Cement Kilns Dust Management In Iraq

Dr. Adnan A. Al-Samawi *, Dr. Mohammed Ali I. Al-Hashimi * & Dr. Sabah Obaid Hamad Al-Shadeed **

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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.

Keywords (Arabic): غبار، نفايات، إنتاج، إدارة.

The project of the cement kilns dust management in Iraq was conducted to determine the emission factors and the economic and environmental impacts. The results showed 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.

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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 °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 Discussion**

**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.

References


[9]. Pataki, E. George, Crotty, M. Erin, 2000, "Understanding and Implementing an Environmental Management System- Step 2: EMS


Nomenclature

APCD = Air Pollution Control Device.
CKD = Cement Kiln Dust.
Co. = Company.
EMS = Environmental Management System.
ISO = International Organization for Standardization.
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].

<table>
<thead>
<tr>
<th>Date of kiln operation</th>
<th>Dry Process</th>
<th>Wet Process</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Kilns</td>
<td>Capacity (k ton/year)</td>
<td>No. of Kilns</td>
</tr>
<tr>
<td>1951-1960</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>1961-1970</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>1971-1980</td>
<td>2</td>
<td>900</td>
<td>7</td>
</tr>
<tr>
<td>1981-1990</td>
<td>15</td>
<td>12280</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>13180</td>
<td>13</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Company</th>
<th>Wet process capacity (k ton/year)</th>
<th>Dry process capacity (k ton/year)</th>
<th>Overall capacity (k ton/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Available</td>
<td>Designed</td>
<td>Available</td>
</tr>
<tr>
<td>Northern</td>
<td>402</td>
<td>875</td>
<td>1321</td>
</tr>
<tr>
<td>Iraqi</td>
<td>0</td>
<td>0</td>
<td>2226</td>
</tr>
<tr>
<td>Southern</td>
<td>1434</td>
<td>2600</td>
<td>1040</td>
</tr>
<tr>
<td>Total</td>
<td>1836 (11%)</td>
<td>3475 (21%)</td>
<td>4587 (27.5%)</td>
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</tbody>
</table>
### Table (3) Chemical analysis of raw meal (feed to rotary cement kiln)

<table>
<thead>
<tr>
<th>Components (wt%)</th>
<th>Northern cement plant’s samples</th>
<th>Iraqi cement plant’s samples</th>
<th>Southern cement plant’s samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ave. Sample No. 1 (Badoosh)</td>
<td>Ave. Sample No.3 (Hammam Alee)</td>
<td>Ave. Sample No. 1 (Qaim)</td>
</tr>
<tr>
<td>CaO</td>
<td>42.1</td>
<td>43.5</td>
<td>41.2</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>3.9</td>
<td>2.8</td>
<td>4.7</td>
</tr>
<tr>
<td>SiO₂</td>
<td>13.9</td>
<td>12.9</td>
<td>13.2</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>1.8</td>
<td>3.0</td>
<td>14.3</td>
</tr>
<tr>
<td>MgO</td>
<td>1.9</td>
<td>0.6</td>
<td>1.1</td>
</tr>
<tr>
<td>SO₃</td>
<td>1.2</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.1</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>L.O.I</td>
<td>35.5</td>
<td>35.4</td>
<td>35.1</td>
</tr>
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</table>

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

<table>
<thead>
<tr>
<th>Cement Plant</th>
<th>Conversion Factor (kg material / kg clinker)</th>
<th>Fuel Consumption (k cal / kg Clinker)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Designed</td>
<td>Actual</td>
</tr>
<tr>
<td>Northern Co.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old Badoosh</td>
<td>1.62</td>
<td>1.76</td>
</tr>
<tr>
<td>Badoosh/2</td>
<td>1.70</td>
<td>1.85</td>
</tr>
<tr>
<td>Badoosh/3</td>
<td>1.76</td>
<td>1.90</td>
</tr>
<tr>
<td>Sinjar</td>
<td>1.72</td>
<td>1.92</td>
</tr>
<tr>
<td>Old Hammam Al Aleel</td>
<td>1.62</td>
<td>1.76</td>
</tr>
<tr>
<td>New Hammam Al Aleel</td>
<td>1.62</td>
<td>1.76</td>
</tr>
<tr>
<td>Sector Average</td>
<td>1.67</td>
<td>1.82</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Iraqi Co.</th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Al Qaim</td>
<td>1.76</td>
<td>2.0</td>
<td>13.6</td>
<td>840</td>
<td>1100</td>
<td>31</td>
</tr>
<tr>
<td>Kubaisa</td>
<td>1.74</td>
<td>1.95</td>
<td>12</td>
<td>820</td>
<td>1100</td>
<td>34</td>
</tr>
<tr>
<td>White Falluja</td>
<td>1.75</td>
<td>1.92</td>
<td>9.7</td>
<td>1500</td>
<td>1750</td>
<td>17</td>
</tr>
<tr>
<td>Kirkuk</td>
<td>1.76</td>
<td>2.0</td>
<td>13.6</td>
<td>840</td>
<td>1100</td>
<td>31</td>
</tr>
<tr>
<td>Sector Average</td>
<td>1.75</td>
<td>1.97</td>
<td>12.2</td>
<td>1000</td>
<td>1375</td>
<td>28</td>
</tr>
<tr>
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<td>------</td>
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</tr>
<tr>
<td><strong>Southern Co.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old Kufa</td>
<td>1.72</td>
<td>1.90</td>
<td>10.5</td>
<td>1550</td>
<td>1800</td>
<td>16.1</td>
</tr>
<tr>
<td>New Kufa</td>
<td>1.72</td>
<td>1.90</td>
<td>10.5</td>
<td>1550</td>
<td>1755</td>
<td>13.2</td>
</tr>
<tr>
<td>Al-Muthana</td>
<td>1.77</td>
<td>2.30</td>
<td>29.9</td>
<td>950</td>
<td>1500</td>
<td>57.8</td>
</tr>
<tr>
<td>Al-Janoob/Samawa</td>
<td>1.80</td>
<td>2.20</td>
<td>22.2</td>
<td>1750</td>
<td>2100</td>
<td>20</td>
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<tr>
<td>Kerbala</td>
<td>1.80</td>
<td>2.40</td>
<td>33</td>
<td>950</td>
<td>1500</td>
<td>57.8</td>
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<tr>
<td>Sadda</td>
<td>1.79</td>
<td>1.92</td>
<td>7.3</td>
<td>1750</td>
<td>2000</td>
<td>14.3</td>
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<tr>
<td><strong>Sector Average</strong></td>
<td>1.76</td>
<td>2.10</td>
<td>19.0</td>
<td>1417</td>
<td>1776</td>
<td>30</td>
</tr>
<tr>
<td><strong>National Average</strong></td>
<td>1.73</td>
<td>1.96</td>
<td>13.4</td>
<td>1253</td>
<td>1581</td>
<td>26</td>
</tr>
</tbody>
</table>

Table (5) Chemical analysis of CKD

<table>
<thead>
<tr>
<th>Components (wt%)</th>
<th>Northern cement plant’s samples</th>
<th>Iraqi cement plant’s samples</th>
<th>Southern cement plant’s samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ave. Sample No. 1 (Badoo sh)</td>
<td>Ave. Sample No.2 (Sinjar)</td>
<td>Ave. Sample No.3 (Ham mam Al Aleel)</td>
</tr>
<tr>
<td>CaO</td>
<td>45.8</td>
<td>48.0</td>
<td>49.2</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>6.1</td>
<td>4.8</td>
<td>3.9</td>
</tr>
<tr>
<td>SiO₂</td>
<td>17.2</td>
<td>15.6</td>
<td>15.2</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>2.5</td>
<td>2.1</td>
<td>3.1</td>
</tr>
<tr>
<td>MgO</td>
<td>3.1</td>
<td>2.1</td>
<td>1.6</td>
</tr>
<tr>
<td>SO₃</td>
<td>7.8</td>
<td>5.9</td>
<td>8.1</td>
</tr>
<tr>
<td>Na₂O</td>
<td>1.1</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>K₂O</td>
<td>1.3</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>L.O.I</td>
<td>17.5</td>
<td>20.1</td>
<td>16.5</td>
</tr>
</tbody>
</table>
Table (6) CKD Particle Size Distribution and Other Physical Properties

<table>
<thead>
<tr>
<th>Wet process</th>
<th>AVe. sample No. 1 (Old Badoosh)</th>
<th>Ave. sample No. 2 (Hammam Al-Aleel)</th>
<th>Ave. sample No. 3 (Kufa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size (µ)</td>
<td>percent</td>
<td>Cumulative percent</td>
<td>percent</td>
</tr>
<tr>
<td>&lt; 10</td>
<td>48</td>
<td>48</td>
<td>50</td>
</tr>
<tr>
<td>10-20</td>
<td>35</td>
<td>83</td>
<td>31</td>
</tr>
<tr>
<td>20-30</td>
<td>8</td>
<td>91</td>
<td>9</td>
</tr>
<tr>
<td>30-40</td>
<td>5</td>
<td>96</td>
<td>7</td>
</tr>
<tr>
<td>&gt; 40</td>
<td>4</td>
<td>100</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dry process</th>
<th>Ave. sample No. 1 (Sinjar)</th>
<th>Ave. sample No. 2 (Kubaisa)</th>
<th>Ave. sample No. 3 (Al-Muthana)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size (µ)</td>
<td>percent</td>
<td>Cumulative percent</td>
<td>percent</td>
</tr>
<tr>
<td>&lt; 10</td>
<td>70</td>
<td>70</td>
<td>75</td>
</tr>
<tr>
<td>10-20</td>
<td>19</td>
<td>89</td>
<td>15</td>
</tr>
<tr>
<td>20-30</td>
<td>7</td>
<td>96</td>
<td>4</td>
</tr>
<tr>
<td>30-40</td>
<td>2</td>
<td>98</td>
<td>3</td>
</tr>
<tr>
<td>&gt; 40</td>
<td>2</td>
<td>100</td>
<td>3</td>
</tr>
</tbody>
</table>

- Bulk Density (gm / t) | 800 – 850
- Water holding capacity (at atmospheric pressure) | (80 – 85)%
- pH | 10.5 - 13

Table (7) Proposed Mitigation Measures.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Mitigation measures</th>
<th>Attributes / Location of intervention</th>
<th>Responsibility</th>
<th>Implementation time frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air quality</td>
<td>Installing ESP &amp; fabric filters to achieve a particulate matter emission of 150 mg/Nm³</td>
<td>Exhaust gases from raw mills, kilns and clinker coolers</td>
<td>Specified by Cement plant management</td>
<td>In agree with MoEn According to the availability of resources and capabilities</td>
</tr>
<tr>
<td></td>
<td>Using water sprays to suppress dust emission from primary crushers</td>
<td>Feeding hood of primary crushers</td>
<td>Cement plants management</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Using water spray (with and without surfactants) on all open piles and storage yards</td>
<td>Open and temporary storage piles at cement plants</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Paving the roads that experience a high traffic rate and spraying unpaved roads regulatory with small nozzle water-spraying system</td>
<td>Roads within cement plants connecting various parts</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Installing adjustable conveyors to reduce dropping height</td>
<td>Raw materials conveying and storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ensuring proper maintenance of equipment on-site</td>
<td>Cement plants workshops</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid waste</td>
<td></td>
<td>Cement plants management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>-------------------</td>
<td>------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adopting a pelletization program for generated CKD</td>
<td>CKD storage silo/piles</td>
<td>Specified by Cement plant Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetting, compacting and covering with a layer of soil CKD at disposal site</td>
<td>CKD disposal site</td>
<td>In agree with MoEn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adopting combustion control approaches to reduce NO\textsubscript{x} emissions</td>
<td>Preheater / precalcinator kiln</td>
<td>According to the availability of resources and capabilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using low-sulfur fuels and raw materials</td>
<td>Fuel tanks and materials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting a green-buffer around cement plants and the quarry</td>
<td>Use endemic species</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adopting a continuous monitoring program</td>
<td>Cement plants laboratory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetting, compacting and covering the generated CKD at the disposal site</td>
<td>CKD disposal site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reusing the generated CKD in the cement manufacturing process</td>
<td>Control room and laboratory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reusing the CKD beneficially when possible</td>
<td>Off-site uses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adopting pelletization of the generated CKD</td>
<td>CKD storage silo and storage yards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selling recyclable faulty equipment to metal recycling industries</td>
<td>Temporary solid waste storage areas at cement plants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transporting non-recyclable equipment especially old fabric filters to approved sanitary landfill</td>
<td>Temporary solid waste storage areas at cement plants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimizing the clinker burning process by providing appropriate instruction/training of the kiln operators as well as through installation of new and modern equipments</td>
<td>Cement plants management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using energy–efficient equipment that should be properly operated and maintained</td>
<td>Installing closed-circuit cooling water system with softening and separation for the mills and clinker cooling sections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using closed loop water recovery systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using on-line analyzers and modern operating control systems</td>
<td>Allows for more steady kiln operation which save resources</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Cont. Table (7)

<table>
<thead>
<tr>
<th>Impact</th>
<th>Mitigation measures</th>
<th>Attributes / Location of intervention</th>
<th>Responsibility</th>
<th>Implementation time frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource use</td>
<td>Implementing a power and fuel consumption audit</td>
<td>Measure consumption at each production section</td>
<td>Cement plants management</td>
<td>Specified by Cement plant Management In agree with MoEn According to the availability of resources and capabilities</td>
</tr>
<tr>
<td></td>
<td>Optimizing the clinker burning process by providing appropriate instruction/training of the kiln operators as well as through installation of new and modern equipments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Using energy–efficient equipment that should be properly operated and maintained</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Using closed loop water recovery systems</td>
<td>Installing closed-circuit cooling water system with softening and separation for the mills and clinker cooling sections</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Using on-line analyzers and modern operating control systems</td>
<td>Allows for more steady kiln operation which save resources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landscape And visual intrusions</td>
<td>Avoiding on-site storage of wastes and equipment</td>
<td></td>
<td>Cement plants management</td>
<td>Specified by Cement plant Management In agree with MoEn According to the availability of resources and capabilities</td>
</tr>
<tr>
<td></td>
<td>Maintaining buildings within facility to preserve their architectural and visual appeal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Planning and implementing an appropriate landscaping program for the site that takes into account restoration or creation of native flora cover</td>
<td>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</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Provisioning a green belt to bar any unsightly intrusion the project may have on the milieu</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Socio-economic</td>
<td>Reducing potential exposure to emissions, especially dust</td>
<td></td>
<td>Cement plants management</td>
<td>Specified by Cement plant Management In agree with MoEn According to the availability of resources and capabilities</td>
</tr>
<tr>
<td></td>
<td>Adopting a monitoring plan to assess potential adverse impacts on nearby receptors</td>
<td>Regular monitoring reports should be made available</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Instigating a formal system which responds in a timely fashion to complaints about nuisances (air pollution, noise, etc.)</td>
<td>Provide a hotline number to communication</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Committing to the publishing of data and reports on environmental performance</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
Table (8) Summary of the proposed monitoring plan.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Monitoring means</th>
<th>Parameters</th>
<th>Location</th>
<th>Frequency</th>
<th>Implementation time frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air quality</td>
<td>Measurements / Sampling</td>
<td>PM/PM&lt;sub&gt;10&lt;/sub&gt;, Temperature, NO&lt;sub&gt;x&lt;/sub&gt;, SO&lt;sub&gt;x&lt;/sub&gt;, and oxygen level</td>
<td>Pyro-processing stacks</td>
<td>continuous</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM/PM&lt;sub&gt;10&lt;/sub&gt;, temperature</td>
<td>Cement grinding, clinker cooler and by-pass stacks</td>
<td>continuous</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM/PM&lt;sub&gt;10&lt;/sub&gt;, NO&lt;sub&gt;x&lt;/sub&gt;, SO&lt;sub&gt;x&lt;/sub&gt;,</td>
<td>Selected receptors around cement plants</td>
<td>quarterly</td>
<td></td>
</tr>
<tr>
<td>Audit</td>
<td>Measurements / Sampling</td>
<td>ESP and Fabric filter components</td>
<td>Existing ESP and Fabric filters</td>
<td>Monthly or in case of a PM emission surge</td>
<td>Specified by Cement plant Management In agree with MoEn According to the availability of resources and capabilities</td>
</tr>
<tr>
<td>Solid waste</td>
<td>sampling</td>
<td>pH and other required specification</td>
<td>Cement plants and CKD disposal site</td>
<td>Weekly or monthly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Audits, documentation and interviews</td>
<td>Generation, storage, recycling, transport and disposal</td>
<td>Cement plants and CKD disposal site</td>
<td>quarterly</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CKD generation rate</td>
<td>Cement plants</td>
<td>daily</td>
<td></td>
</tr>
<tr>
<td>Resource Use</td>
<td>metering</td>
<td>Water and energy consumption</td>
<td>Cement plants and associated quarries</td>
<td>continuous</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Audit</td>
<td>Raw material consumption</td>
<td>Cement plants and associated quarries</td>
<td>continuous</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Assess the state of the adopted re-vegetation scheme and reassess visual intrusion following 3 years of landscape</td>
<td></td>
<td>quarterly</td>
<td></td>
</tr>
</tbody>
</table>
### Cont. Table (8)

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