Cement Kilns Dust Management In Iraq

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Abstract

Hundred thousands tons of cement kiln dust (CKD) as well as other emissions are generated annually from existing cement plants in Iraq with significant economic and environmental impacts. Therefore, an environmental sector plan should be adopted to scrub the emissions and sound management of CKD waste leading to save resources and secure better environmental quality are called for.

A survey was conducted and carried out covering all cement plants. Analysis of data collected has shown that the production capacity was significantly decreased to about 38 % on the average of the designed capacity. The consumption of raw materials and fuel per unit production was increased by about 13 % and 23 %, respectively. The amount of generated CKD is found to be variable among the different cement plants. It can be estimated that the generated CKD on the average is about (8-33) % of the production output depending on the conditions of each plant.

This study serves to establish a factual basis to develop a convenient environmental management plan for the cement industry sector. This study proposes an environmental mitigation and monitoring plan to address the environmental and social challenges to improve the environmental performance of Iraqi cement industry sector.

Keywords: CKD, Dry process, Wet process, Environmental Management.

أدارة غبار أفران الاسمنت في العراق

الخلاصة

تطرح المعامل القائمة لانتاج الاسمنت في العراق مئات الالاف من الاطنان من غبار افران الاسمنت (CKD) اضافة الى الملوثات الاخرى سنويا، مع مايرافق ذلك من تاثيرات اقتصادية وبيئية. لذا اصبح من اللزام تبني خطة بيئية لقطاع الاسمنت من اجل تخفيف الانبعاثات والملوثات المطروحة، اضافة الى الادارة السليمة لتلك النفايات بما يضمن حفظ الموارد وبيئة أفضل.

تم تنفيذ مسح لمعامل الاسمنت. تحليل البيانات التي تم تجميعها اظهر ان الطاقات الانتاجية لمعامل الاسمنت قد انخفضت بصورة مؤثرة لتكون بالمعدل حوالي (% 38) من الطاقة التصميمية. وان استهلاك المواد الاولية والوقود ازداد لكل وحدة انتاج ليكون (% 13) و (% 23)، بالترتيب. ان كمية غبار افران الاسمنت (CKD) المتولدة قد ازدادت، وتختلف من معمل لاخر. يمكن حساب كميتها المتولدة بالمعدل حوالي (% 33-8) من كمية الانتاج اعتمادا على ظروف كل معمل.

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هذه الدراسة تخدم في نشر اساس يعتمد لتطوير خطة ادارة بيئية موثوقة لقطاع الاسمنت في العراق، والذي يمثل جوهر الدراسة. ان الدراسة تقترح خطتين احدهما لتخفيف الضـــغوط البيئية وبالتالي الاقتصادية والاجتماعية، والاخرى للمراقبة والالتزام البيئي، لتحسين الاداء البيئي لقطاع الاسمنت في العراق.

Introduction

The cement industry, as with most others, has certain aspects that have caused serious problems relating to the human health and environment. The environmental consequences of the cement industry operations include resource extraction (fuel and raw materials), dust emissions, gaseous air pollutants (including greenhouse gas emissions), waste generation and other effects (UKEA, 2005) [1]. Therefore, the adoption of a proper environmental management plan will enhance the sustainability of cement production and the expected benefits from plants operations (El-Fadel et al., 2005) [2].

Cement Manufacturing Process

The production of cement is a highly energy-intensive process. Limestone, clay, sand, and gypsum are used as raw materials in the production of cement. Although a variety of cement types are produced in Iraq (ordinary Portland cement, sulfate-resisting Portland cement, white Portland cement, and others), cement production generally follows a standard series of steps as shown in Fig. 1. Portland cement is derived from a combination of calcium (usually in the form of limestone), silica, alumina, iron oxide, and small amounts of other materials. These raw materials are quarried, crushed, ground together, and then burned in rotary kilns at temperatures near (1480 ^{o}C). The resulting material is called clinker. The clinker is finely ground into a powder and mixed with gypsum to slow down the "setting" (i.e., hardening) of the cement when it is used in concrete (USEPA, 1993) [3]. There are basically two distinct methods of blending the raw mixture: the wet process and the dry process (Duda, 1976; Peray, 1972) [4,5].

Wet Process Kiln

Wet process kilns are longer than dry process kilns because a substantial portion of the kiln length (20 to 25 percent) must be used for evaporation of the slurry water. When compared to dry process kilns, reported advantages of wet process kilns include more uniform feed blending, generally lower emissions of kiln dust, and compatibility with moist climates where complete drying of raw feed is difficult to achieve. The primary disadvantage associated with wet process kilns, however, is that they require significantly more energy, because large quantities of water must be evaporated from the raw feed, resulting in higher operational costs. Typical energy requirements for wet process kilns range from 1,530 to 1,670 kcal/kg of clinker produced (Maryna, 2006) [6].

Dry Process Kiln

Dry process kilns operate with a high exit gas temperature. The high exit gas temperatures can therefore be used in suspension preheater kilns (as shown in Fig. 2), the raw meal is fed to the top of a series of cyclones passing down in stepwise counter-current flow with hot exhaust gases from the rotary kiln thus providing intimate contact and efficient heat exchange between solid particles and hot gas. As the raw material passes through each of the four stages, it gets hotter and becomes more processed before entering the kiln, resulting in more uniformly processed material.

Increased energy efficiency is a major advantage of dry process kilns in comparison to wet process kilns. Available data indicate that dry kilns are approximately 10-25 percent more thermally efficient than wet kilns, requiring 1,250 to 1,390 kcal/kg of clinker produced(USEPA, 1993; Peray, 1972) [3,5].

Alternative Ckd Management Practices And Potential Utilization

CKD is a fine-grained solid alkaline material generated as the primary by-product of the production of cement (UKEA, 2001) [7]. Gross CKD is the dust collected at the Air Pollution Control Devices (APCDs) associated with a kiln system. After collection, gross CKD is either recycled back to the kiln system or removed from the kiln system as net CKD. When CKD is removed from the kiln system, it can be treated for return to the kiln system, beneficially utilized which can be considered a viable option or disposed. Fig. 3 illustrates the potential management pathways for gross CKD.

CKD Recycling

Although net CKD may be viewed as a waste, its nature as essentially an intermediate product makes direct return to the kiln, or recycling, a desirable option for cement plant operators. If more CKD could be returned to the kiln system via recycling, less net CKD would be generated. Decreasing net CKD quantities reduces the quantity of dust that must be managed in some other manner (Kessler, 1995)[8].

CKD Treatment and Return to the Process

CKD that contains alkalies or possesses other undesirable characteristics may be treated so that it can be returned to the kiln system. Although few treatment processes have been commercially adopted on a wide scale, research into CKD treatment and recycling has yielded a number of promising technologies. These include pelletizing, leaching with water, leaching with potassium chloride solution, alkali volatilization, recovery scrubbing, and fluid bed dust recovery (USEPA, 1993; UKEA, 2001) [3,7].

Beneficial Use of CKD

CKD may be useful in a variety of applications, including construction, stabilization, waste treatment, and agriculture. Due to the variability in dust composition, uses of CKD should be undertaken only after the material's characteristics have been properly evaluated with respect to the intended application (USEPA, 1993) [3].

CKD On-site land disposal

Waste CKD is most commonly land-disposed in on-site WMUs. At cement production facilities, landfills and piles are the most common on-site management method. CKD piles are not engineered structures but are instead accumulations of CKD in designated areas usually around or near the facilities. Such piles may or may not be above grade, and they may or may not be contained within the quarry.

Planning For Environmental Management

To control and properly manage pollutants, the governments have developed environmental regulations that organizations (such as cement's companies) must comply with or face penalties, fines and liability. Facilities presuppose respond to these regulations and problems with a systematic approach to planning, controlling, measuring and improving the environmental performance. An environmental management system (EMS) can provide a structure for organizations to manage, assess and continuously improve the effectiveness and efficiency of the management of their environmental activities (Pataki et al., 2000) [9].

Environmental management can be built up in many ways, for instance on the basis of the company's own system or after an acknowledged standard. The philosophy is exemplified in the five fundamental principles built into the EMS standard. These principles, as shown in fig. 4, include commitment, planning, implementation, measurement and evaluation, and continual improvement. The fundamental purpose of the EMS is to control and reduce the environmental impacts of facility's processes and products (Pataki et al., 2000) [9].

The size of the cement industry sector makes the reduction of its environmental impacts very important choice to prevent continued environmental degradation through adopting an (EMS) to enable the cement industry sector improving the environment by following a defined sequence of steps to identifying new methods to better manage waste, conserve resource and improve energy efficiency for environmentally responsible manufacturing process (Hulpke, 2001) [10].

Survey (Experimental And Data Acquistion)

The Iraqi cement industry consists of three regional state companies (Southern, Iraqi, Northern) operating the 16 cement facilities which are producing thousands of tons yearly of cement kiln dust (CKD) as a "solid waste". The survey of the sixteen cement plants was prepared as data collection worksheet and distributed to all plants. To minimize the non-response and the lack of data, information submitted by plants in response to the survey was supplemented and evaluated against data obtained from other sources. These other sources include sampling and measurement activities, data collection from documents and reports; site visits observations and utilizing the published international experience in this field.

Trends in Kiln Technology and Production Capacity Distribution

The age distribution of kilns both in terms of numbers and capacity are shown in table 1. There has been a trend over the years toward large kiln capacity for both wet and dry processes. The production capacity of Iraq cement industry which is distributed over three regional state companies is shown in table 2, which consisted of (79 %) produced by dry process kilns and the remaining (21%) produced by wet process kilns.

Process Inputs and Outputs

An understanding of the issues surrounding CKD requires knowledge of both the raw materials and the fuels (process input) used in cement kiln systems. The mean of chemical composition of raw materials mixture which used as a feed to rotary cement kilns are shown in table 3 for many different plants.

The designed and interdependent conversion factor (the quantity of raw materials required to produce unit of product) and the designed and actual heat consumption are shown in table 4 for all cement plants of the three cement companies. CKD generation rates vary widely among facilities on both a gross and net basis. The mean of chemical analysis of CKD which generated is shown in table 5, and the particle size distribution and other physical properties are shown at table 6, for different cement plants of the three cement companies.

Results And Disscution

Trends in Kiln Technology and Production Capacity

The earliest cement kilns as shown in table 1 were producing Portland cement by wet process which was the dominant process in the production of Portland cement till the year of 1971 where the dry process was utilized. The trend in number of kilns erected over the years is shown in Fig. 5, for both, wet and dry processes. Through the eighties of the last century, the erection of cement plants was transformed completely in Iraq to the high production dry process kilns, in spite of the fact that the wet process kiln remained competitive with the more energy efficient dry kilns.

The production capacity of the earlier plants were lower than the capacity of modern plants which are equipped with innovations such as suspension preheater and precalcinar which improve the overall energy efficiency of the kiln. As shown in Fig. 6, generally there are growing trends in production capacity which resulted from both, the increase in number of cement kilns and production capacity of modern kilns. Nowadays, both wet and dry process kilns have large production capacity.

The overall available production capacity as shown in fig. 7, accounts 38.5 percent (11 % wet and 27.5 % dry) of the total design (installed) capacity. The available capacity is distributed as 10.5 %, 13 % and 15 % as produced by the Northern, Iraqi and Southern cement companies, respectively.

Consumption of Raw Materials

An examination of table 4 shows that to produce one ton of cement, the average designed quantity of raw materials (kiln feed) required are 1.67, 1.75 and 1.76 tons for Northern, Iraqi and Southern cement companies, respectively. At the present time, all cement plants consume materials greater than the quantities specified by designed figure. As shown in the same table 4. The average present quantities of raw materials required to produce one ton of cement are 1.82, 1.97 and 2.10 for Northern, Iraqi and Southern cement companies, respectively. The average designed conversion factor on the national scale is 1.73, while the average of the interdependent at present time on the national scale is 1.96, that means to produce one ton of cement, 1.96 tons of raw materials should consumed instead of 1.73 tons with approximately 13 percent over consumption of raw materials. The average over consumption estimated is 9 %, 12.2 % and 19 % for Northern, Iraqi and Southern cement companies, respectively.

Consumption of Fuel

Fuel efficiency in rotary kilns varies considerably from one to another depending on the type of the kiln system and the process which is used. As a rule, dry process kilns, as indicated in table 4, have higher fuel efficiency (less fuel consumption) than wet ones, because the dry kiln does not require additional heat to remove the moisture from the slurry. Suspension preheater kiln is the most efficient kiln, where the hot exit gases are used to preheat and partially calcined the feed before it enters the kiln (USEPA, 2006; Peray, 1972) [11,5]. As shown in table 4, the average current heat consumption on the national scale is account 1581 kcal/kg clinker, while the average design consumption is account 1253 kcal /kg clinker with about 26 % over consumption of fuel oil. Increasing fuel consumption lead to increasing the quantity of air needed to complete composition of fuel rather than proportionally increasing the volume of exit combustion gases. An increase in volume flow rate of the exit gases for the same cross-sectional area of the kiln lead to excessive flow velocities inside the kiln. Increasing gas turbulence in the kiln can maximize the dust carried out by exit gas stream which causes overloading on the APCDs which in turn causes reduction in its capture efficiency which lead to increasing the losses (USEPA, 1993) [3].

CKD Quantities and Management

Based on available data, private interviews with various cement plants operators, site observation and the scientific analysis and logical conclusions on the difference between the designed and interdependent conversion factor of raw materials into cement, the first approximation of the quantity of CKD generated can be estimated to be between (8 to 33) wt % of the clinker output depending on the conditions of each plant. In general as shown in figure 8, the approximate average percent of CKD generated are 9 %, 12 % and 19 % for Northern, Iraqi and Southern cement companies, respectively, while the national average is about 13 % of production output.

Investigation of CKD management practices at Iraqi cement plants have showed limited options. Most plants were employing the CKD land-disposal alternative. CKD accumulates as an irregular piles and accumulation usually near by the plants; most of these piles are unlined and uncovered. That has caused, and may continue to cause, contamination of the ambient air and nearby surface water and ground water. Limited quantities of CKD for beneficial use was recorded at some plants; some are used as a filler material with asphalt and in other cases as a road base.

Many of the cement plants are directly recycling some portion of the CKD collected. Increasing the rate of direct recycling of CKD is possible and is simple and most effective means of reducing the over consumption of raw material and fuel. This in turn reduces the quantity of CKD disposed of and its related economic and environmental impacts.

Resource Saving And Pollution Abatement

In the cement industry using resources more efficiency is an essential step toward creating a more sustainable society. That means producing more with less, i.e. less waste and pollution and fewer resources. Cement plants can achieve process efficiency by reducing fuel and materials use and minimizing pollution by continuously increasing the efficiency of manufacturing equipments and processes.

Environmental Mitigation Plan

The primary potential adverse environmental impacts that are associated with the operations at cement plants can be controlled or contained by careful planning and adopting proper management practices. As well as relying on effective environmental monitoring and training to support management decisions. A mitigation plan proposed several impact-mitigation or control measures that will earn cement plants more acceptability by eliminating or reducing to the extent possible potential impacts. Table 7 presents a summary of the proposed elements of the mitigation plan that can be adopted by cement plants management (UKEA, 2005; El-Fadel, 2005) [1,2].

Environmental Monitoring Plan

Monitoring of air quality, waste generation, resource use, health and safety, landscape and visual intrusion, and socio-economic indicators as well as operations is essential at cement plants. While cement plants can directly assist in the implementation of the monitoring activities, it is recommended that an independent third party consultant be responsible for the overall implementation of the monitoring in close coordination with cement plants (El-Fadel, 2005) [2]. A summary of the proposed monitoring plan is presented in table 8.

Conclusions And Recommendations

Conclusions

- At the present time, all cement plants consume raw materials and fuels greater than the quantities specified by designed figures per unit of production. The average over consumption of raw materials estimated are 9 %, 12 % and 19 %, while the average over consumption of fuel oil are 20 %, 28 % and 30 % for Northern, Iraqi and Southern cement companies respectively.
- The available production capacity is 38.5 % from the total design capacity, compost of 27.5 % dry and 11 % wet. The contribution of each company as 10.5 % produced by Northern company, 13 % produced by Iraqi company and 15 % produced by Southern company.
- The amount of CKD generated is highly variable among plants and over time at individual plants. The quantity of CKD generated can be estimated on average as about (8 – 33) % of the production output, depending on the condition of each plant.
- Most plants are adopted the CKD land-disposal alternative. Where CKD accumulated as an irregular piles and accumulations which usually disposed or spread near or around the plants site. All these landfill and piles are unlined and uncovered. Dust particles may be suspended in the air by either wind erosion or a mechanical disturbance which causes environmental impacts.
- The pollution caused by cement industry, generally higher than the permit levels according to the existing regulatory allowance. Therefore, remedy the situation and put into place effective enforcement mechanisms for environmental laws and regulations be required to secure better environmental quality.

Recommendations

- Increasing thermal efficiency of the cement making process by improving gas/solid heat transfer, e.g. using an efficient chain system, increasing heat recovery from clinker cooler, minimizing infiltration of cold ambient air leaking into the preheater and kiln system and reducing heat losses.

- Recycling CKD from dust collectors into the process.
- Modernization of plants and production technologies.
- Improving process control to optimize the combustion process and operating conditions.
- Installing pollution control devices to facilities which have no one and adopting preventative maintenance, rehabilitation and upgrading program to the existing air pollution control devices.
- Applying a propriety procedures and techniques to controlling fugitive dust emissions.
- Minimizing of CKD generation rate by optimizing the process control to reduce the quantity which disposed of. At the same time utilizing the beneficial uses of CKD which provides an objective means for making progress toward sustainable development.
- Adopting the proposed environmental mitigation and monitoring plans.
- The cement companies and/or plants should embark on a strategy for adopting an environmental management system such as ISO 14001.

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Nomenclature

APCD = Air Pollution Control Device.
CKD = Cement Kiln Dust.
Co. = Company.
EMS = Environmental Management System.
ISO = International Organization for Standarization.
L.O.I. = Loss on Ignition.
MoEn = Ministry of Environment.
WMUs = Waste Management Units.

Table (1) Age distribution of cement kilns in Iraq (USAID, 2007; State owned enterprises guide, 2005) [12,13]**.**

Date of kiln operation	Dry Process		Wet Process		Overall	
	No. of Kilns	Capacity (k ton/year)	No. of Kilns	Capacity (k ton/year)	No. of Kilns	Capacity (k ton/year)
1951-1960	0	0	4	400	4	400
1961-1970	0	0	2	225	2	225
1971-1980	2	900	7	2850	9	3750
1981-1990	15	12280	0	0	15	12280
Total	17	13180	13	3475	30	16655

Table (2) Production capacity of cement general state companies.

Company	Wet process capacity (k ton/year)		Dry process capacity (k ton/year)		Overall capacity (k ton/year)	
	Available	Designed	Available	Designed	Available	Designed
Northern	402	875	1321	3950	1723 (10.5%)	4825 (29%)
Iraqi	0	0	2226	5290	2226 (13%)	5290 (32%)
Southern	1434	2600	1040	3940	2474 (15%)	6540 (39%)
Total	1836 (11%)	3475 (21%)	4587 (27.5%)	13180 (79%)	6423 (38.5%)	16655 (100%)

Table (3) Chemical analysis of raw meal (feed to rotary cement kiln)

Compon-ents (wt%)	Northern cement plant's samples			Iraqi cement plant's samples			Southern cement plant's samples		
	Ave. Sample No. 1 (Badoosh)	Ave. Sample No.2 (Sinjar)	Ave. Sample No.3 (Hamm-am Aleel)	Ave. Sample No. 1 (Qaim)	Ave. Sample No. 2 (Kirkuk)	Ave. Sample No. 3 (Falluja)	Ave. Sample No. 1 (Kufa)	Ave. Sample No. 2 (Al-Muthana)	Ave. Sample No. 3 (Kerbala)
CaO	42.1	42.2	42.7	43.5	42.3	42.5	41.2	43.4	43.7
Al_2O_3	3.9	4.3	3.9	2.8	3.6	3.5	4.7	2.3	2.7
SiO_2	13.9	13.2	13.6	12.9	14.3	13.6	13.2	13.4	13.1
Fe_2O_3	1.8	2.0	2.1	3.0	2.0	0.3	2.2	2.8	3.4
MgO	1.9	1.6	1.6	0.6	2.1	1.1	2.7	1.7	1.1
SO_3	1.2	0.3	0.4	0.7	0.5	0.8	1.1	1.0	0.9
Na_2O	0.1	0.3	0.2	0.3	0.4	0.1	0.4	0.4	0.4
K_2O	0.1	0.4	0.3	0.2	0.5	0.2	0.4	0.4	0.5
L.O.I	35.5	34.6	35.0	35.4	35.2	35.1	35.1	35.0	34.9

Table (4) Conversion factor and Fuel consumption for cement plants.

Cement Plant	Conversion Factor (kg material / kg clinker)			Fuel Consumption (k cal / kg Clinker)		
	Designed	Actual	% of deviation	Designed	Actual	% of deviation
Northern Co.						
Old Badoosh	1.62	1.76	8.6	1700	2000	17.6
Badoosh/2	1.70	1.85	8.8	900	1100	22
Badoosh/3	1.76	1.90	8.0	950	1250	31.5
Sinjar	1.72	1.92	11.6	1000	1200	20
Old Hammam Al Aleel	1.62	1.76	8.6	1750	2000	14.3
New Hammam Al Aleel	1.62	1.76	8.6	1750	2000	14.3
Sector Average	1.67	1.82	9.0	1342	1592	20
Iraqi Co.						
Al Qaim	1.76	2.0	13.6	840	1100	31
Kubaisa	1.74	1.95	12	820	1100	34
White Falluja	1.75	1.92	9.7	1500	1750	17
Kirkuk	1.76	2.0	13.6	840	1100	31

Sector Average	1.75	1.97	12.2	1000	1375	28
Southern Co.						
Old Kufa	1.72	1.90	10.5	1550	1800	16.1
New Kufa	1.72	1.90	10.5	1550	1755	13.2
Al-Muthana	1.77	2.30	29.9	950	1500	57.8
Al-Janoob/Samawa	1.80	2.20	22.2	1750	2100	20
Kerbala	1.80	2.40	33	950	1500	57.8
Sadda	1.79	1.92	7.3	1750	2000	14.3
Sector Average	1.76	2.10	19.0	1417	1776	30
National Average	1.73	1.96	13.4	1253	1581	26

Table (5) Chemical analysis of CKD

Compon-ents (wt%)	Northern cement plant's samples			Iraqi cement plant's samples			Southern cement plant's samples		
	Ave. Sample No. 1 (Badoosh)	Ave. Sample No.2 (Sinjar)	Ave. Sample No.3 (Hammam Al Aleel)	Ave. Sample No. 1 (Qaim)	Ave. Sample No. 2 (Kirkuk)	Ave. Sample No. 3 (Falluja)	Ave. Sample No. 1 (Kufa)	Ave. Sample No. 2 (Al-Muthana)	Ave. Sample No. 3 (Kerbala)
CaO	45.8	48.0	49.2	45.5	47.2	49.7	41.9	48.2	44.9
Al_2O_3	6.1	4.8	3.9	5.0	4.8	5.0	4.6	3.8	3.1
SiO_2	17.2	15.6	15.2	14.2	15.3	17.1	13.1	17.4	14.5
Fe_2O_3	2.5	2.1	3.1	3.1	1.9	0.3	2.5	3.8	2.7
MgO	3.1	2.1	1.6	2.3	2.7	1.4	3.4	2.7	1.9
SO_3	7.8	5.9	8.1	6.1	6.9	6.6	6.2	5.5	7.6
Na_2O	1.1	0.6	0.8	1.3	1.9	0.9	2.1	1.3	1.4
K_2O	1.3	0.7	0.9	1.8	2.1	1.1	2.7	1.4	1.6
L.O.I	17.5	20.1	16.5	18.4	18.3	19.4	22.2	17.1	21.9

Table (6) CKD Particle Size Distribution and Other Physical Properties

Wet process						
Particle size (μ)	Ave. sample No. 1 (Old Badoosh)		Ave. sample No. 2 (Hammam Al-Aleel)		Ave. sample No. 3 (Kufa)	
	percent	Cumulative percent	percent	Cumulative percent	percent	Cumulative percent
< 10	48	48	50	50	54	54
10-20	35	83	31	81	33	87
20-30	8	91	9	90	8	95
30-40	5	96	7	97	4	99
> 40	4	100	3	100	1	100
Dry process						
Particle size (μ)	Ave. sample No. 1 (Sinjar)		Ave. sample No. 2 (Kubaisa)		Ave. sample No. 3 (Al-Muthana)	
	percent	Cumulative percent	percent	Cumulative percent	percent	Cumulative percent
< 10	70	70	75	75	71	71
10-20	19	89	15	90	13	84
20-30	7	96	4	94	9	93
30-40	2	98	3	97	4	97
> 40	2	100	3	100	3	100
Bulk Density (gm / ℓ)			800 – 850			
Water holding capacity (at atmospheric pressure)			(80 – 85) %			
pH			10.5 - 13			

Table (7) Proposed Mitigation Measures.

Impact	Mitigation measures	Attributes / Location of intervention	Responsibility	Implementation time frame
Air quality	Installing ESP & fabric filters to achieve a particulate matter emission of 150 mg/Nm^3	Exhaust gases from raw mills, kilns and clinker coolers	Cement plants management	Specified by Cement plant Management In agree with MoEn According to the availability of resources and capabilities
	Using water sprays to suppress dust emission from primary crushers	Feeding hood of primary crushers		
	Using water spray (with and without surfactants) on all open piles and storage yards	Open and temporary storage piles at cement plants		
	Paving the roads that experience a high traffic rate and spraying unpaved roads regulatory with small nozzle water spraying system	Roads within cement plants connecting various parts		
	Installing adjustable conveyors to reduce dropping height	Raw materials conveying and storage		
	Ensuring proper maintenance of equipment on-site	Cement plants workshops		

	Adopting a pelletization program for generated CKD	CKD storage silo/piles		
	Wetting, compacting and covering with a layer of soil CKD at disposal site	CKD disposal site		
	Adopting combustion control approaches to reduce NO_x emissions	Preheater / precalcinator kiln		
	Using low-sulfur fuels and raw materials	Fuel tanks and materials		
	Planting a green-buffer around cement plants and the quarry	Use endemic species		
	Adopting a continuous monitoring program	Cement plants laboratory		
Solid waste	Reducing gas turbulence in the kiln and avoiding excessive flow velocities	Preheater / precalcinator kiln	Cement plants management	Specified by Cement plant Management In agree with MoEn According to the availability of resources and capabilities
	Using chains near the cool end of the kiln to minimize dust generation rates	Preheater / precalcinator kiln		
	Wetting and compacting the generated CKD at the disposal site	CKD disposal site		
	Reusing the generated CKD in the cement manufacturing process	Control room and laporatory		
	Reusing the CKD beneficially when possible	Off- site uses		
	Adopting pelletization of the generated CKD	CKD storage silo and storage yards		
	Selling recyclable faulty equipment to metal recycling industries	Temporary solid waste storage areas at cement plants		
	Transporting non-recyclable equipment especially old fabric filters to approved sanitary landfill	Temporary solid waste storage areas at cement plants		
	Optimizing the clinker burning process by providing appropriate instruction/training of the kiln operators as well as through installation of new and modern equipments			
	Using energy –efficient equipment that should be properly operated and maintained			
	Using closed loop water recovery systems	Installing closed-circuit cooling water system with softening and separation for the mills and clinker cooling sections		
	Using on-line analyzers and modern operating control systems	Allows for more steady kiln operation which save resources		

Cont. Table (7)

Impact	Mitigation measures	Attributes / Location of intervention	Responsibility	Implementation time frame
Resource use	Implementing a power and fuel consumption audit	Measure consumption at each production section	Cement plants management	Specified by Cement plant Management In agree with MoEn According to the availability of resources and capabilities
	Optimizing the clinker burning process by providing appropriate instruction/training of the kiln operators as well as through installation of new and modern equipments			
	Using energy –efficient equipment that should be properly operated and maintained			
	Using closed loop water recovery systems	Installing closed-circuit cooling water system with softening and separation for the mills and clinker cooling sections		
	Using on-line analyzers and modern operating control systems	Allows for more steady kiln operation which save resources		
Landscape And visual intrusions	Avoiding on-site storage of wastes and equipment		Cement plants management	Specified by Cement plant Management In agree with MoEn According to the availability of resources and capabilities
	Maintaining buildings within facility to preserve their architectural and visual appeal			
	Planning and implementing an appropriate landscaping program for the site that takes into account restoration or creation of native flora cover	Planting one row or more of tree seedling along the fence line of the site. Dedicate an area corresponding to at least 10 % of the total site area for landscaping and greenbelt		
	Provisioning a green belt to bar any unsightly intrusion the project may have on the milieu			
Socio-economic	Reducing potential exposure to emissions, especially dust		Cement plants management	Specified by Cement plant Management In agree with MoEn According to the availability of resources and capabilities
	Adopting a monitoring plan to assess potential adverse impacts on nearby receptors	Regular monitoring reports should be made available		
	Instigating a formal system which responds in a timely fashion to complaints about nuisances (air pollution, noise, etc.)	Provide a hotline number to communication		
	Committing to the publishing of data and reports on environmental performance			

Table (8) Summary of the proposed monitoring plan.

Impact	Monitoring means	Parameters	Location	Frequency	Implementation time frame
Air quality	Measurements / Sampling	PM/PM_{10}, Temperature, NO_x, SO_x, and oxygen level	Pyro-processing stacks	continuous	Specified by Cement plant Management In agree with MoEn According to the availability of resources and capabilities
		PM/ PM_{10}, temperature	Cement grinding ,clinker cooler and by-pass stacks	continuous	
		PM/PM_{10}, NO_x, SO_x,	Selected receptors around cement plants	quarterly	
	Audit	ESP and Fabric filter components	Existing ESP and Fabric filters	Monthly or in case of a PM emission surge	
Solid waste	sampling	pH and other required specification	Cement plants and CKD disposal site	Weekly or monthly	
	Audits, documentation and interviews	Generation, storage, recycling, transport and disposal	Cement plants and CKD disposal site	quarterly	
		CKD generation rate	Cement plants	daily	
Resource Use	metering	Water and energy consumption	Cement plants and associated quarries	continuous	
	Audit	Raw material consumption	Cement plants and associated quarries	continuous	
		Assess the state of the adopted re-vegetation scheme and reassess visual intrusion following 3 years of landscape		quarterly	

Cont. Table (8)

Impact	Monitoring means	Parameters	Location	Frequency	Implementation time frame
Landscape and visual intrusions	Visual inspection and photographic documentation	Visual inspection and photographic documentation of the existing landscape and assessing the current visual intrusions	Cement plants, quarry sites, landscape area, surrounding receptors	Biannually prior to the development and implementation of the landscape program	Specified by Cement plant Management In agree with MoEn According to the availability of resources and capabilities
		Assess the state of the adopted re-vegetation scheme and reassess visual intrusion following 3 years of landscape		quarterly	
Socio-economic	Field questionnaires	Population perception	Cement plants and region of influence	annually	
	Interviews	Employment records	Cement plants	continuously	
Operation monitoring	Visual inspection and documentation	Production rate, gas flow rates, counter readings, pressure values, temperatures, abnormal readings, overloads, stoppage, outages	All facilities and major equipment at the plant and quarry site	daily	
Health and safety	Health and safety surveys	Proper use of personal preventive equipment, presence of safety signs, first aid kit and fire fighting devices	Cement plant, roads linking plant with the main road network	continuously	
		Injury / illness records	Cement plant		

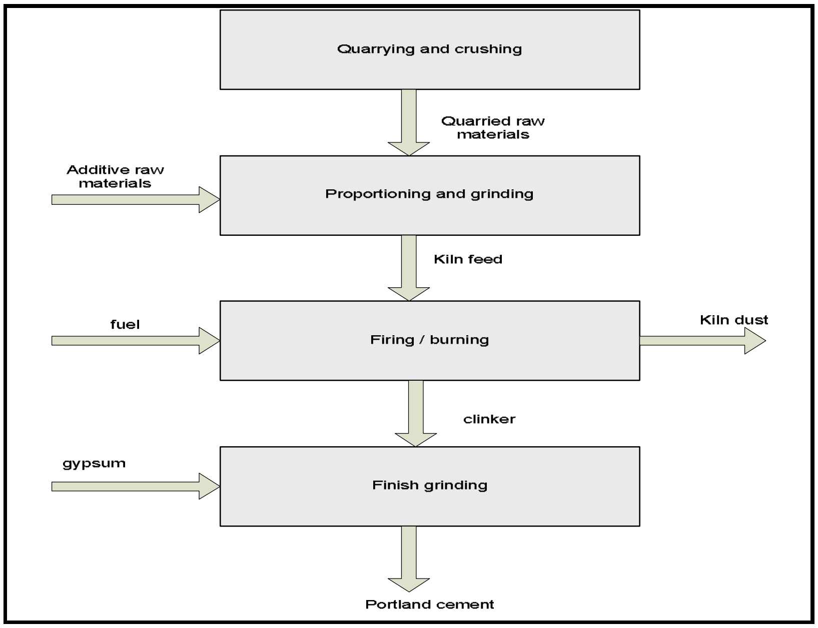

Figure (1) Basic flow diagram of the Portland cement manufacturing process (USEPA, 1993) [3].

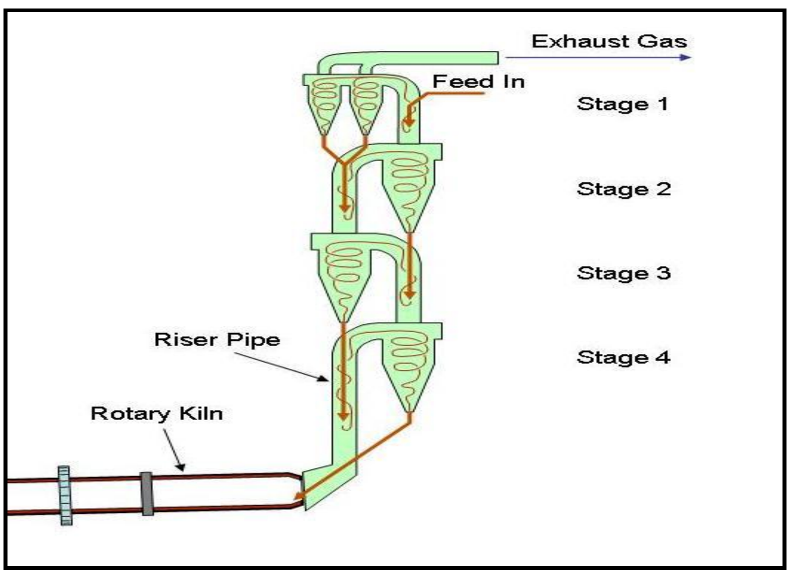

Figure (2) Suspension preheater (UKEA, 2001) [7]

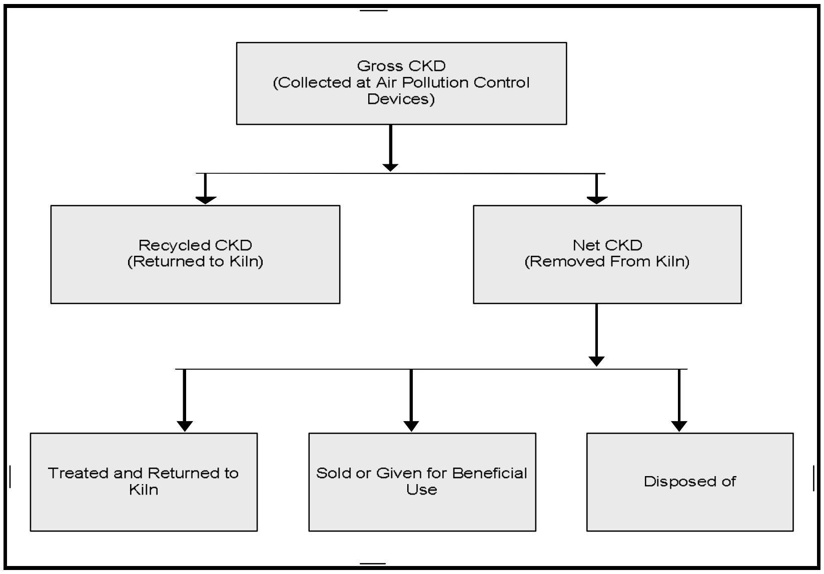

Figure (3) Flow chart of gross CKD management practices (USEPA, 1993) [3].

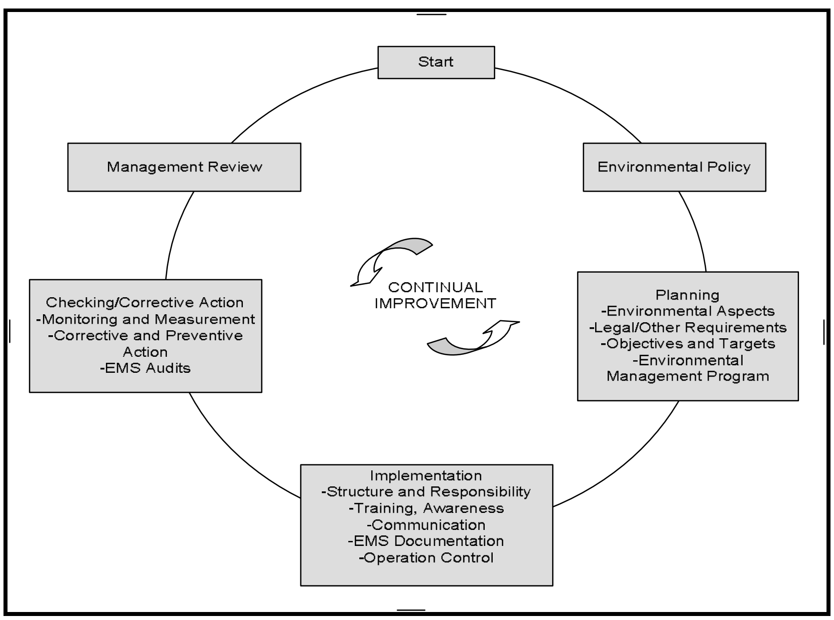

Figure (4) key elements of environmental management system (Pataki et al., 2000) [9].

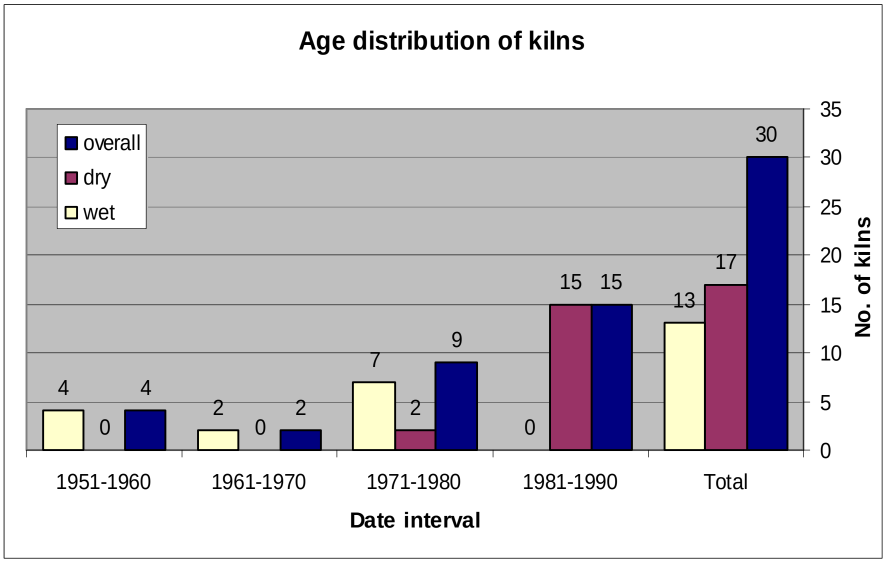

Figure (5) Age distribution of cement kilns.

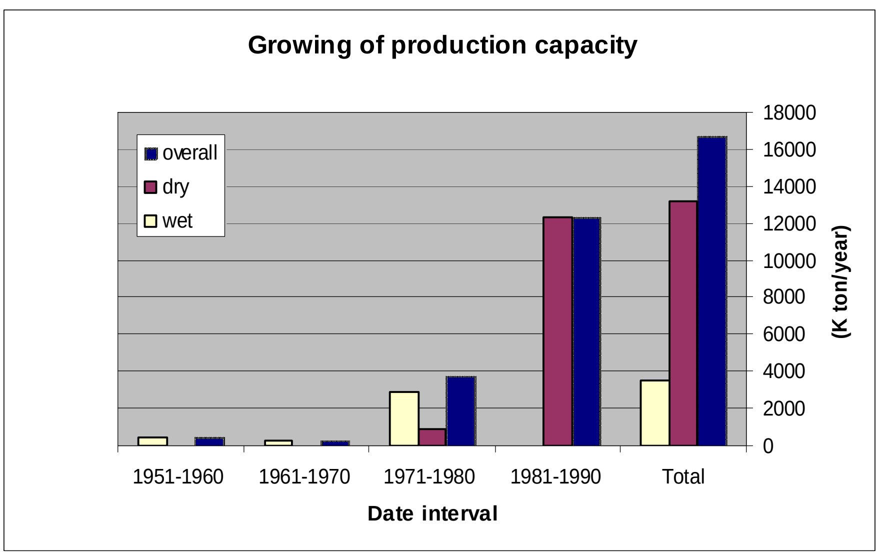

Figure (6) Production capacity growing.

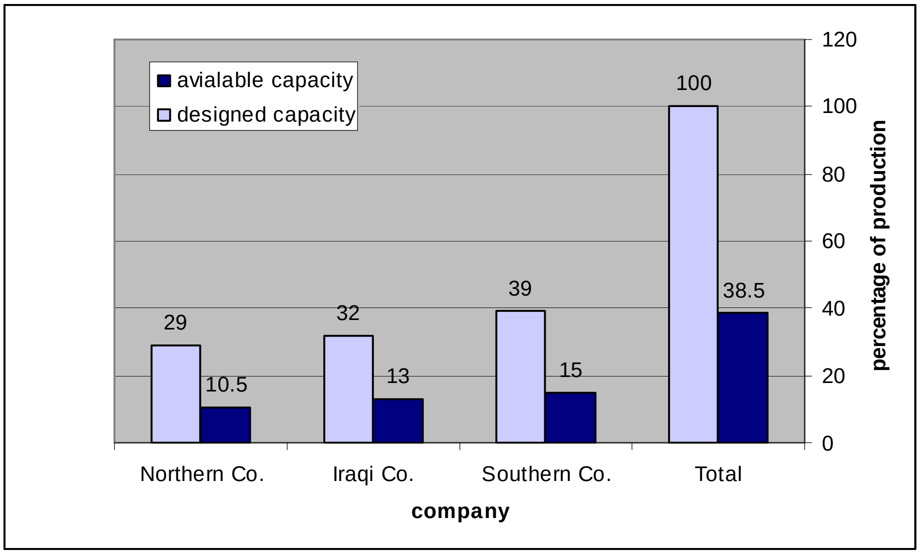

Figure (7) The percentage of available production capacity of each company.

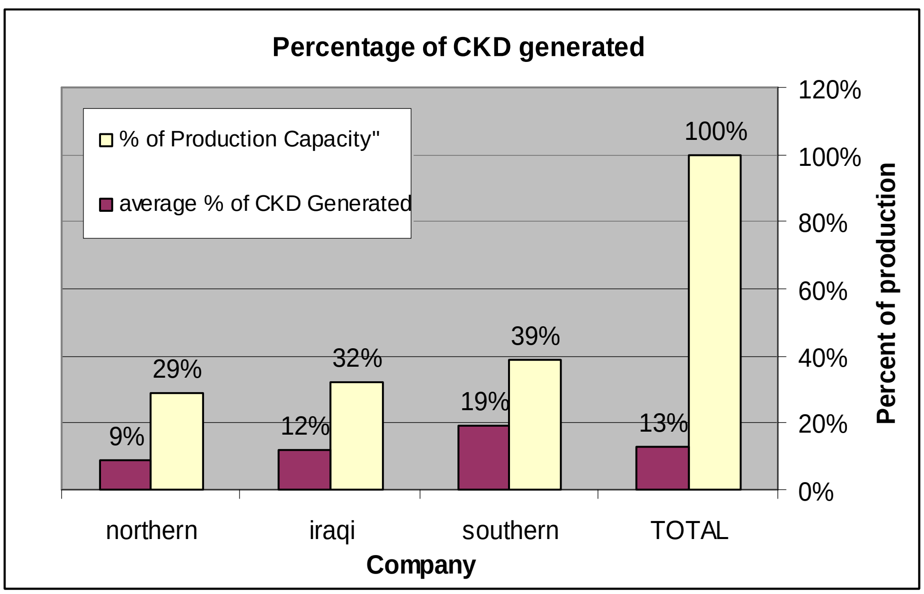

Figure (8) Percentage of CKD generated compared with capacity.