A review of the Effects and Control of the Mercury Emissions from Cement industry

CCTC 2013 Paper Number 1569694125

Faizul M. Mohee[1]
[1] University of Waterloo, Ontario, Canada

Abstract

The emission of hazardous wastes like Mercury from cement plants is a big concern to the environmentalists, due to its significant hazardous effect on the human life. Environmental Protection Agency in USA has published a final amendment to the National Emission Standards for Hazardous Air Pollutants on August 6, 2010 under the 'Clean Air Act'. This includes a significant change in the emission limit of several pollutants from the cement plants, including a limit for the mercury emission from the plants. According to the Portland cement Association, the guideline for Hg control is economically unachievable by the cement companies, since it requires a set up for the Hg control in most of the plants. Several Hg emission control techniques were discussed in this article. These techniques include the change of raw materials and fuel, the materials management by dust wasting, the injection of activated carbon, the wet scrubber method, dry or semi-dry scrubbing, Mercury Roasting method, etc. The most efficient method for controlling the mercury emission depends on a number of factors like the source of mercury emission, the typical speciation of mercury in the flue gas, and the availability of sorbent materials and water. Using these technologies the removal of Mercury from the cement kilns is possible to the EPA given limits of 55 pounds per million tons of clinker for the existing source kilns and 21 pounds per million toms of clinker for the new source kilns.

Keywords: Hg emission, cement production, EPA, NESHAP, Hazardous Air Pollutants, Clean Air Act, Dust wasting, Activated Carbon, Wet Scrubbing, Mercury Roasting.

L'émission de déchets dangereux comme le mercure provenant des cimenteries préoccupe beaucoup les environnementalistes en raison de ses effets dangereux sur la vie humaine. L'Environmental Protection Agency des États-Unis a publié le 6 août 2010 un amendement final aux normes nationales d'émission de polluants atmosphériques dangereux dans le cadre de la loi « Clean Air Act ». Cet amendement comporte entre autres une modification substantielle de la limite d'émission de plusieurs polluants issus des cimenteries, y compris le mercure. Or, selon la Portland Cement Association, les cimenteries ne sont pas en mesure d'appliquer les lignes directrices en matière de lutte contre les émissions de mercure, car celles-ci nécessitent la mise en place d'installations au coût prohibitifdans la plupart des usines. Plusieurs techniques de lutte contre les émissions de mercure ont été examinées dans cet article. Ces techniques comportent un changement de matières premières et de combustible, la gestion des matériaux et notamment de la perte de poussière, l'injection de charbon activé, le dépoussiérage par voie humide, le lavage à sec ou demi-humide, le grillage du mercure, etc. La méthode de lutte contre les émissions de mercure la plus efficace dépend d'un certain nombre de paramètres, comme la source d'émission de mercure, la spéciation type du mercure dans les gaz de combustion, ainsi que la disponibilité des agents absorbants et de l'eau. Ces technologies permettent l'extraction du mercure des fours à ciment en respectant les limites définies par l'EPA, soit 55 livres par million de tonnes de ciment clinker pour les fours existants et 21 livres par million de tonnes de clinker pour les fours neufs.

Mots-clés : émissions de mercure, production de ciment, EPA, NESHAP, polluants atmosphériques dangereux, Clean Air Act, perte de poussière, charbon activé, dépoussiérage par voie humide, grillage du mercure.

1. Introduction

Mercury is a very harmful element for the human life and due to the risk of its hazardous effect on human health, the increasingly growing Mercury emission from different sources is a growing concern. One of the major sources of Mercury is its emission from the cement kilns in the cement industries. The total Mercury emission in Ontario from cement industries and different sources is described in the section 3. Overall, this report deals with the new Hg control limits for the cement kilns from the Environmental Protection Agency (EPA) of United States, and the effects of it from both the cement companies and the normal people's health and environmental perspectives, and the available technologies to control the Mercury level to the EPA baseline.

According to EPA (2010), Fisher (2010) and Laudal *et al.* (2010), EPA issued their air toxic standards for the Portland cement manufacturing in June, 1999. It did not include any limits on the total hydrocarbon, acid gases or Mercury emissions. In 2000, several organizations filed petition in favor and against that rule. In December 2006, EPA amended the air toxic standard for Portland cement kilns. It banned the usage of fly ash in cement kilns and had Hg emission limit much lower than the current one. Several environmental groups, cement industries and Portland Cement Association (PCA) sued PCA on their amendments. In May 2009, EPA again proposed a number of new limits on emissions of different pollutants in their National Emission Standard for Hazardous Air Pollutants (NESHAP) under the provisions of the 'Clean Air Act'. PCA strongly opposed these limits expressing their deep concern about potential closure of several cement factories in USA due to this new proposed rule (Shaw, 2009). Then finally, on August 6, 2010, EPA issued a final amendment to two of its rules that is intended to decrease the emission of Mercury, SO_2, NO_x and particulate matters from the new and existing cement factories by a certain limits in USA by 2013. According to EPA (2010), 158 currently operating cement kilns in USA out of a total 181 currently operating kilns will be affected by this new rule, and seven other kilns will be affected by the new source performance standards. The remaining kilns will need to follow the rules for the hazardous wastes.

2. EPA's Mercury Regulatory Requirements In 2010

Under the 'Clear air Act', EPA should impose industry-based standards for 187 hazardous air pollutants. According to EPA (2010), the Mercury emission from the cement kilns from the projected 2013 emission level should be decreased by 92%, by a total of 16,600 pounds. Other pollutants from the cement kilns also should be decreased by a significant amount: total hydrocarbon by 83% (10,600 tons), Particulate matter by 92% (11,500 ton), Acid gases by 97%, SO_2 by 78% and NO_X by 5 (6600 tons). Besides, a major source of any hazardous air pollutants can be emitted to a maximum limit of 10 tons a year, while the total of all hazardous air pollutants can be emitted to a maximum of 25 tons per year (EPA, 2010).

According to EPA (2010), for the cement kilns for the Mercury emission, the emission limits are 55 pounds per million tons of clinker for the existing source kilns, and 21 pounds per million

toms of clinker for the new source kilns. Both limits will be based on 30-days emission results. It can be noted that these limits are slightly higher than the proposed limits in 2009: 43 lb/ million tons of clinker and 14 lb/ million tons of clinker, respectively. The final rule said that all these limits should be achieved by 2013.

This new rule also removed the ban on the usage of fly ash from the utility boilers in the cement production, and put limits on the emission of total hydrocarbon (24 ppmv for both old and new source kilns), HCl (3 ppmv for both old and new source kilns), particulate matters (0.04 lb/ton of clinker for existing source kilns and 0.01 lb/ton of clinker for the new source kilns), NO_x (1.5 lb/ton clinker for new source kilns) and SO_2 (0.4 lb/ton of clinker) (EPA, 2010)

To ensure that these requirements are being met, EPA has mandatory provision for the cement kilns to install continuous mercury monitors, using either sorbent traps (PS-12B) or instrumental monitors (PS-12A) (EPA, 2010). EPA proposed the NESHAP standards based on the lowest Hg emission rate achieved by the lowest 12% kilns in USA. In order to achieve the Hg emission rate, the rest 88% cement plants will need some changes in their cement production system – some operational adjustments or some add-on technologies (Paone, 2010).

3. Mercury Emissions From Cement Plants And Mercury Inventory In Ontario

The total Mercury emission in Ontario from different sources was estimated by Sang and Lourie (1997) as 4100 Kg per year. According to Sang and Lourie (1996), the mercury discharged to the surface waters in Ontario is 2500 Kg per year. Sang and Lourie (1997) estimated that the Hg emission to the atmosphere from the cement industry in Ontario is 300 Kg per year, and it is 8% of all the Hg emission all over the province. They also showed that the cement industry is the fourth largest single contributor of this pollutant just after the landfill incinerators (24%), the coal and other fossil fuel based power plants (10%) and the coal/coke making industries (9%) in the province. According to Sang and Lourie (1996), the mercury discharged to the surface waters in Ontario is 2500 Kg per year.

Laudal *et al*. (2010) showed the current mercury concentration measured from ten cement factories in USA in 2010. They found that the pre-heater/ pre-calciner type kilns emit 0.28 to 237.00 µm / dscm of mercury for the 'raw mill on' condition, and 11.37 to 2802.00 µm/ dscm of mercury for the 'raw mill off' condition. The 'Wet' type cement kilns produce 3.35 to 24.10 µm/ dscm of mercury for the case of 'No In-line raw mill' condition. The 'Long Dry' type kilns emit 6.64 to 26.13 µm/ dscm of mercury for the case of 'No In-line raw mill' condition (Laudal *et al*., 2010). From these results, it can be said that the current mercury emission from different cement plants is widely varied. Fukuzaki *et al.* (1986), measured the daily emission of mercury from a cement kiln, and found this quantity as 1.5 kg, mostly originated from the raw material – limestone. They also measured that the emitted Hg was 600 gm per 3900 tons of cement production and 900 gm of Hg emission per 5600 tons of cement production in that cement plant.

4.0 Effects Of The New EPA NESHAP Rule

4.1 Positive Effects

According to Fukuzaki *et al.* (1986), the effects of emitted mercury have direct influence (upto 4% Hg was found in ground and leaves of tress) upto five km radius around the cement kiln. According to EPA (2010), the increased cost of cement production will be outweighed by many times. They estimated that the new rule would save $7 to $19 in public health expenditure for each dollar of cement production cost. EPA (2010) showed that the annual benefit of this rule will be $6.7 billion to $18 billion annually in 2013 in USA. They also showed that the new rule, with limits on Mercury emission along with the limits on particulate matters, SO_2, NO_X, etc., will prevent the following each year from 2013 (EPA, 2010):

- 17,000 cases of serious asthma,
- 1,500 cases of heart attacks,
- 650 cases of chronic bronchitis,
- 1,000 emergency room visits due to respiratory problems,
- 130,000 working days when people miss work,
- 750,000 working days when people must restrict their activities due to air-pollution related diseases, etc.

According to EPA (2010), after emitting from the cement kilns, when mercury reaches water, microorganisms in water converts mercury into highly toxic methyl-mercury (CH_3-Hg) that is accumulated in fishes. If people consume those fishes, they will get several critical diseases. Methyl-mercury exposure to human body damages the developing nervous system in the human body, especially; it is a prime concern for women of childbearing age, unborn babies, and young children. This damage can also damage children's ability to think and learn. Richter *et al.* (2005) showed the potential environmental impact of mercury emissions from the Portland cement kilns, particularly the risk of the fish-consuming population around the Hg-source location (around the cement kilns). They showed that the key parameters to this risk level are mercury emission rates from the kilns, mercury speciation, methylation rates, and watershed and water-body configurations. Through a mathematical modeling, Richter *et al.* (2005) showed that 12% of all the mercury emitted from a cement kiln is deposited locally which are directly effective for the health hazards for the Hg-polluted fish-consuming population around the cement kilns.

4.2 Negative Effects on Cement Companies

Shaw (2009), the senior vice-president of Portland Cement Association (PCA), on behalf on PCA, has defended the position of the cement industries on the new rule of EPA on the Mercury emission. PCA is an association of 45 member-companies having 93 cement plants in 35 states in USA. According to him, most of the cement plants are near to the mines, and use raw materials containing Mercury, and it is unrealistic for them to change raw materials or relocate to new source of no-Hg raw materials. He also argued that the installation of Hg-reducing systems in the cement plants will be very costly, and many of the cement plants may need to close down due to this new rule of EPA NESHAP. In 2010 amendments, EPA made their Hg limits little bit flexible compared to the 2009 limits, but still kept it much lower than the 2006 limit for the new kilns. So the negative effect is on the cement companies. Due to their change in production system and installation of Hg-removal technologies, their production cost will increase. EPA (2010) also showed an estimation that the pollution preventing installation related and relevant social costs in the cement plants will be around $350 million annually in 2013 in one financial analysis and $950 million annually in 2013 in an another financial analysis.

5 CEMENT KILN MERCURY REDUCTION TECHNOLOGIES

Several mercury emission control technologies are available for the cement industries. The techniques include the change of raw materials and fuel, the materials management by dust wasting, the usage of activated carbon during the dust wasting, the wet scrubber method, dry or semi-dry scrubbing and injection of dry sorbents method, Mercury Roasting method, etc. This section discusses these mercury control methodologies. The life cycle of mercury in the cement kiln is very important for its removal. Figure 1 shows the mercury life cycle in a pre-heater cement plant. There are two cycles of Hg in cement kilns – external cycle and internal cycle.

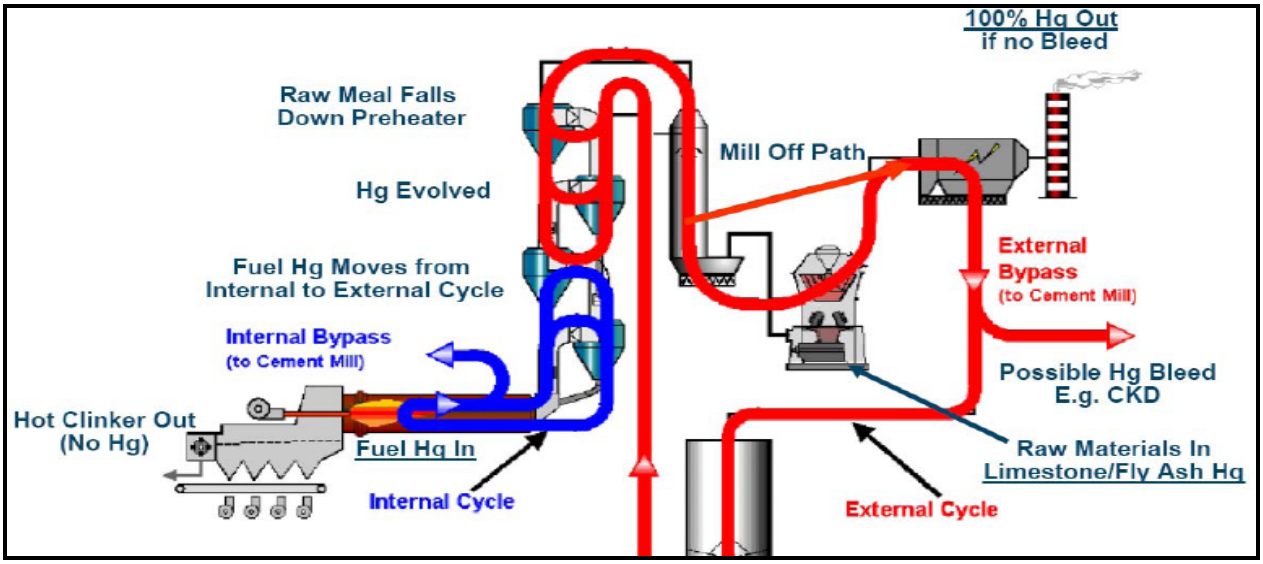

Fig. 1: The Mercury cycle in a pre-heater cement kiln. (from Crowley, 2010)

5.1 Sources and Factors of Mercury emitted in the Cement Kilns

The most significant two sources of Mercury in the cement kilns are the raw materials and the fuels (Paone, 2010; and Laudal *et al*., 2010). The factors affecting the Hg emission from the cement plants are as follows (Laudal *et al*., 2010):

a. Age and type of the cement plant,

b. Fuel burned,

c. Handling of the Cement Kiln Dust (CKD),

d. Handling of the Bag-house dust,

e. Air pollution control devices in use, and

f. The form of the mercury – oxidized or elemental.

According to Paone (2010), PCA estimated the mean, median and standard deviation of the Hg emission for different types of raw materials during the cement production. They found that the CKD (mean of 253 ppb), fly ash (205 ppb), iron ore (78 ppb) and shale (57 ppb) emit the maximum amount of Hg. On the other hand, slag (mean of 12 ppb), mill scale (12 ppb) and limestone (17 ppb) causes smaller amount of Hg emission. Although the mean Hg production for limestone was found low, the standard deviation value for limestone is quite high. While the mean Hg content in limestone is 17 ppb, the maximum of 400 ppb (0.4 ppm) Hg was found in a cement kiln Hg emission (Paone, 2010). Figure 2 shows the contribution mercury from the raw materials (limestone), fuel (coal) and other components in the cement kiln.

The Mercury emitted from the cement plant is any of these three forms: elemental mercury (Hg^0), or in oxidized ionic forms of mercurous (Hg^+) or mercuric ion (Hg^{+2}) forms. The

boiling and melting points of all these forms are between the limits of 270˚C and 600˚C (Paone, 2010). The form of Hg, in which it is emitted, is very important for the control of Hg emission, and also for its hazardous effects on the health of the human beings. Through a mathematical modeling, Richter *et al.* (2005) showed that 80%, 10% and 10% of the total emitted mercury from cement kilns are in mercury vapor (Hg^0), mercury vapor (Hg^{+2}), and mercury particle (Hg^{+2}) forms, respectively. They also showed that 12% of all the emitted mercury are deposited locally, which is the effective hazardous portion of the emitted mercury from the cement kilns. Fukuzaki *et al.* (1986) measured that the particulate and gaseous mercury concentrations in the cement kiln air are 0.15-0.68 ng/m^3 and 4.1-8.7 ng/m^3, respectively. This shows that the quantity of the hazardous component – the particulate mercury is quite high. Fig. 1 shows the external and internal mercury life cycle in a pre-heater cement kiln system. It can be noted that there is one input – with the raw materials, and two outputs – clinker mercury and stack mercury (no bypass) in the cement kiln system (Crowley, 2010).

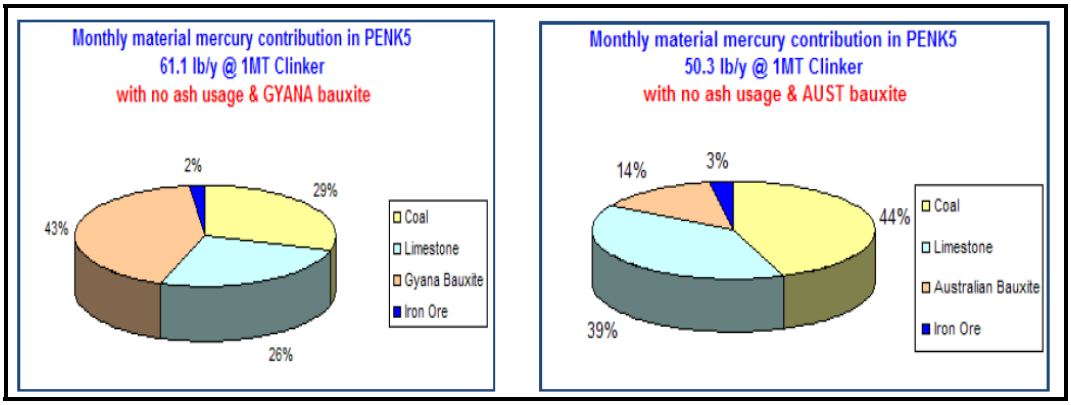

Fig. 2: Contribution of mercury from different raw materials (limestone) and fuel (coal) and other sources. (from Crowley, 2010)

5.2 Changes in Raw materials and Fuel

The simplest method to control mercury emission is to use raw materials and fuels with no or less quantity of mercury. According to Paone (2010), in order to reduce the mercury emission, the firing rate of fuel with higher levels of mercury should be reduced and should be blended with other fuels containing lower mercury level. Alternate fuels with lower mercury content, such as natural gas can be considered, if it is cost effective. CKD, fly ash, iron ore, shale, etc. raw materials contain higher level of mercury. So these additive materials should be avoided in order to reduce the total mercury emission from the cement kiln. For the primary raw material – limestone, limestone should be collected from sources where low mercury content limestone is available (Paone, 2010). Usually, the processed raw materials like steel slag are mercury free. On the other hand, the alumina sources are the most consistent source for mercury. (Crowley, 2010).

5.3 Mercury Reduction by Dust wasting method

Dust wasting method is one of the most widely currently used methods to reduce the mercury emission from the cement plants. According to Crowley (2010), the main concept of this method is that the main bag house dust should be wasted in order to control mercury emission from the kiln. Mercury condenses below 270˚C and that leads to the condensation of mercury in the returning dust from the pre-heater. Also, the dust mercury level increases when the raw mill is down. The dust wasting method was developed based on these two matters. Figure 3 shows the effect of the hours of bleeding on the mercury reducing efficiency in this

method. From this figure, it can be said that the mercury content of the main bag house dust varies with time if a constant amount of dust is wasted everytime. Crowley (2010) also found out that the mercury concentration level in the wasted dust is around 180 ppb of mercury. The efficiency of this method largely depends on the mercury cycle in the cement plant and the tendency of the increasing dust mercury level when the raw mill is down. Lowering the temperature at the main baghouse will increase the accumulation of mercury in the dust, and thus the emission of gaseous mercury content can be reduced. (Paone, 2010). The mercury removal efficiency by dust wasting method has a mercury removal efficiency of between 35% (Paone, 2010) and 40% (Crowley, 2010). According to Crowley (2010), the cost of the dust wasting method is 18.5% of the cost of the cement production and the additional cost of the raw feed replacement crushed limestone costs. He estimated that the total material costs for the mercury reduction in this method is around $2,700 per pound of mercury reduced. Considering the capital costs of the bins and pneumatic truck transport costs, his estimated cost is $6,000 per pound of mercury reduced. He also showed that 10% of the kiln feeds should be wasted for the mercury reduction in this method (Crowley, 2010).

Dust wasting method has some negative side effects on the quality of cement produced. Dust wasting activities may produce an unacceptable drop of C_3S in the clinker. In order to solve this, a properly designed dust wasting method should provide high LSF materials to supplement for the managing the low C_3S in the clinker during the dust wasting time (Crowley, 2010).

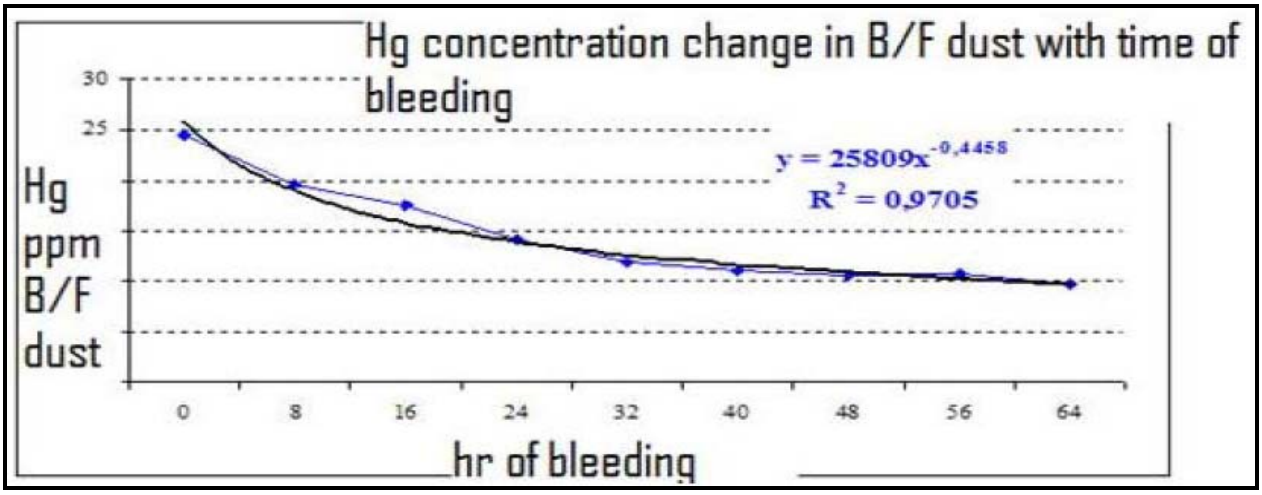

Fig. 3: Mercury reduction by the dust wasting method and effect of the number of hours of bleeding. (from Crowley, 2010)

5.4 Use of Activated Carbon

The effectiveness of elemental and oxidized mercury control using Activated Carbon Injection (ACI) is a very site specific matter. It is different in different cement plants. The mechanism of mercury removal by activated carbon requires elemental mercury to be absorbed on the surface on the activated carbon. Figure 4 shows the effects of different fuel sources on the efficiency of the activated carbon in the reduction of mercury from the cement kilns. Figure 5 shows the effects of SO_3 in the mercury reducing efficiency of this method. According to Laudal *et al.* (2010), in order to improve the Hg-removal efficiency in ACI method, the following should be performed:

- Setting up a polished bag-house to ensure the quality of the bag-house dust, and to maintain the ability to recycle the dust back to the system, and thus to ensure high level of Hg control. But both the capital costs and maintenance costs are very high.
- Injection of enhancement agents of treated activated carbons,

- Installation of a wet scrubber,
- Appropriate handling of CKD – dust wasting or not wasting.
- The temperature of the hopper heaters and the materials collected in the hoppers should be monitored carefully.
- Installation of a watering system to decrease the potential increasing fugitive dust emission due to very fine particles collected in the secondary bag-house.
- Changing the raw materials to reduce the mercury concentration entering into the cement kiln; and
- Changing the process to a lower gas temperature. Carey et al. (1997) showed that the mercury capture by activated carbon is indirectly proportional to the flue gas temperature. The mercury capture is significantly higher at kiln temperature of 250˚C compared to >400˚C kiln temperature.
- Polishing FF (TOXECON^{TM}) increases the residence time and the contact between the mercury and the activated carbon particles, and thus increases the potential Hg-capture by activated carbon.

The Dry Sorbent Injection method using activated carbon is able to emit greater than 75% of the total mercury. The cost of extra activated carbon is around $2000/ ton of carbon, and the operating cost can increase by $0.60/ ton of clinker. Installation of a second large baghouse can be difficult due to the space limitation within the cement plant (Paone, 2010)

At least two cement kilns in Europe and at least one cement kiln in North America have installed this system. Other sorbents like hydrated lime can also be used instead of activated carbon. Multi-pollution control technique, since other pollutants including SO_2 will also be absorbed by the sorbent (Paone, 2010).

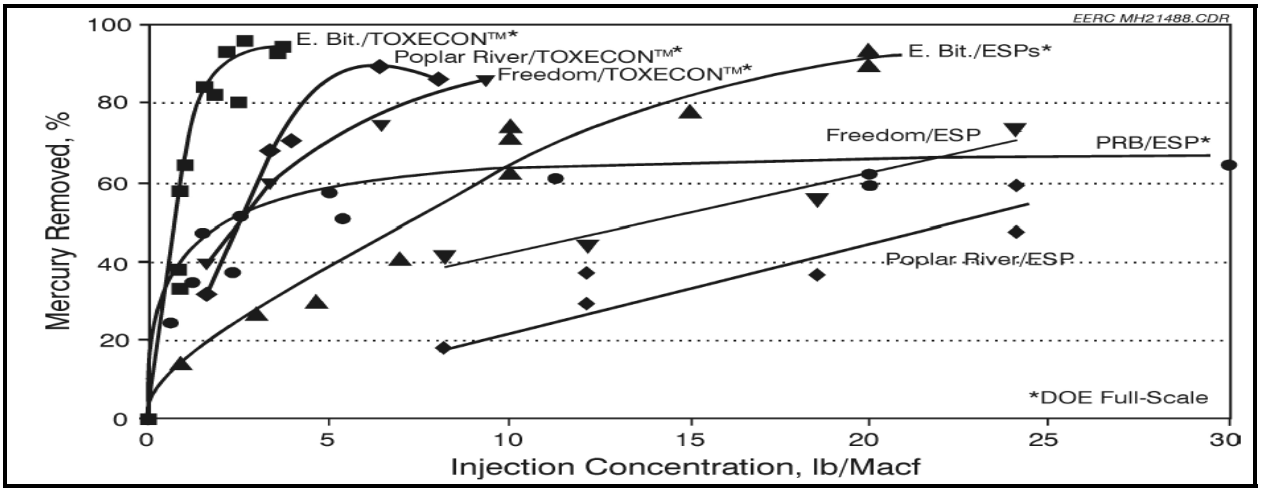

Fig. 4: Impact of the fuel (coal) type and the Activated Carbon concentration on the mercury removal efficiency. (from Laudal et al., 2010)

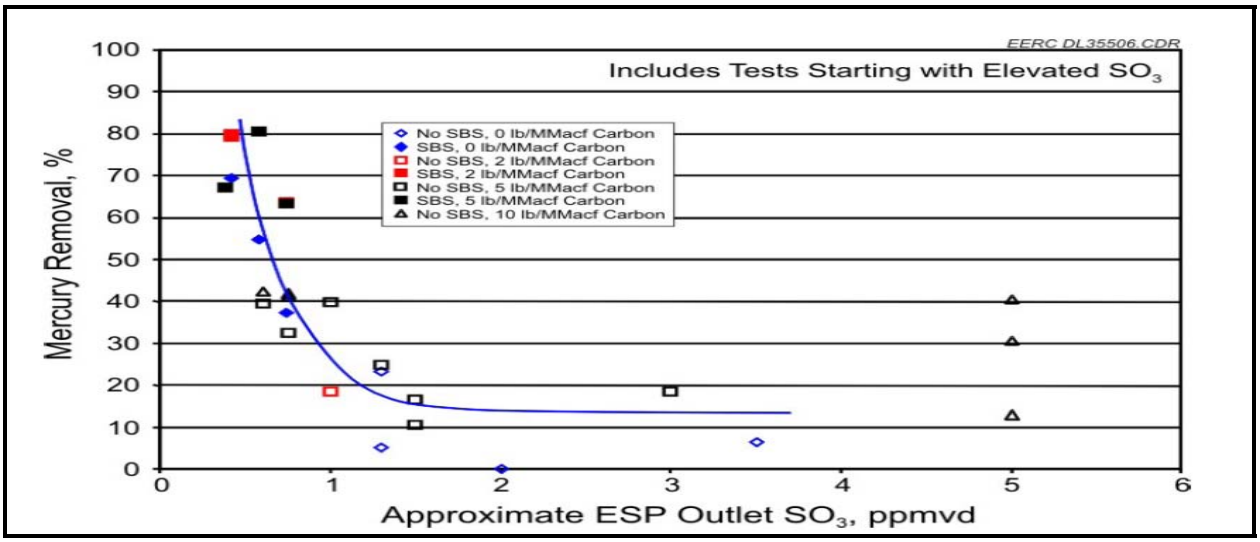

Fig. 5: Effect of SO_3 on the mercury removal efficiency using Activated Carbon Injection. (from Laudal et al., 2010)

5.5 Wet Scrubbing

Wet Scrubbing is a currently used mercury reduction technology in the cement kilns in USA. Wet Scrubbers have been installed in several cement kilns in USA till now. According to Paone (2010), the basic idea in this method is that the flue gases should be passed through a spray of slurry consisting of lime, limestone or CKD. The lime in the slurry reacts with SO_2 in the gas and creates $CaSO_3$. CanSO3 is then oxidized and forms $CaSO_4$, and then removed as gypsum slurry. The very low temperature in the exhaust of the wet scrubber leads to the condensation of mercury. Then the condensed mercury in the form of soluble $HgCl_2$ is removed with water.

According to Paone (2010), this method requires a big quantity of water - a minimum of 30 gallons of water per 1000 ft^3 process gas in order to achieve the target mercury limit. The pH of the basin slurry should be carefully monitored in order to ensure the proper crystallization of gypsum in the scrubber. Multi-pollution control technique, since other pollutants including acid gases, SO_2 and other condensable pollutants are also absorbed by the sorbent. The data from the currently installed wet scrubbers in the cement kilns indicate that the mercury emission is usually reduced during the time when the raw mill is down, and is usually increased when the raw mill is in operation. Figure 6 shows the schematic diagram of the mercury removal in the wet scrubber method in a cement kiln.

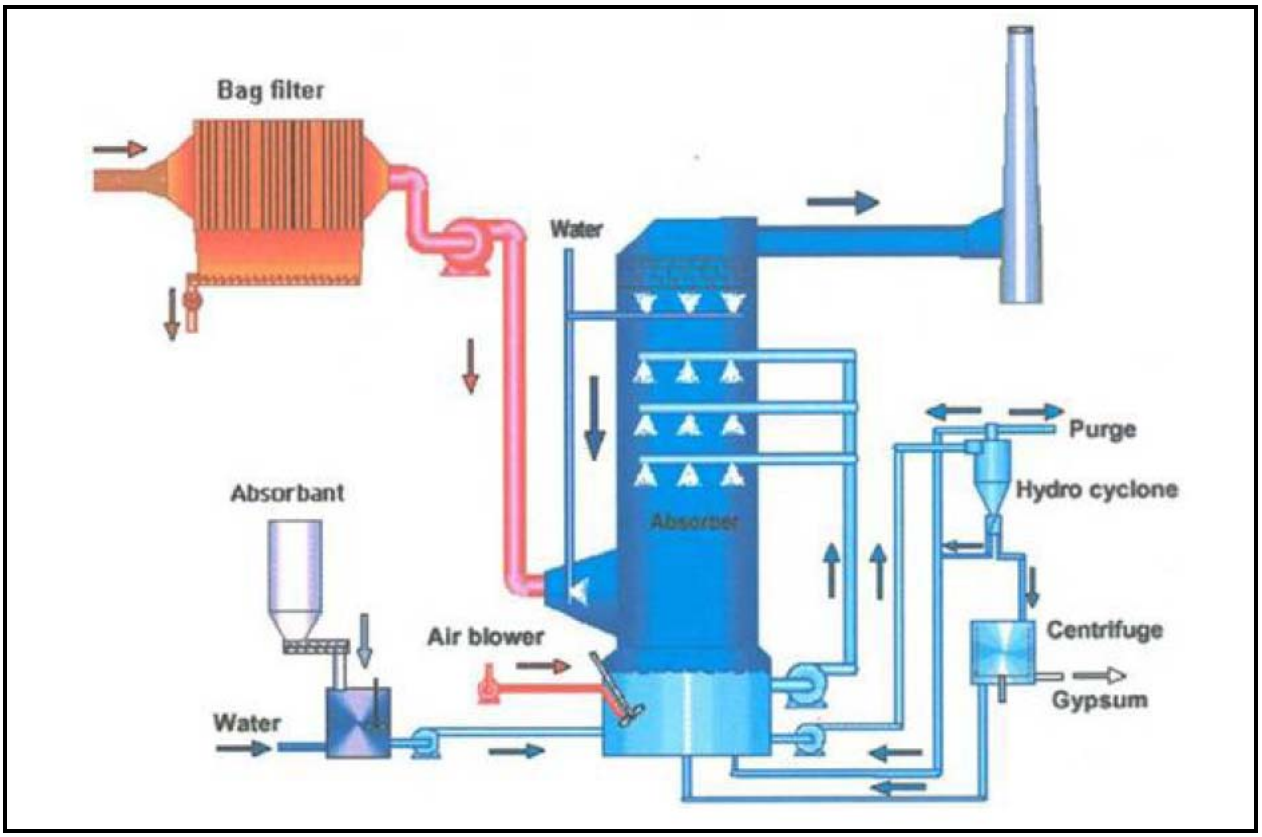

Fig. 6: Wet Scrubber in a Cement Kiln (from Paone, 2010).

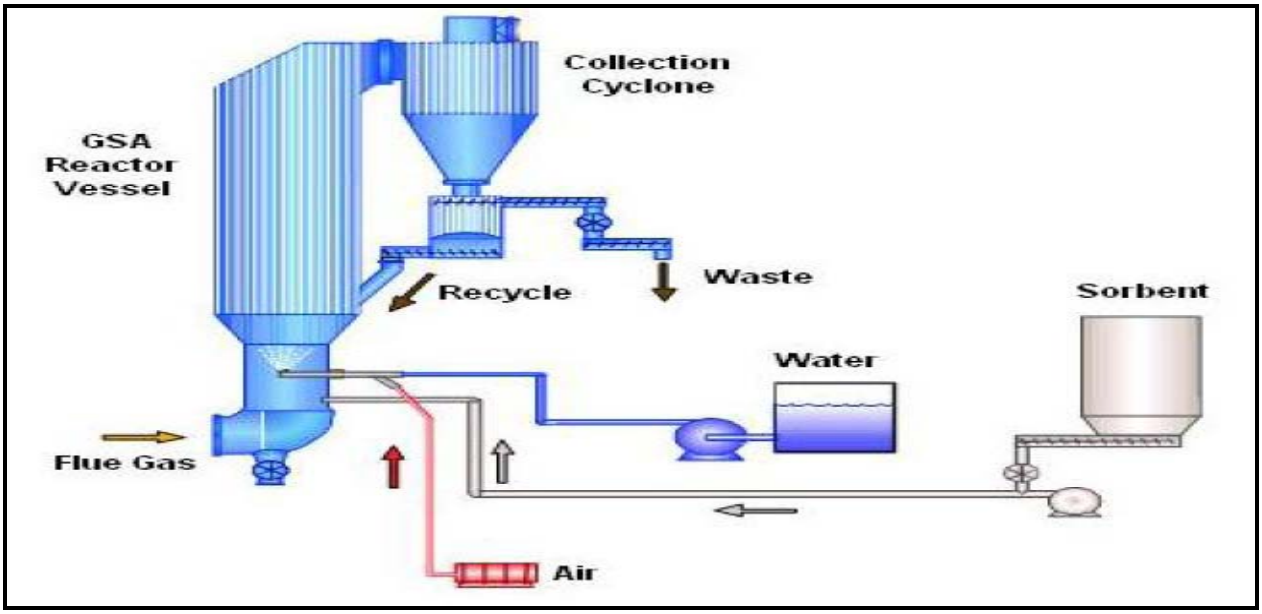

Fig. 7: Gas Suspension Absorber in the Dry or Semi-Dry Scrubbing system. (from Paone, 2010).

5.6 Dry or Semi-Dry Scrubbing

Gas Suspension Absorber (GSA) is used in this system. The gas in the cement kiln is run through a sorbent. All the pollutants removed in this method are in dry form. According to

Paone (2010), the flue gas is moved upward through the reaction vessel (Fig. 7) and a sorbent is mixed. Water is sprayed to control the temperature to the adiabatic dew-point. Then the gas is moved through the cyclones for dusting, and mercury is captured (Fig. 7). The material captured in the cyclone is then re-circulated through the GSA reaction vessel. At the end, the sorbent, along with the absorbed mercury, is removed and wasted (Paone, 2010).

From the experimental studies, this method shows a mercury removal efficiency of 80%-90%. The power cost in this method is also much less than the wet scrubber method. This is also a multi-pollution control system for both the acid gases and mercury (Paone, 2010).

5.7 Mercury Roasting

Cleaning the dust of mercury through 'roasting' is another method of reducing mercury emission from cement kilns (Fig. 8). According to Paone (2010), a hot gas source heats up the dust above the boiling point of mercury. Under this condition, the dust will be captured. Then the gas is cooled, and the mercury is condensed into a sorbent stream and can be captured, and removed from the plant. A hot electrostatic precipitator (ESP) can be used to capture the cleaned dust, and a baghouse can be used to capture the sorbent (Paone, 2010).

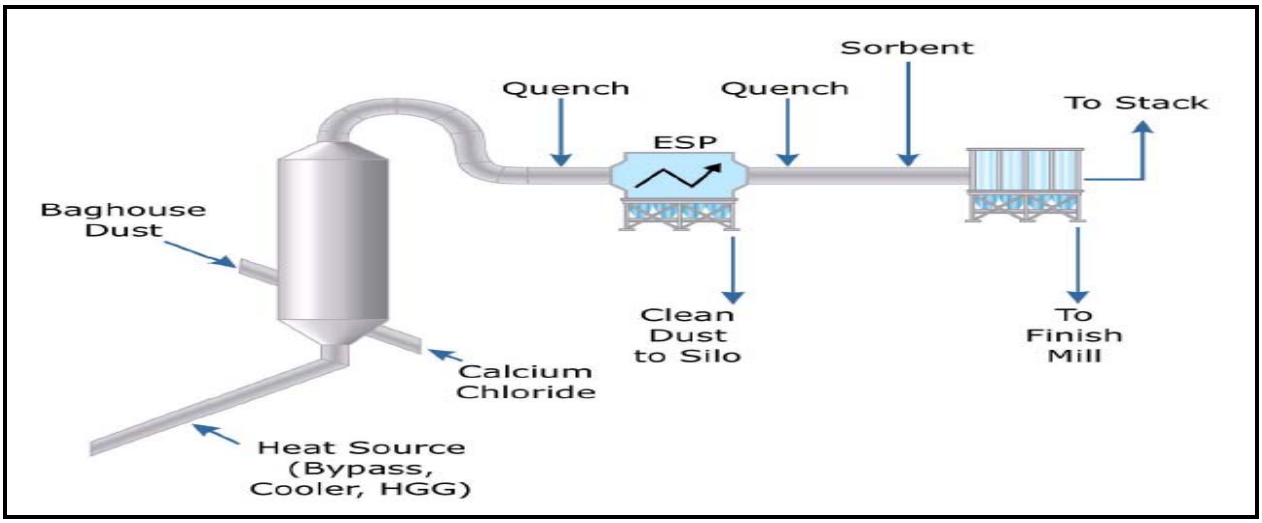

Fig. 8: Roasting system for mercury control in cement kiln. (from Paone, 2010)

5.8 Comparison between the mercury reducing methods

According to Paone (2010) and Crowley (2010), the mercury removal efficiency in the dust wasting method is 35% - 40%. Several of this system are already in run in several cement kilns. Greater than 75% of the mercury emission can be reduced by the Activated Carbon dry sorbent injection method. At least 3 cement kilns in North America and Europe are using this system. From the experimental studies, the dry and semi-dry method shows a mercury removal efficiency of 80%-90% from a cement kiln. From the experimental studies, it was found that mercury roasting method can remove 75% of the total mercury from the cement kilns, but none of this system has yet been installed in any cement kilns in North America (Paone, 2010). Figure 9 shows the comparative efficiency of mercury removal of the different methods. From this figure, it can be said that the simplest methods like change of raw materials and waste dusting are the most effective methods. The most economic and efficient method for controlling the mercury emission depends on a number of factors like the source of mercury emission, the typical speciation of Hg in the flue gas, and the availability of sorbent materials and water (Paone, 2010).

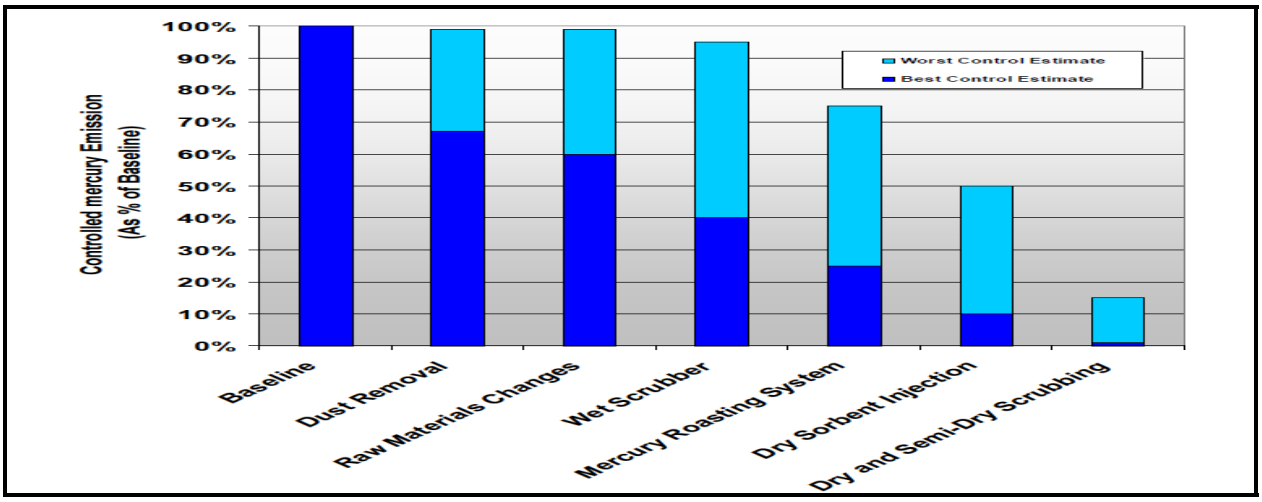

Fig. 9: Comparison of the efficiency of the mercury removal techniques from the cement kilns. (from Paone, 2010)

6. CONCLUSION

The high emission of Mercury from the cement kilns is a significant concern of the people these days. EPA has published a final amendment to the NESHAP on August 6, 2010 under the 'Clean Air Act', that include a significant change in the emission limit of several pollutants from the cement plants, including a limit for the Mercury emission from the plants. According to the Portland cement Association (PCA), the guideline for Hg control is economically unachievable by the cement companies, since it requires a set up for the Hg control in most of the plants. Several Hg emission control techniques were studied, compared and discussed in this article. These techniques include the change of raw materials and fuel, the materials management by dust wasting, the usage of activated carbon, the wet scrubber system, dry or semi-dry scrubbing and injection of dry sorbents system, Mercury Roasting system, etc. The most economic and efficient method for controlling the Hg emission depends on a number of factors like the source of mercury emission, the typical speciation of Hg in the flue gas, and the availability of sorbent materials and water. As a first option, the changing of raw materials and fuel and dust wasting should be considered. Using these technologies the removal of Mercury from the cement kilns is possible to the EPA given new limits.

REFERENCES

[1] Carey, T. R., O. W. Hargrove, C. F. Richardson, "Factors affecting Mercury control in utility flue gas using Sorbent Injection", In Proceedings of the Air & Waster Management Association 90th Meeting Annual, Toronto, ON, Canada, 1997.

[2] Crowley, D., "Cement Kiln Mercury Reduction Strategies: A case study in materials management", 52nd Cement Industry Technical Conference, 2010 IEEE-IAS/PCA , Colorado Springs, CO, USA, 2010.

[3] Environmental Protection Agency (EPA), "Fact Sheet: Final Amendments to the National Air Toxics Emission Standards and New Source Performance Standards for Portland Cement Manufacturing", 2010.

[4] Environmental Protection Agency (EPA), "National Emission Standards for Hazardous Air Pollutants From the Portland Cement Manufacturing Industry and Standards of Performance for Portland Cement Plants", 2010.

[5] EPA Notice EPA-HQ-OAR 2002-0051; FRL-RIN 2060-A015 – National Emissions Standard for Hazardous Air Pollutants from the Portland Cement Manufacturing Industry.
[6] Fisher, S., "FEPA sets mercury limits for cement industry", *Pollution Engineering*, 2010, vol. **42**, no. 8.
[7] Fukuzaki, N., R. Tamura, Y. Hirano and Y. Mizushima, "Mercury emission from a cement factory and its influence on the environment", *Atmospheric Environment*, 1986, vol. **20**, No. 12, pp. 2291-2299.
[8] Laudal, D. L., J. P. Kay, M. L. Jones and J. H. Pavlish, "Issues associated with the use of activated carbon for Mercury control in cement kilns", IEEE, 2010, pp. 1-9.
[9] Paone, P., "Mercury controls for the cement industry", 52nd Cement Industry Technical conference 2010 IEEE – IAS / PCA, IEEE, Colorado Springs, CO, USA, 2010.
[10] Paone, P., "Mercury reduction technologies for cement production", 7th colloquia of managers and technicians of cement plants, Madrid, Spain, 2009.
[11] Paone, P., "Heavy metals in the cement industry: A look at volatile cycles and simple mitigation techniques", IEEE-IAS/ PCA Technical Conference, Miami, Florida, 2008.