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Analysis and Developments of PGNAA Installation at Al-Rashadiya Lafarge Cement Plant in Jordan

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Abstract

The developments of prompt gamma neutron activation analysis (PGNAA) and its functionality as on-line/real-time chemical analyzer attracted several industries to utilize this technology which provides accurate tracking and chemical mapping simultaneously. The cement industries are no exception. In this study, the installation of PGNAA system in Jordan, provided by Thermo Fisher Scientific Company at Lafarge Plant Cement Factory is examined. In collaboration with Lafarge, data were collected and analyzed. Comparison among manual testing methods utilized before and after installing the cross belt analyzer (CBA) had been made to improve the quality of final products rang and cost savings. The study has demonstrated that kiln feed uniformity index (KFUI) achieved Lafarge standard, and cost reduction of clay and pozzolana after installing CBA were achieved. The results of this study are important since several industries with similar products in Jordan could benefit from the outcome and recommendations made based on this case study at Lafarge in Jordan.

Keywords
PGNAA studies, Cement, CBA improvements, KFUI impact

1. Introduction

The modern high-tech and rapidly changing societies these days becomes more dependent upon sophisticated materials that can be used in high-end applications. The quality and properties of these sophisticated materials require new scientific techniques as well as computerized equipment to improve precision and quality during manufacturing processes, and the quality of final products. In the past two decades, wide range of scientific techniques such as X-ray, electrons and neutrons probes utilized along with computerized equipments for testing during manufacturing processes for optimal product quality. Of these neutrons probe is the least known, yet it is the most important and widely used in a variety of industries – cement, concrete, mining, coal, phosphate, petrochemicals and oil and gas. Prompt gamma neutron activation analysis (PGNAA) which utilize neutron beam (probe) to measure composition of light elements simultaneously in samples ranging in size from micro-grams to macro-grams is the focus of this study [1,2]. In 1990, the prompt gamma neutron activation analyzer was used to measure concentrations of up to 18 elements in cement, sand, aggregate, concretes and up to nine elements in several types of steel. All major elements except oxygen are measurable by using the PGNAA technique [3, 4].

In the cement industry, PGNAA enables the optimal blending of raw materials before processing and the verification of chemical uniformity of the final product [3]. In the coal industry, on-line measurements have found particular use in reporting the thermal energy and sulfur content of coal and for determining the fraction of the coal that is not hydrocarbon and will remain as ash after combustion. In mineral industry, another important industrial application of PGNAA is borehole logging for both the delineation of ore deposits and the in-situ determination of ore quality. Borehole logging is a valuable addition for mine exploration and mapping, enabling an automatic real-time update of the mine plan. PGNAA can be calibrated to analyze a wide variety of raw materials such as iron, nickel or copper ore, coal or limestone. Borehole logging has mainly developed in open pit coal mines for the determination of ash content as well as in-situ assaying of iron and sulfur [3]. Borehole logging in blast holes produces a representative analysis of the bulk material before being mined. Due to both industrial constrains and the needs for high efficiency detectors, scintillations are generally used for performing Gamma spectrometry. Spectra processing is crucial since the best accuracy has to be obtained in the analysis of raw materials while the strength of the neutron source is as low as possible and the sampling rate is high, typically, measurements occur every minute in process control [4]. Design of the facility has focused on three related factors. First, the high quality of the neutron beam and the low background in the guide hall will allow closer sample-detector spacing, resulting in higher counting efficiency and better sensitivity, especially in the energy region below 1million electron volt (MeV). Second, the high-count rates possible with this high efficiency (greater than 50 k counts per sec) can be measured without loss of quality with recent advances in instrumentation [1]. Finally, the improved efficiency will make attractive the use of gamma-gamma and gamma-conversion-electron coincidence counting in analytical measurements, with considerably improved specificity.

In this study, the implementation of PGNAA system provided by Thermo Fisher Scientific Company (Modern Technology and Industrial Park, Sorrento Valley area of San Diego, California, USA) at Al-Rashdiya Plant Cement Factory (Lafarge Cement Factory, Rashadiya, Jordan) was studded [5]. In collaboration with Lafarge, data were collected and analyzed as well as the layout of the PGNAA equipment in relation to the plant operation – online analysis, closed loop...etc. to see the visibility of implanting the system (PGNAA) in other factories in Jordan in order to achieve the best optimization of the products produced in a variety of industries in the future.

2. Site Preparation

The Thermo Cement Group within Thermo Fisher Scientific supplied two on-line 6th Generation Gamma-Metrics Cross Belt Analyzers to Al-Rashadiya Cement Plant of Jordan Cement Company, Jordan. The proposed analyzers designed to be installed on a conveyor belt feeding the pre-blending Limestone & Marl stockpiles. Both systems will provide continuous on-line analyses of the composition of the pre-mix materials (limestone & Marl) being delivered to respective stockpiles. Material analysis updates provided once per minute monitoring. In addition, the system will track the cumulative composition of the pre-blending pile and determine optimal blend proportions for the material available in the quarry in order to meet quality control constraints.

Analyzer assembly (see Figure 1) contains the critical components needed to support prompt gamma neutron activation analysis (PGNNA). The shielding is comprised of an assembly of the upper and lower modules that are supplied in to size to fit the existing equipments. The slider bed provides a low friction and low wear, replaceable surface on which the conveyer belt rides. One or more source is installed in the source cartridge. Depending on the application, up to 80 μg of Cf ^{252} may be loaded. The Detector cartridge contains one or two gamma ray detectors and contains a moisture gauge for cement application. Analyzer electronics enclosure contains: Low and high voltage power supplies; Computer with digital signal processor card; Interface with external equipment such as weigh scales; Termination points for electrical power; Termination points for communication cables; Operator console (OPCON). A powerful computer installed in an office or a control room that processes the data from the electronics enclosure and archives all analytical results.

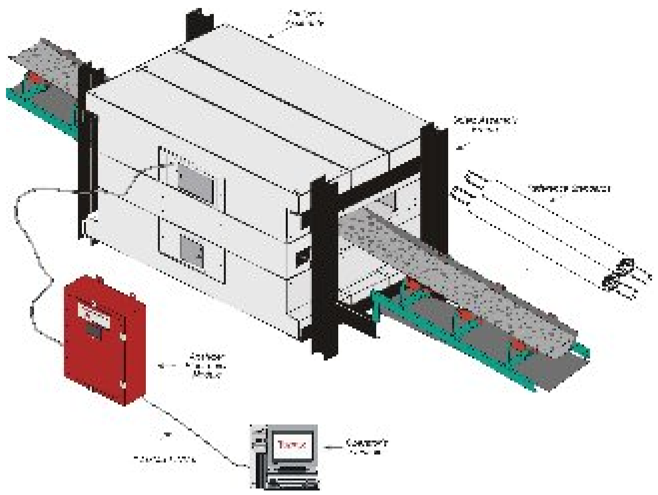

Figure 1: Gamma-Metrics CBX Cross Belt Analyzer System Components [5]

3. Results and discussion

Following a period of evaluation after CBA implementation and one year of operation, the objectives are worthly examined whether they been fullfiled or not. Herewith, significant objectives are handled in details. Cost and quality are the major criteria to assess the conformity of CBA objectives. Clinker production rate and cement-clinker ratio are the major issues those plant must emphasize to enhance and improve. Referring to the operational experience, kiln feed uniformity index (KFUI) i.e. material uniformity, and kiln stability influence the clinker productivity and fuel consumption rate as well. In general the main objectives of CBA are to [6]:

- Improve kiln feed uniformity and clinker productivity.
- Decrease raw material cost.
- Decrease specific heat and power consumptions.
- Increase cement over clinker ratio.
- Improve market competency.

3.1 Kiln feed uniformity index (KFUI)

The most important priority of Al-Rashadyia plant is to achieve Lafarge KFUI standard which is below 14 (reading KFUI). After collecting the data about KFUI befor and after implementation of CBA a comparison made and the results are shown in Figure 2. Note that Lafarge's standard of KFUI (KFUI $\leq$ 14) is achieved after the implementation of CBA as well as the lower variation in KFUI in 2009 resulted from CBA use.

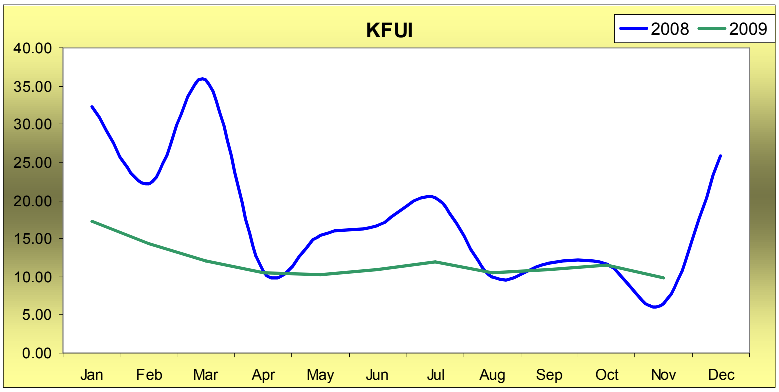

Figure 2: KFUI of 2008 and 2009 (before-2008 and after-2009 CBA installed)

3.2 Raw material cost reduction

The raw material consist of three primary substances: Limstone (limstone quarry was manged by the plant), the cost of one ton of limstone is 0.43 JD, limstone is proportioned ≥ 70% in raw mix. Clay, it is a corrective material, which was managed by a contractor and 1 ton of clay costs1.42 JD. Pozzolana, it is a corrective material, which was managed by a contractor and 1 ton of pozzolana costs 1.42 JD (Note that 1 JD = 1.42 US $).

It is observed that reducing corrective material proportions results in cost reduction. CBA maximize the limestone proportions by maximizing the use of limestone quarry. In 2008 the total clinker production was 2060849 ton. Based on the figures given from the company, cost of raw materials in 2008 = 2,559,433 / 2,060,849 = 1.24 JD/ton. In 2009 the total clinker production was 1,706,592 ton. Cost of raw materials = 1,990,855 / 1,706,592 = 1.166 JD/ton. From this two figures the effect of the CBA on the percentage of the raw material saving = 1.24-1.166 = 0.08 JD / ton. Totaling 16,000 JD/year (based on 2 M ton/year production).

3.3 Grinding & Product range improvement (market driven)

The more chemistry-stable clinker is the higher capability to produce readily different types of cement meeting market requirements and customer satisfaction. That is shown through the plant statistcs sheet deployed in Lafarge group where the Cement kiln (C/K) ratio was increased 2% (1.14 in 2008 while 1.16 in 2009) which significantly affected plant performance. Furthermore, Stability in clinker chemistry was strongly reflected on power consumption in cement grinding process. Before the implementation of CBA, the percentage of the substances (Limeston, Pozzalan and Clay) was more diffecult to measure it and make the specific types of cement, while after implementing CBX the results can be measured exactly and make more new types of cement.

3.4 Quality Control

There are two main line of piles that supplies the main components (limestone, clay, and pozzolana) line A and line B. Every line has two piles; pile A1 and A2; B1 and B2. Every pile can supply certain percentage of main components. The main components have percentage of the composition of materials added to every main component which has main parameters that the plant use it for measuring the quality, these parameters are: Lime Saturation Factor (LSF); Silica Ratio (SR); Aluminum Ratio (AR).

3.4.1. LSF parameter

This parameter depends on four type of materials; SiO_2, Al_2O_3, Fe_2O_3, and CaO. Every type has a percentage of the mixture and also depends on the percentage of every type of the main component of the clinker. In the manual scenario the factory/operator read the data every one hour and uses equation (1) to calculate LSF parameter. After the installation of CBA the data reading was continuous. The final average readings of LSF were collected to compare the quality control before and after CBA implementation. The data for fifteen days are acceptable to comparison.

$$LSF = CaO * 100\% / [2.8 * SiO_2 + 0.65 Fe_3O_2 + 1.18 * Al_2O_3] \quad (1)$$

Specification for the upper control limit and lower limit are set by the quality control department for all parameters. For the LSF parameter, Minitab software is used for analyzing and comparing the data as shown on Figures 3 and 4.

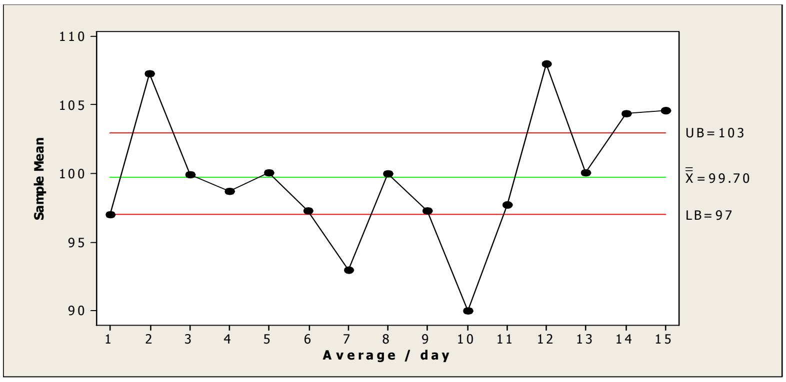

Figure 3: Control chart for LSF parameter (before CBA installed)

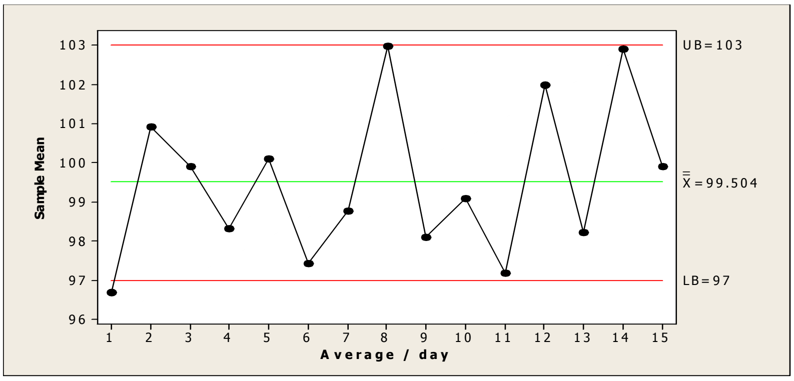

Figure 4: Control chart for LSF parameter (after CBA installed)

3.4.2 SR parameter

This parameter depends on three type of materials; SiO_2, Al_2O_3, and Fe_2O_3. Every type has a percentage of the mixture and also depend on the percentage of every type of the main components of the cement. The final reading of the SR was collected to compare the quality control before and after CBA implementation. Equation (2) was used to calculate SR parameter. The data before and after the installation of CBA are shown in Figures 5 and 6.

$$Sr = SiO_2 / [0.65 Fe_3O_2 + 1.18 * Al_2O_3] \quad (2)$$

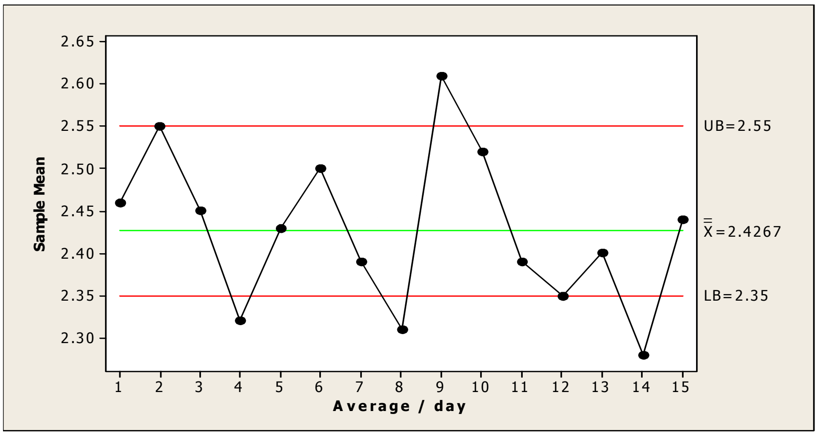

Figure 5: Control chart for SR parameter (before CBA installed)

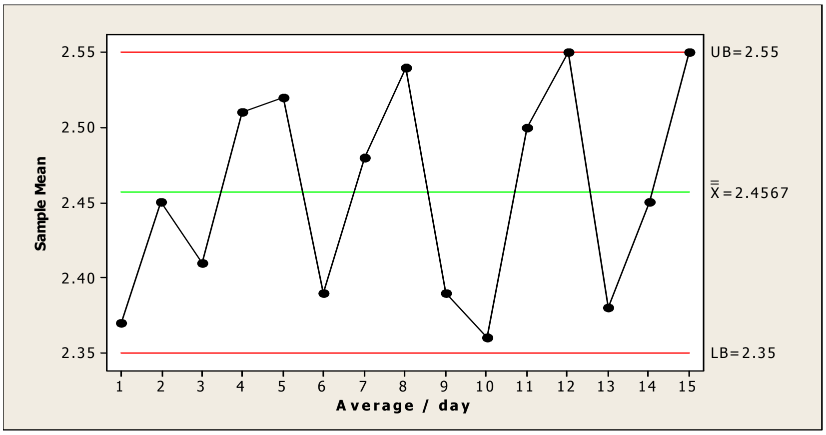

Figure 6: Control chart for SR parameter (after CBA installed)

3.4.3 AR parameter:

This parameter depends on two type of materials; Al_2O_3 and Fe_2O_3. Every type has a percentage of the mixture and also depends on the percentage of every type of the main component of the cement. The data shown in Figures 7 and 8 were calculated using equation (3).

$$LR = Al_2O_3 / Fe_3O_2 \qquad (3)$$

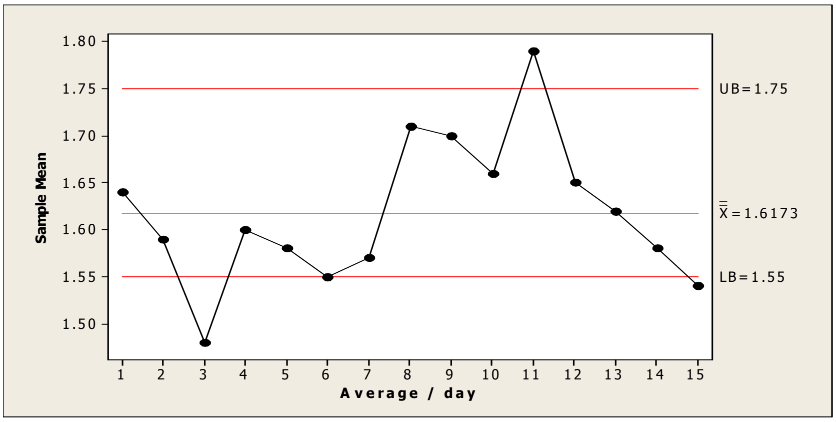

Figure 7: Control chart for AR parameter (before CBA installed)

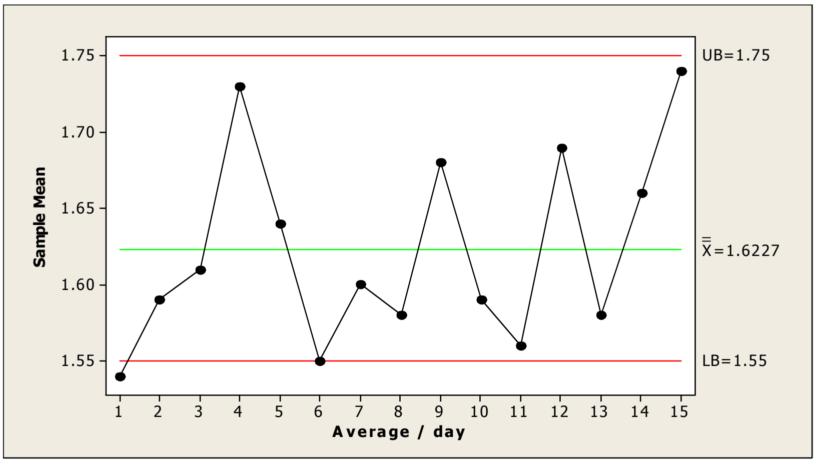

Figure 8: Control chart for AR parameter (after CBA installed)

The readings as shown in the Figures 4, 6 and 8 show the major effect of installation of CBA on quality control. Note that there is one data point lie on the control limit on the LSF and SR reading, and most data fall within limits.

5 Conclusions

The objective of this study was to install PGNAA at Al-Rashadiya Lafarge cement factory in Jordan. The implications of the results may be extended to all factories in Jordan using similar product of various chemical composition, as well as engineering systems having similar structures to the one studied here.

Installing the analyzer assembly over the existing belt contains the critical components needed to support PGNNA (Figure 1). The installation was carried out with minimal distraction to the existing facilities. Clinker production rate and cement-clinker ratio are the major issues that the plant must emphasize to enhance and improve. Referring to the operational experience, kiln feed uniformity index (KFUI) achieved Lafarge standard (Figure 2). The analysis of raw material cost focused on increasing usage of limestone by decreasing clay and pozzolana which showed cost reduction after installing CBA. Although the approach used to analyze quality control parameters was simplistic, data points lied within the range of Lafarge standards after implementation of CBA (Figures 4, 6 and 8). Finally, the CBA implementation led to obvious beneficial effects on cement factory which can be extended to other factories with similar products in Jordan.

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