from the process [2].

1) Pollution from the process: In the process itself, the various effluent pollutants can be formed at different stages. Table 1 summarizes the main pollutants and the regions where they are formed in the process. The principal environmental issues related to the process are listed in Table 2.

2) Pollution to the air: Unwanted discharges to the air tend to be the most common environmental effect of silicon production. This type of pollution consists both of particles from the process as well as gaseous compounds. The main visible effluent is associated with gray silica particles consisting of approximately 85-95% Si02. This dust pollution is normally cleaned in filters connected to the furnace off-gas system.

3) Pollution to the soil and surface and ground water: The formation of skull in a ladle, for example, may create an off-grade mixture of metal refractory which must be disposed. Finally, some of the air pollutants may be carried to the soil or water. In the case of slag producing ferroalloy processes like the production of manganese and chromium ferroalloys, slag storage and landfills may create pollution to the soil or water. The use of wet cleaning equipment for the off-gas may also create water pollution [2].

TABLE I:
MAIN PROCESS REGIONS WHERE EMISSIONS ARE FORMED [2]

Process region	Pollution type formed	Comments
Reaction zone	• Metals with boiling points below the process temperature, approximately 1900 °C. • CO gas • SO_2	In the reaction zone the process will form CO and SiO gases. Low boiling point metals will escape as gases and then condense or oxidize to form impurities in the amorphous silica-dust from the furnace.
Combustion zone	• Amorphous silica particles • Nitrogen-bearing gases • CO_2 gas • Elutriated particles from the raw materials • Carbonaceous soot-formation	In the combustion zone SiO gas oxidizes to form solid amorphous SiO_2-particles. The reaction is vigorous and some nitrogen-bearing gases are formed. The off gas velocity may mechanically entrain some raw material fines into the off-gas.
Cooling water system	• Loss of energy • Hot water pollution	Waste energy from silicon production is normally quite significant. Loss of energy may be considered as a form of pollution. Hot water discharge into surroundings may be unwanted.
Tapping area	• Tapping fumes, mainly amorphous silica-particles • Some slag	The tapping and casting processes may be sources of internal environment problems or waste material generation.

TABLE II:
THE MAIN POSSIBLE ENVIRONMENTAL EMISSIONS FROM THE SILICON PROCESS [2]

POLLUTION TO	Pollution types	Pollution	Geographical Area Impact	Potential Environmental Effect:
Air	Gases	• CO_2 gas • Sulfur-oxides (SO_x) • Nitrogen oxides (NO_x) • Volatile Organic Compounds (VOC)	• Global • Regional/local • Regional/local • Regional/local	• Global warming • Health hazard • Acidification and health impact • Acidification and health impact • Ground near ozone formation
	Oxides	• Visible amorphous silica particles	• Regional/local	• Visual/smoke formation
	Metallic Components	• Mercury and other heavy metals	• Local	• Health hazard
	Others	• Polycyclicaromatic hydrocarbon PAH • Chlorinated Hydrocarbons	• Regional/local • Regional/local	• Health hazard • Severe health hazard, dioxins bioaccumulates in the food chain
Soil		• Small amounts of slag • Disposal from dust cleaning • Conversion of some of the pollutants in the air to soil pollution.	• Local • Regional/local • Regional/local	• Local water/ground pollution • Local water/ground pollution • Local water/ground pollution
Water		• Hot water from the process • SO_2 may lead to acid precipitation • Conversion of air pollutants to water pollution.	• Local • Regional/local • Regional/local	• Increase local water temperature • Acidification • Surface water and ground water contamination

A. Emissions

The main substances emitted from the manufacturing process are silica powder and carbon monoxide. Sulphur oxide also forms due to the Sulphur content of the carbon donors, and nitrogen oxide is created by the reaction of nitrogen with oxygen in the hot air over the furnace [3].All of the emissions will be conducted through a fume scrubbing system with bag filters. These collect silica powder, a valuable by-product used for instance in the cement industry. Above the furnaces, where atmospheric oxygen comes into contact with hot carbon monoxide, the latter oxidizes further into carbon dioxide. Iran Ferro silica obtained emission allowances for greenhouse gases. The emission of heavy metals from the silicon manufacturing process is low. Usually the greater part of the heavy metals remain in the final products, both silica powder and silicon. To augment product quality, it is therefore important to utilize specially selected, pure quartz that have been washed to remove ash. The assumption made here, however, is that all of the mercury (Hg) is bonded organically; therefore, its concentration will not be reduced by washing. Adopting the latest technology in bag filters for minimizing the dust in emissions will further reduce the release of heavy metals accompanying dust. Based on this, the dust released through stacks should be approximately 0.1% or even less of the total dust formed in the production process [3].

B. Run-off

Water discharge from the silicon plant consists mostly of precipitation running off the roofs and off the asphalt areas of the property. It could also be that quartz will be wetted or washed to some degree in order to reduce dust formation. Discharged water from the roofs or site, as well as from wetting raw materials, will be treated to make sure that the amount of solid matter remains within limits; however, the size and design of the relevant equipment has not yet been decided [3]. Sewage from the staff facilities, canteen and associated operations is expected to be piped into the wastewater system and treated in accordance with its standards. The connecting point is in the southwest corner of the lot, in keeping with area planning.

C. By-products and waste

The main by-products and waste from the proposed operations are the following [3]: Silica powder (to be sold), Slag (to be sold), Sweepings left by raw materials and products Silicon dioxide, which is formed again in the furnaces upon the combustion of silicon and silicon monoxide, is collected from the plant's fume scrubbing system as silica powder. Silica powder is an important by-product, which can be used as an additive in cement mixtures and other construction materials such as mortar and plaster. Prior to material entering the bag filters, it will pass through a separator which serves to protect the bags by removing coarser, hotter material. In many places, useful channels for the leftover material have been found at unrelated industrial companies. The aim is to do the same here, but if no such channel emerges, it is presumed that this material will have to be landfilled as waste. Slag is formed during the post-processing of molten silicon. Samples taken from the liquid while it is being drained into a crucible are chemically analyzed. Oxygen-rich air is then blown into the hot liquid, along with calcium, silicon particles, silicon monoxide and possibly aluminum; in case this is not present in sufficient amounts in the liquid. This produces a slag phase which has the purpose of precipitating various elements, above all metals, leaving purer silicon behind while removing the undesired elements. The resulting slag, however, is a commodity put to many uses, such as producing metals, various special kinds of concrete, etc.

IV. Mitigation Management Plans

A. Pollution Control Plan

The following Environment Management Plan aims at minimizing the pollution at source [4].

1) Air Quality

- High efficiency bag filters and Gas Cleaning Plant (GCP) must be installed to control dust emissions from exhaust gases;
- To ensure that the bag filter system is operated as per the specified procedures;
- Fine dust collected in the bag filters to be collected in barrels and shall be used in low lying areas;
- Periodic maintenance of bag filter system to be carried out in order to ensure efficient operation;
- Regular monitoring system in stack emission will be in place;
- Unloading of materials from trucks shall be carried out with proper care avoiding dropping of the materials from height & the material will be moistened by sprinkling water while unloading;
- Raw material ground hopper and bins shall be provided with dry fog system;
- Enclosures shall be provided for conveyors and transfer points of conveyors; and
- Sprinklers shall be provided for dust suppression at dust generation points.

2) Soil Quality

All stack emission sources will be provided with appropriate high efficiency air pollution control equipment;

- Dust suppression arrangement at raw material storage yard;
- Closed container collection, storage and transportation of all hazardous wastes within the plant and outside;
- Separate drains for storm water and process effluents to collect storm water and reuse back to process;
- Process effluents transfer to WWTP in closed pipes for treatment and reuse; and

- Regular road sweeping for recovery of dust from the spilled areas within the plant boundary.

With the proposed mitigation measures, the impact on soil quality outside the project boundary will be negligible.

3) Water Quality

The recommended measures to minimize the impacts and conservation of fresh water are:

- Maximum recycling of treated wastewater generated in cooling tower into process;
- Provision of appropriate treatment facility to treat domestic sewage from plant;
- Utilization of treated domestic wastewater and dust suppression;
- Provision of separate storm water system to collect and store run-off water during rainy season
- Treatment of storm water to remove contaminants, if any before discharging.

B. Environmental Monitoring Plan

The environmental monitoring is important in terms of evaluating the performance of pollution control equipment installed in the project. The regular monitoring program of the environmental parameters is essential to take into account the changes in the environment [4]. A comprehensive monitoring program is suggested in Table 3. As a whole, the objective of environmental monitoring is:

- To verify the result of the impact assessment study in particular with regard to new developments;
- To follow the trend of parameters which have been identified as critical;
- To check or assess the efficacy of the controlling measures;
- To ensure that new parameters, other than those identified in the impact assessment study, do not become critical through the commissioning of new installations;
- To check assumptions made with regard to the development and to detect deviations in order to initiate necessary measures; and
- To establish a database for future impact assessment studies for new projects.

TABLE III:
THE MONITORING SCHEDULE FOR ENVIRONMENTAL PARAMETERS

Particulars		Monitoring Frequency	Method of Sampling	Important monitoring Parameters
Air Quality				
A	**Stack Monitoring**			
1	Stack	Once in a month	ISO-Kinetic, Flue Gas Analyzer	PM, CO, SO2 & NOx
B	**Ambient Air Quality Monitoring**			
1	locations around the plant	Twice in a month	24 hr continuous	PM10, SO2, NOx and CO
2	Work zone monitoring	Once in a month	Low volume sampler	PM10, SO2, NOx and CO
C	**Fugitive Emissions**			
1	Raw material handling, feed area, product processing area and other areas	Once in a month	8-hour basis with High Volume Sampler	PM
D	**Water and Wastewater Quality**			
	Domestic Wastewater			
1	WWTP of factory	Once in three months	24 hr composite	TSS, BOD, COD, pH, temperature, oil & grease and heavy metals
	Industrial Effluents			
1	Ferro Silicon Factory	Once in month	24 hr composite	pH, SS, O&G, heavy metals

V. CONCLUSIONS

During last decades there is increased awareness of pollution hazards among the people and various measures are being taken to effectively protect ecology by pollution control from Ferro-alloy plants also. It is extremely essential to have the knowledge of the process of Ferro-alloy production, which produces pollutants, for an efficient selection of the control equipment (5). The proposed expansion project does not have significant pollution potential with proper and judicious implementation of the mitigation and environment management measures. So the impacts can be minimized and maintained well enough within the permissible limits specified by the regulatory authorities. Moreover, the project will generate job opportunities for the local population so the development of this project certainly has positive impacts in terms of bridging demand and supply gap and providing the employment opportunities to the locals during the course of its execution. Thus, it can be concluded that with the strict implementation of the pollution control and mitigation measures, and proper environmental management system in place, the proposed factory will be beneficial to the society and will contribute to the economic development of the region in particular and the country in general.

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