AMERICAN UNIVERSITY OF ARMENIA

APPLICATION OF NEW TECHNOLOGIES TO REDUCE NITROGEN OXIDE EMISSIONS INTO THE ATMOSPHERE: POLICIES TO SHIFT ENVIRONMENTAL BEHAVIOR IN ARMENIA

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LIA HOVHANNISYAN

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SIGNATURE PAGE

Faculty Advisor **Date**

Dean **Date**

American University of Armenia

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List of Abbreviations

CJSC	Closed Joint Stock Company
EECCA	Eastern Europe, Caucasus and Central Asia
EIMC	Environmental Impact Monitoring Center ("Hayecomonitoring")
MAC	Maximum Allowable Concentrations
MNP	Ministry of Nature Protection
MoF	Ministry of Finance
NOx	Nitrogen Oxides
NSS	National Statistical Service
PPP	Polluter Pays Principle
PRTR	Pollutant Release and Transfer Register
RoA	Republic of Armenia
SEI	State Environmental Inspectorate
SRC	State Revenue Committee
STS	State Tax Service
SCR	Selective Catalytic Reduction
SNCR	Selective Non-Catalytic Reduction
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change

Abstract

Human activities worldwide are increasingly threatening the integrity of the natural systems that make life possible on this planet. Armenia faces serious environmental challenges, which require serious and immediate actions to promote environment protection. One of the key concerns is the air industrial pollution.

In this context, the present research evaluates the potential environmental risks and negative impacts from the cement production. The paper aims to identify the ways of the modernization of cement production to prevent, minimize, mitigate, or compensate for the adverse environmental impacts in Armenia. Specifically, the study reviews some advanced cement production technologies, which allow introducing energy and raw material saving measures. The paper also analyzes applicability of the alternative technologies in Armenia to reduce Nitrogen Oxides emissions, and assesses cost effectiveness of suggested alternative technologies.

After addressing the technology of cement industry currently in use in Armenia and suggested alternative ones, the study proceeds with analysis of the issues in the legal and institutional frameworks that hinder compliance assurance and enforcement of air polluting companies, as well as effectiveness of the economic instruments through the system of environmental fees.

Finally, the research gives recommendations on how to implement the result-oriented strategies and effective policies to control and prevent air pollution.

Introduction

> Increasing awareness that our global ecological life support is endangered is forcing us to realize that decisions made on the basis of local, narrow, short-term criteria can produce disastrous results globally and in the long run.
>
> (Costanza 199, 123)

Air quality in Armenia has improved markedly since the industrial closures that followed independence from the Soviet Union in 1991. However, much of this improvement can be only temporary given emerging interests in re-opening some former polluting factories. Therefore, somewhat improved situation with air pollution in Armenia at present provides a false sense of security concerning what may become a priority public health concern over the next decade. Even now, however, public health suffers from chronically polluted air. Sources of pollution include industrial centers, mining enterprises, chemical and power plants, and rapidly growing park of vehicles. Much pollution comes from out-of-date industries, which are the legacy of Soviet period (Environmental Information Systems in Armenia 2006).

The purpose of this Policy Internship Project is to evaluate one narrow and specific aspect of the air pollution in Armenia - the NOx emissions from the stationary sources - cement production facilities. The cement production is an important industry for Armenia and worldwide. One need only mention reinforced-concrete walls and girders, tunnels, dams, and roads to realize the dependence of our society upon cement products. However, cement is one of the most environmentally hazardous materials in the world, adding more carbon dioxide to the atmosphere than the entire weight of the global airline industry. Another hazardous component of air pollution by cement plants is the emission of nitrogen oxides, which have negative impact on ecosystems and human health.

The present policy internship paper reviews some advanced cement production technologies, which allow introducing energy and raw material savings. The paper analyzes the applicability of the alternative technologies in Armenia to reduce NOx emissions, and

assess cost effectiveness for the use of alternative technologies. The technical information and analysis in this paper will be useful for the designated state agencies responsible for environmental protection in Armenia to develop and implement regulatory programs to control NOx emissions from cement kilns. Finally, the paper looks at some methods and gives recommendations on how to improve the legal framework, administrative and financial mechanisms, as well as define a set of policy priorities with regard to application of fiscal instruments or incentives for polluters and natural resource users to shift their environmental behavior.

Research Questions

The paper answers the following research questions:

1. What are the amounts of NOx emissions in Armenia and which portion is from cement production?
2. How NOx air polluting chemical compounds should be controlled?
3. What kind of technological processes are used in cement production for the reduction of NOx emissions?
4. How is the current system of air pollution fees designed in Armenia?
5. What are the institutions governing administration and collection of environmental fees from the cement plants?
6. What is the role of environmental fees as economic instruments for polluters and natural resource users to shift their environmental behavior?

Methodology

The methodology applied for this research is based on the primary data analysis, namely analysis of the best international practices of controlling emissions by cement factories and relevant legal documents; as well as secondary data analysis, analysis of the different reports, discussion papers, policy papers and scientific articles. Necessary information was obtained through the interviews with the officials from the Ministry of Nature Protection, specifically the Department of Meteorology and Monitoring of Atmosphere Pollution (MNP), the State Environmental Inspectorate and the National Statistical Service. For the selection of interviewees the purposive sampling method was used.

Literature Review

Background

Air is one of the basic vital elements of the natural environment. Polluted air has negative impact on biosystems, economic and social activity and human health. The major source of air pollution is anthropogenic activity, mainly industries.

Industrial development in Armenia between the 1920s and the 1980s had left significant negative effects on the ecosystems and biodiversity of the country, including: loss and, degradation of natural habitats, pollution of soils, water and air. Over this time, industrial development increased GDP by a factor of 1,000.

After Armenia gained independence in 1991 industrial production steeply ceased down. While along with industrial standstill in the 1990s emissions from stationary and mobile sources decreased, too, air pollution currently is again becoming an important issue, especially in urban areas. The sources of air pollution in the cities are energy generating facilities, industrial enterprises, motor transport etc. Air pollution may be exacerbated by unfavorable meteorological conditions and shortage of trees and other greenery. Currently

Yerevan, Hrazdan, Vanadzor and Ararat are densely populated urban areas with highly polluted air (Reference on State of the Surface Water and Atmosphere in Localities, August 2008).

Prior to the economic crisis (1989-1994) substantial levels of pollution were recorded from the country's industrial centers, totaling around 245,000 tones annually (54,400 tones of solid particles and 190,900 tones of liquid or gaseous emissions). This included around 50 different pollutants, including sulphate anhydride (58%), nitric oxides (15%) and carbon oxides (14%). At present only a small portion of industries remain operational (10-30%) and emissions of pollutants have dropped dramatically to 15,000-20,000 tons per year (Armenia: Economic Crisis and Meeting the Challenges of Reform 1995). Thus, pollution continues to have negative impacts on both natural ecosystems and agricultural lands in the country. Of great concern is the continued release of chemical waste, gaseous emissions and heavy metals from key industrial sites (Reference on State of the Surface Water and Atmosphere in Localities, August 2008).

In this regard, addressing the environmental challenges that the country faces requires a comprehensive set of actions, not the least of which is establishment of strict air quality standards and capacity to monitor and enforce the compliance. Other vital elements of government actions should include creation of economic incentives to change environmental behavior of industrial companies and generation of a fundamental understanding of the critical importance of environmental protection for the economic and physical wellbeing of the country and its people. Therefore the government should impose a combination of command-and-control mechanisms with market-based incentives to make the polluting companies start realizing the necessity to shift to cleaner and safer technologies of production and/or treatment of their emissions, particularly into atmosphere.

The Cement Industry: Brief Description of Production Technology and Current Status in Armenia

Due to increasing amounts of emissions from cement plants, optimization of cement production technology and introduction of energy and raw material saving measures has become one of concerns for the Ministry of Nature Protection.

Below we briefly review the technology of cement production. Cement is a hydraulic binder used in conjunction with other materials whose performance can only be figured out and predicted during its manufacture. To make cement, raw materials such as limestone, cement rock, sand, iron ore, clay and shale are crushed, blended and fed into a kiln. These materials are then heated in the kiln to temperatures above 2900°F (1600^0C) to initiate a chemical reaction that produces cement "clinker," a round, marble-sized, glass-hard material. The clinker is then cooled, mixed with gypsum and ground to produce cement.

Almost all cement clinker is produced in large rotary kiln systems. In fact, there are four types of kilns in use - long wet kilns, long dry kilns, kilns with a preheater and kilns with a precalciner. The long wet and dry kilns and most preheater kilns have only one fuel combustion zone, whereas the newer precalciner kilns and preheater kilns with a riser duct have two fuel combustion zones. In a wet kiln, the ground raw materials are suspended in water to form slurry. In a dry kiln, the raw materials are dried to a powder (Manufacturing - the cement kiln 2009).

Nearly most of the emissions of polluted substances from cement manufacturing are the result of the high process temperatures out of these kilns. The environmental consequences of cement industry operations include releases to air of nitrogen oxides (NO_x), sulphur dioxide (SO_2), particulates and carbon dioxide (CO_2); use of resources, especially primary raw materials and fossil fuel; and generation of waste.

Thus, while there are several polluting substances in the process of cement production, the focus in this study is made on one of the key polluters – nitrogen oxide.

Nitrogen Oxides Emissions

Nitrogen oxides, or NOx, are gaseous pollutants that are primarily formed through combustion process. NOx is the generic term for a group of highly reactive, acidifying gases, all of which contain nitrogen and oxygen in varying amounts (See Appendix, table 1). Nitrogen oxides are precursors to ground-level ozone, which can trigger serious respiratory problems. NOx also contribute to acid rain and global warming (Atmospheric Environment 2000). In addition, they have adverse effect on human health causing respiratory problems, such as asthma, emphysema and bronchitis, damage to lung tissue and premature death, aggravating existing heart disease (Emissions control systems for today's air quality standards 2008).

While flue gas is within the combustion unit, about 95% of the NOx exists in the form of nitric oxide (NO). The balance is nitrogen dioxide (NO_2), which is unstable at high temperatures. NOx is generated in one of three forms; fuel NOx, thermal NOx, and prompt NOx. Fuel NOx is produced by oxidation of nitrogen in the fuel source. Combustion of fuels with high nitrogen content such as coal and residual oils produces greater amounts of NOx than those with low nitrogen content such as distillate oil and natural gas. Thermal NOx is formed by the fixation of molecular nitrogen and oxygen at temperatures greater than 3600°F (2000°C). Prompt NOx forms from the oxidation of hydrocarbon radicals near the combustion flame and produces an insignificant amount of NOx (Environmental Management 2009).

Essentially all NOx emissions associated with cement manufacturing are produced in cement kilns. In cement kilns, NOx emissions are formed during fuel combustion by two main mechanisms:

- Oxidation of molecular nitrogen present in the combustion air which is termed thermal NO formation

- Oxidation of nitrogen compounds present in the fuel which is termed fuels NO formation.

Because the typical operating temperatures of the cement kilns differ, the NOx formation mechanisms also differ among these kiln types. In a primary combustion zone at the hot end of a kiln, the high temperatures lead to predominantly thermal NOx formation. In the secondary combustion zone, however, lower gas-phase temperatures suppress thermal NOx formation. Energy efficiency is also important in reducing NOx emissions; for example, a high thermal efficiency means less heat and fuel are consumed and, therefore, less NOx is produced (Delivering measurable value daily to the most recognized names in the ministry 2009).

Often the raw material fed to the kiln may also contain a significant amount of nitrogen compounds which may lead to feed NO formation similar to fuel NO formation. Because of the high temperatures involved in the burning or clinker formation step, thermal NO formation provides the dominant mechanism for NOx formation in cement manufacturing (Nitrogen Oxides (NOx), Why and How They are Controlled 1999).

Consequently, the optimization in cement production means better control over clinker and cement quality, which enables to increase of blending additives in cement and reduces the share of clinker, and as a result, to reduce the emission of NO_x into the atmosphere. Therefore, there is a prevailing necessity to minimize variability in material composition and processing throughout the manufacturing process. Quality assurance systems must be developed to control the composition of all inputs to the manufacturing process and all processing conditions (Global Cement Report Seventh Edition Tradeship Publications 2008).

Findings

Cement Production in Armenia: NOx Emissions and Alternative Technologies

In Armenia there are two cement plants: "Mika-Cement" CJSC (located in the city of Hrazdan) and “Ararat-Cement” Multi-Group CJSC (in the town of Ararat). Both were built in the Soviet period.

“Mika-Cement” CJSC, which occupies a territory of 540 thousand sq m, is specialized in production of Portland cement and utilizes the most energy intensive wet process technology, main equipment of which was produced by former Soviet Union manufacturers before 1971, when due to cheapness of fossil fuels energy efficiency was not a priority. Thus, the enterprise has more than a thirty-year history. It was put into operation as a structural subdivision of Hrazdan mining combine in 1970. In 1977 the enterprise was re-structured into the Hrazdan Cement Plant and became one of the main cement producers in the region. Its produce was used not only locally, but also exported to Georgia and Azerbaijan. However, from 1992 until privatization in 2001, the plant operation was unstable and cement output fell dramatically due to economic recession and transportation blockade of Armenia. Nevertheless, after privatization and establishment of "Mika Cement" CJSC the cement production volume has increased from 14.5 thousand tons in 2001 to 240 thousand tons in 2004 (“Mika-Cement” Company 2005).

As a result, the energy consumption benchmarks of the plant are high, compared with the world’s best practice with similar wet process technology “Mika-Cement” plant produces 1.2mln tons of cement grades 400, 500 and 600. According to the data obtained from the National Statistical Service the plant produced about 0.9 million tons of cement in 2006 and this number increased up to 1.35 million tons in 2007. The company exports 40% of its produce to Iran, Georgia and Russia (See Appendix, table 2).

Another cement plant in Armenia, "Ararat-cement" CJSC, began its operation since 1993 by the wet method of production. High rates of growth in construction sector at that time required rapid increase of cement production volumes and for this reason the Research Institute "Yujgiprocement" designed the expansion of Ararat Cement Plant, according to which the new technological line of cement production by dry method was constructed in 1983-1990 with 1.2 million ton productive capacity annually (Ararat Cement Company 2005).

In 1998 "Ararat-Cement" was a state-owned company in subordination of the Ministry of Building Materials Industry of the Republic of Armenia and operated with 7-10%-of its capacity. In 2002 "Ararat-Cement" in the framework of privatization policy conducted by the government of independent Armenia was sold to "Multi Group" Concern. Due to large volume of investments done after the privatization, a number of major construction projects in Yerevan used the cement produced by "Ararat-Cement" CJSC, such as the Sport and Concert Compound in Tsitsernakaberd, Palace of Youth, "Ayrarat" movie theatre, Yerevan Underground, "Hrazdan" stadium, The Northern avenue and others. The product has a great demand in the whole market of Georgia, and it is also exported to Iran, Iraq.

However, growing demand and increasing volumes of production from cement plants, result in expansion of NOx emissions, which affect natural and agricultural ecosystems, and human health. In addition, the current transitional conditions of the economy, numerous social and economic challenges that the country faces and shortage of financial resources in the state budget do not allow to spend sufficient funds for sustainable management of natural resources, specifically for the reduction of air polluters and invest in the sector with the goal of promoting environmentally sound practices.

According to the data obtained through the the Department of Meteorology and Monitoring of Atmosphere Pollution of the MNP the emissions of air substances in 2006

were equal to 56 polluting substances (from the list of 82 polluting substances), whereas in 2007 this number was equal to 40 polluting substances (from the list of 100 polluting substances). Meanwhile, in 2007 the emissions of NOx were equal to 1700 tons. Compared to other countries Armenia in 2003-2009 was in 38th place from the list of 141 countries by its NOx emissions per capita. (Environment Statistics: Pollution 2009).

Based on the data obtained from the SEI and the NSS, out of the total NOx emissions in 2007 the portion of NOx emission from the cement production composed 18.36%. The NOx emissions in 2007 both for Ararat and MIKA plants comprised from 100 to 200 tons. The amount of environmental fees paid for NOx emissions varied from 1 to 3 million drams annually. Moreover, it is interesting to note that the projected production of 10 million tons of cement by Mika-Cement plant in 2014 will result in emission of 740 tons of NOx. (See Appendix, table 3).

It is important to mention that according to data obtained from the MNP there was no considerable growth in the amount of the MAC of air emissions in 2003-2008 for both Ararat and Mika cement plants (See Appendix C, table 1)

In view of perspectives for increasing emissions in the air in the next 5 years it is important to review possible technologies that will reduce emissions into air from cement production. After reviewing the international practice and analyzing different techniques for reducing NOx emissions 3 alternative technologies with special process control approaches for Ararat and Mika cement plants were identified. These technologies are the following: Low NOx Burner, Mid-Kiln Firing and Selective catalytic reduction. As a result of applying these technologies the amount of NOx will be reduced from 30 to 90 percent (Alternative Control Techniques Document....1994).

Since these alternative technologies have the NOx control approaches applicable to the cement production, they may be classified into two categories:

- Combustion control approaches where the emphasis is on reducing NOx formation
- Post combustion control approaches which control the NOx formed in the combustion process.

Process control approaches are based upon providing optimum kiln operating conditions, which increase the energy efficiency and productivity of the cement-making process while minimizing NOx emissions.

Before introducing the above mentioned technologies it is worth to mention that since "Mika-Cement" plant uses wet cement kilns and "Ararat-Cement" – dry cement technology, the possibility for applying the alternative technologies are different.

In addition, to the specific NOx formation mechanisms, the energy efficiency of the cement-making process is also important as it determines the amount of heat input needed to produce a unit quantity of cement. The energy consuming processes are associated with grinding of raw materials, clinker and additives, firing of clinker kilns and cement production. A high thermal efficiency would lead to less consumption of heat and fuel and would produce less NOx emissions.

Since the four types of cement kilns show different combustion characteristics as well as energy efficiencies and heat requirements, the available NOx emissions data are grouped by these cement kiln types. The four different cement kiln types, however, do appear to have different levels of NOx emissions and different characteristics influencing NOx formation (See Appendix, table 4).

All these process controls - approach technologies are based upon providing optimum kiln operating conditions which increase the energy efficiency and productivity of the cement-making process while minimizing NOx emissions.

1. *Low NOx burners.* In the first stage, fuel combustion is carried out in a high temperature fuel-rich environment and the combustion is completed in the fuel-lean

low temperature second stage. By controlling the available oxygen and temperature, low NOx burners attempt to reduce NO formation in the flame zone.

2. *Mid-Kiln Firing*. This technique can be potentially applied with other waste-derived fuels. Secondary combustion of fuel is inherently present in all precalciner kilns and preheater kilns with riser duct firing and such kilns produce less NOx emissions compared to long dry kilns.
3. *Selective Catalytic Reduction (SCR)* uses ammonia in the presence of a catalyst to selectively reduce NOx emissions.
4. *Selective Non-Catalytic Reduction (SNCR)* technology is applicable to preheater/precalciner type kilns with limited data indicating its effectiveness. SNCR reduces NOx with ammonia or urea without a catalyst.

The above mentioned technologies are considered to be needed for proper kiln operation. The achievable NOx reductions while applying these techniques is from 20 to 90 percent. (See Appendix, table 5).

Based on the analysis of the report issued by the Emission Standards Division, U.S. EPA (Alternative Control Techniques Document…1994), in-depth interviews with the experts at the SEI, as well as discussions with the Head of the Department of Economics of Nature Protection and Nature Use, the present study introduces the total capital and annualized operating costs for each of the three control technologies as applied to "Mika-Cement" and "Ararat-Cement" plants (See Appendix, table 6, table 7).

The cost effectiveness of the technology has been calculated by dividing the total annual cost of a given technology by the annual NOx reduction likely to be achieved as a result of applying that technology (See Appendix, table 8, table 9).

The results of the cost effectiveness analysis demonstrate that the introduction of the alternative technology will be effective for the cement plants. Nevertheless, it is clear that for

an entrepreneur paying comparably low environmental fees (equal to approximately 1.5 mln. AMD annually) it is preferable to continue paying the fees than introducing an environmentally friendly technology with the capital cost equal to approximately 500 million AMD (for Low-NOx Burner technology, for example). In this regard, the fee rates for stationary sources should have to be increased at least 10-fold, if they were to provide incentives for the pollution reduction.

In this context, the legal framework for the environmental protection is the key pillar to address the above mentioned statement. Armenia has made a commitment to harmonize the national environmental policy with the principles of sustainable development and according to national development priorities.

Legal Framework for Air Pollution Prevention and Control

> "… The contemporary battleground over words like "nature" and "environment" is more than a matter of mere semantics, but a leading edge of political conflict."
> (Harvey 1993, 96)

Since independence, the RoA has adopted a number of laws relating to environmental protection. Article 10 of the Constitution of the Republic of Armenia (adopted in 1995 and amended in 2005) stipulates that the State is responsible for environmental protection, reproduction and wise use of natural resources.

There are 3 government agencies primarily involved in administering environmental protection in Armenia. The MNP designs overall environmental policy and applies administrative and economic instruments, introduces new types of these instruments; oversees compliance to established standards and enforces the law. Fee rates are established through the legislative process, where both the MNP and MoF can initiate a legislative process to review and revise the fee rates. Responsibilities for control and enforcement of

pollution prevention and fee payments are split between the MNP and the STS. The SEI, which is part of the MNP, is in charge of controlling the reported pollution volumes versus permitted, and the STS control the payments due (Ministry of Nature Protection of the Republic of Armenia).

Relating to air protection the Republic of Armenia performs scientifically and legally proved actions to prevent chemical, physical, biological and other harmful influences on a state of air based on the RoA Law on "Atmospheric Air Pollution Prevention" (HO-121, adopted on 01.11.1994).

According to the Article 5 of this law, the Government of the RoA is competent to establish not only the specifications of MAC of substances polluting air and MAC of physical harmful influences, but also the procedure of development and approval of specifications of MAC of substances polluting air. These norms should meet interests of health protection of people and environment, or the estimation of the status of atmospheric air. All those influences on a state of air for which there is no corresponding specifications are forbidden. Hence, the legal framework of the system of environmental protection should take into the account the establishment of the MAC of harmful substances in accordance with their influence on environmental sustainability and human health (National Assembly of the Republic of Armenia).

Apart from administrative regulations the government also applies economic instruments to reduce air pollution. Major economic instrument for regulating environmental pollution is the system of environmental fees imposed on users of natural resources and polluters. The legal framework of the system of environmental fees for pollution and use of natural resources in Armenia is formulated by the law "On Environmental and Nature Use Fees" (Law No. 270 of 30.12.1998) and Law on "Environmental Fee Rates" (Law No 245 ratified in 27.12.2006) (National Assembly of the Republic of Armenia).

These laws and related regulations establish economic mechanisms for environmental protection, particularly air pollution prevention and control. The Law on "Environmental Fee Rates" (2006) identifies 6 major pollutants against which fees are charged, but this list is not all-inclusive: other pollutants specified by the emission permit can be taxed if their amount exceeds MAC (see article 2 of the Law) (Air Quality and Health Eastern Europe, Caucasus and Central Asia 2003).

Each polluting enterprise is required to calculate amounts of payments on their own, and pay them on a quarterly basis to the state budget in compliance with procedure established by the Law on "Environmental Fees" (2006). So it is in fact a self-assessment mechanism. After registering the report at SEI the second copy is submitted to Tax Inspectorate. Nevertheless, the overall effectiveness of the air pollution fee system is still limited due to the complexity and rigidity of the legislative system. The environmental fees are still viewed as a fiscal instrument to generate additional revenues to the state budget, rather than act as economic instruments to shift polluter's behavior. Despite the legal definition of environmental fees as having the purpose of creating revenues in order to carry out environmental measures, there are no environmental funds in Armenia.

According to the existing legal system of environment protection, each enterprise in Armenia is issued with a so called "ecological passport," which includes MAC levels for a range of pollutants. Consistent with this, the specific pollution fees, including penalties for exceeding permissible pollution limits are introduced in terms of emissions of specific pollutants on a per ton basis (Economic Commission for Europe: Environmental Performance Reviews, Armenia 2000). However, the introduction of the "ecological passport" has not addressed the issue, since the calculation of fee payments is predominantly based on self-assessment by polluters and hence depends on the accuracy of their statements. Moreover, a serious flaw in the current system of environmental fees is that fees due are always calculated

based on production volumes. Therefore, as long as the production volumes rather than not the actual level of emissions determine fee liabilities, there is no direct link between actual reductions in discharges and a reduction in due fee payments, and, therefore, no incentive to reduce pollution.

In fact, no record on violation of MAC amounts is recorded in Armenia during 2003-2007 (Reference on State of the Surface Water and Atmosphere in Localities, August 2008). The uncertainties in reporting data are abused by polluters: they take advantage of the fact that information is generally asymmetrical: polluters are better informed than victims or governments. Consequently, Armenia is still far behind to meet the PPP principle, which states that those who cause pollution should bear the costs of pollution prevention and control measures (The Polluter Pays Principle and Fisheries: the Role of Taxes and Charges 2001).

The limited resources of the environmental authorities have a major impact on the enforcement of fee payments. Overall, the data suggest that not only are pollution and product fee rates too low to induce behavioral changes, they also seem to not always have been set with a view to damage caused by specific pollutants. There is the need to establish the specifications of MAC of substances polluting atmospheric air and maximum permissible physical harmful influences based on ambient air quality standards.

In this regard, there is a need to harmonize the legislative basis of air quality assessment, which should be consistent with the international requirements and EU regulations. The mechanisms should be applied to review the number of pollutants subject to fees, increase the pollution fee rates and collection rates, providing significant incentives to reduce pollution. In order to increase collection rates of environmental fees, it is important that discretionary powers of regional and local environmental agencies implementing the fees be limited. The mentioned limitation is also essential due to the fact that the selection of effective

environmental fee parameters should be based on a determination of priority environmental problems.

Thus, for the reforms to be successful, it will be necessary to separate the incentive objective of the system from the revenue-raising one. One reason for this is that an incentive environmental fee, if it functions effectively, will lead to pollution reduction and, therefore, to lower revenues over time. Another consideration is that in order to gain political acceptance for a high rate of an incentive fee, the government often has to recycle the revenues back to industry for investments into pollution prevention and control.

The stronger role of the MNP would be desirable in designing economic instruments of environmental policy in order to ensure that they reflect environmental priorities and correspond to the existing environmental legislation. The provision of high quality information and analysis is therefore crucial to carrying out environmental policy decisions and environmental strategies.

In parallel to improving the legislation and institutional framework, the government of Armenia needs also to upgrade its standards, norms and procedures in the area of environmental information management and monitoring (Johnson 1993).

Institutional Framework for Air Pollution Prevention and Control

Policy-making and implementation should be based on realistic assessment of the current state of the environment. Exchanging data and information, inter-agency coordination and decision-making processes are important to improve the management of the environment both nationally and globally. State environmental monitoring is an important source of information and basis for execution of laws and policy making.

The institutional framework for monitoring the state of atmospheric air and determine pollution levels consists of several agencies under the umbrella of the Ministry of Nature Protection (Environmental Performance Reviews: Armenia 2000).

- Environmental Impact Monitoring Center. The functions of the Center include the monitoring, forecast, assessment and study of anthropogenic impact on the environment and its consequences for development and execution of state policy and strategies on environmental security, nature protection and permissible use of natural resources. The EIMC also provides the relevant, comprehensive information to state bodies, organizations and population (Academy for Institutional Development 2006).

- State Environmental Inspectorate. The SEI through 7 structural divisions and 11 territorial divisions ensures environmental compliance on the entire territory of the country with the purpose of protecting the environment and the rational use of natural resource. The SEI contributes to the prevention and reduction of harmful environmental impact as a result of economic activity, etc.

- Armenian State Hydrometeorological and Monitoring Service (ArmStateHydromet).

The agency currently maintains 45 meteorological stations, 3 climate observation stations, 8 hydrological stations and 96 hydrological observation points. The primary responsibilities of the agency is to support to state policy making and management in the area of hydrometeorology and environmental monitoring, ensure forecast, prevent and (or) mitigate any threat to economy or human life and property within the general context of the RA, as well as state program implementation aimed at carrying out environmental monitoring, and identifying hydrometeorological emergencies (Armenian State Hydrometeorological and Monitoring Service 2008).

- Department of Meteorology and Monitoring of Atmosphere Pollution, MNP.

The mission of the department is to project and implement the state policy of the short-term, medium-term and long-term programs in the sphere of meteorology and monitoring of atmosphere pollution. The state agency is responsible for:

- Assessment and analysis of the new legislation, as well as an amendment of existing legislation for making the monitoring systems integrated and optimized.
- Insurance of the earliest possible response to any atmosphere pollution problem occurring as a result of inefficient use of environmental resources.
- Establishment of inspections to develop mutually agreeable schedules and approaches for achieving compliance, preventing overlapping, duplication, or poor co-ordination of work. The department's mission is to clarify roles and provide sufficient authorities to bodies designated to take timely and adequate enforcement actions to prevent air pollution.
- Facilitation of public participation in decision-making and launching awareness raising campaigns in order to contribute to the prevention and reduction of atmospheric air pollution.

In fact, these monitoring agencies are supposed to properly receive and aggregate all ambient pollution related data. However, due to poorly defined mandates and reporting and accountability mechanisms, the country is still lacking an effective system monitoring. The capacity of above mentioned agencies is still poor and in fact even diminishes in spite of some recent assistance provided by international donor organizations. For example analytical capacity of SEI to determine pollutants in the air is still very weak. While in 1990 SEI had seven laboratories, between 2003 and 2006 this number reduced to three due to lack of funding (Department of Environmental Conservation. Division of Air Quality 2006). On the basis of the current monitoring system, environmental reporting does not occur with any degree of consistency. Many reporting requirements on air pollution are not met, and reports

from the cement companies are regularly repeating the outdated information. This is explained not only by the lack of financial and technical resources within the relevant ministries or organizations, but also by the lack of adequate regulatory and institutional setting to ensure that the currently discrete data are accessible to the key environmental policy making institutions at any given time (Environmental Pollution and Product Charges in Armenia 2004).

According to RA Law on "Environmental Oversight" (adopted on 22 July 2004), self-monitoring or industrial monitoring is the implementation of internal monitoring and record-taking by industrial organizations during the performance of their functions and operations, with the purpose of a timely discovery of any harmful environmental impact and abatement of its consequences (Article 4, "Basic concepts used in the Law"). Nevertheless, there is no effective system of self-monitoring for the industrial enterprises in Armenia. According Hasmik Saroyan, Head of Division of Meteorology and Monitoring of Atmosphere Pollution (MNP), the primary data collection is done by laboratories at the industrial facilities, which are not reliable and impossible to verify. She claims that since there are only 3 laboratories in the territorial divisions of SEI, a limited set of analysis is possible to conduct. The data storage and data-retrieval systems are underdeveloped. Hence, lack of technical capacity (skills, equipment, chemicals, vehicles, mobile labs) sets a limit for the development and the expansion of the monitoring network and overall improvement of the effectiveness of monitoring activities. Due to such challenges, Hasmik Saroyan states that while choosing different approaches to monitor an air quality parameter, there should be a balance between the availability of the method, its reliability, and level of confidence, costs and the environmental benefits. Concurrently, that is the responsibility of the government to gradually enhance self-monitoring and self-reporting by industrial enterprises.

Hence, an assessment of available air quality data demonstrates a lack of information on many significant air quality variables. More information is needed on short term fluctuations of NOx concentration in the air. Moreover, some data are also at the disposal of the private sector. While the government agencies have no clear mechanisms for accountability and reporting, the cement entrepreneurs often hide the data they have obtained as they consider it as their competitive advantage. It is even unclear, which organizations have the data and what the sources are. There are no formal regulatory mechanisms for interagency data and information exchange. Furthermore, the data are often not easily available even for the MNP.

It is also very important to note, that the current environmental data collection system is not based on an ecosystem approach. Hence, the present state of environmental monitoring in Armenia is still inadequate to meet the requirements of the 3 Rio Conventions, which Armenia has ratified (UNCBD and UNFCCC in 1993, UNCCD in 1997 and Kyoto in 2002). (National Consultant on Environmental Information Management 2009)

The present study analyzing the legislative basis for the assessment of the NOx emissions and investigating the data related to production activity of "Ararat-Cement" and "Mika-Cement" plants revealed that the air-monitoring information in Armenia is still not transparent ("Ararat-Cement" Company, "Mika-Cement" Company 2005). The data are mainly used for administrative purposes, and provided only to some governmental bodies in a summary form. As a general rule, the data are released only in response to an official request, and only for the indicators given in the request. Moreover, the data are not accessible for the public.

According to Ashot Harutyunyan, the Head of the Department of Economics of Nature Protection and Nature Use, another issue is insufficient funding, which does not allow the government to modernize and expand its monitoring network and improve the overall effectiveness of monitoring activities. There are no adequate financial resources allocated for

environmental monitoring, information processing and exchange, and even the limited resources allocated for this purpose are not efficiently used. He also added that the quality of monitoring and environmental impact assessment programs is low, as well as planning and operational capacity of monitoring agencies.

To make the monitoring information available, a national unified monitoring system of the air pollution should be developed. The monitoring program must be designed with the characteristics of the laboratory technology able to measure the chemicals of concern in a way that accurately reflects what is in the environment. Only the careful specifications of the purpose of the monitoring program would permit the program to be designed to serve that particular need. Consequently, the existing institutional setting and transparent self-monitoring policy needs to be reformed in order to improve the national monitoring system of the air pollution assessment.

Thus, the analysis of existing situation in Armenia revealed the weaknesses and barriers preventing an effective monitoring of substances polluting air; including fulfilling the country's international obligations.

Conclusion

> "National authorities should endeavor to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should in principle bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment."
>
> (Johnson 1993, 120)

A general conclusion that can be drawn from the evolution of Armenia's environmental system is that any substantial improvement is difficult to obtain without changing the system radically. Otherwise, to transfer the current system into one that is both environmentally and economically effective is likely to take a long time. Moreover, a reform of the system of

economic instruments of environmental policy should be linked to reforms of other environmental policy instruments, such as permitting, monitoring, and enforcement. It should be guided by a policy that provides clear and realistic environmental priorities and targets.

Since out of the total NOx emissions in 2007 the portion of NOx emission from the cement production composed 18.36%, it is apparent that growing demand and increasing volumes of production from cement plants result in expansion of NOx emissions, which affect natural and agricultural ecosystems, and human health. The analysis of the activity of the "Ararat-Cement" and "Mika-Cement" plants has shown that it is necessary for the entrepreneurs to apply the alternative technologies for the cement production, in order to reduce NOx emissions into the atmosphere. In this regard, the introduction of the process and product technologies, the organization of production and distribution, collective consumption standards, consumer norms and habits have to be adapted to the objectives of environmental sustainability.

However, based on the cost-effective analysis of applying the above mentioned alternative technologies, it is apparent that the primary challenge in addressing the issue of air NOx emissions from the cement production is the lack of incentives. As for an entrepreneur paying comparably low environmental fees is more preferable than to apply an expensive but environmentally friendly technology.

Hence, the reduction and control of NOx emissions and the application of alternative technologies to reduce the air pollution is a relatively complex issue. Some of these technologies may be quite expensive. Control over the toxic chemicals in the air is not, therefore, a matter of making a quick or easy choice among technical options. There is a need to analyze and introduce more successful pollution prevention and emission control technologies and strategies (Life Cycle-Based Air Quality Modeling for Technology Assessment and Policy Applications 2006). It is an ongoing management process, in which

both technical and managerial innovations present opportunities for improvement in a very imperfect patchwork.

While the application of the alternative technologies might mollify the negative impact of cement production on the environment, new instruments and mechanisms have to be designed and introduced to shift the polluters' environmental behavior. In view of the fact that funds for environmental investments are limited and should go into actions, no major environmental investments or activities in Armenia can in the short run be carried out without the development of the international cooperation. Hence, the broad-based international support for managing environmental awareness and developing investments programs should be given due consideration.

Armenia has to learn to develop the economic dynamic of social life, not only with scientific ecological knowledge, but also with an ethical dimension founded on ecological reasoning. Any further reform of the air pollution prevention and control system in Armenia should be based on an adequate policy response as well as timely and appropriate national decision-making process.

Policy Recommendations

Thus this paper analyzed the challenges in the legal and institutional frameworks that discourage or at least do not encourage cement manufacturers to introduce environmentally friendly technology that will allow to reduce NOx emissions into the atmosphere. The present study suggests therefore the following policy recommendations on how to implement the result-oriented strategies and effective policies to control and prevent air pollution. There are apparently two paths to be taken:

1. Introduction of more effective regulations, strengthening of compliance assurance and enforcement.

Although the environmental legislation is in place in a number of areas, Armenia still needs proper enforcement of legal provisions. It is important to strengthen the country's capacity to develop and implement environmental policies, integrate environmental policies into the economic reform process and increase the state's commitment to address the environmental issues. This should be a policy that supports the management structure in creating a system capable of identifying environmental priorities and translating those priorities into action. The main objective is to introduce more effective regulations, strengthen of compliance assurance and enforcement. The Armenian authorities designated for the compliance monitoring should not only be pre-occupied with monitoring and enforcement, but also give enough efforts to compliance promotion. In this context, the areas and mechanisms that would assure the compliance to the established standards for NOx emissions include:

- Improvement of the horizontal and vertical coordination between various regulatory agencies responsible for the oversight and control over the air pollution, mainly collaboration between the SEI and the STS;
- Development of an integrated industrial pollution control system for comprehensive air quality assessment and management;
- Provision of training for the different agencies within the MNP to ensure appropriate quality assurance and control requirements. This includes the maintenance of the monitoring system when necessary, the use of recognized quality management systems and periodic checks by an external accredited laboratory.
- Procurement of monitoring equipment, laboratory facilities and vehicles for monitoring agencies to guarantee that the measurements or estimates are reliable, comparable, consistent and auditable; improve the quality of sampling and inspection of the air polluting industries, namely cement plants

- Encourage closer collaboration between industries in Armenia and scientific community to study best available pollution abatement technologies in Armenia;
- Implementation of the air pollution prevention and control through the furtherance of the "polluter pays" principle and in line with the principles of sustainable development.

2. Improvement of economic mechanisms to shift environmental behavior of polluters.

While regulations without reliable enforcement lead to distrust and disrespect toward the laws, the economic instruments are often an effective way to change the environmental behavior of polluters and raise additional revenues that can be used to finance environmental investments. The only mechanisms for the cement entrepreneurs to apply the suggested alternative technology to reduce the NOx emissions are the economic instruments. In this regard, there is the need for:

- Introduction of the mechanisms for providing grants and loans by the government to major air polluters for introducing new equipment and technologies. The fund revenues can be based on the fees collected from polluters to finance environmental programs;
- Creation of a pollutant release and transfer register system (PRTR), which is the first legally binding international instrument on pollutant release and transfer registers (adopted in 2003, Kiev Protocol). The PRTR should contain information on releases from specific industrial sites of certain specified pollutants to air considered to cause the most significant threats to environment or health. For the PRTR be effective, it should be mandatory, annually and publicly accessible.
- Establishment of the self-monitoring programs with tax privileges to those pollutants that effectively carry out them. Strengthening monitoring and reporting is expected to bring benefits to enterprises in the form of improved environmental management and performance. These reports should provide summary information in a format facilitating easy comparison with permit limits. It is very important for the entrepreneurs to make

the independent monitoring document publicly available, thereby creating reliability towards the entrepreneurs' activity.

- Assessment of economic, fiscal, institutional and environmental feasibility of raising environmental fees to fully internalize externalities. In this regard, it is important that the actual level of emissions determine fee liabilities. The MAC of harmful substances should be established based on ambient air quality standards. The mechanisms should be applied to review the number of pollutants subject to fees, increase the pollution fee rates and collection rates, providing significant incentives for the polluting entrepreneurs to shift environmental behavior.

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APPENDIX

Table 1: The Family of NOx Compounds and Their Properties:

Formula	Name	Nitrogen Valence	Properties
N_2O	Nitrous Oxide	1	Colorless gas Water soluble
NO N_2O_2	Nitric Oxide Dinitrogen Dioxide	2	Colorless gas Slightly water soluble
N_2O_3	Dinitrogen Trioxide	3	Black Solid Water soluble, decomposes in water
NO_2 N_2O_4	Nitrogen Dioxide Dinitrogen tetroxide	4	Red-brown gas Very water soluble, decomposes in water
N_2O_5	Dinitrogen pentoxide	5	White solid Very water soluble, decomposes in water

Table 2: Growth Trends of the Cement Production in "MIKA-Cement" Plant by Years, with the Corresponding Increase of NOx Emissions.

Production years	**2004**	**2005**	**2006**	**2007**	**Planned production for 2014**
Production of cement (tons)	240,000	800,000	900,000	1,350,000	10,000,000
Amounts of klinker used (tons)	192,000	640,000	720,000	1,080,000	1,200,000
NOx emissions (tons):	17.78	59.27	66.68	100.02	740.00

Table 3: Air Emissions by Cement Factories in Armenia

	Total Air Emissions in 2007 (ton/year):	**NOx Emissions in 2007 (ton/year):**	**Maximum Permissible Air Emissions (tons)**	**Maximum Permissible NOx Emissions (tons)**
Ararat cement	1600.56	212.17	**2008:** 3840.83	**2008:** 509.35
MIKA cement	1362.40	100.02	**2003:** 2422.40 **2008:** 2483.02	**2003:** 182.7 **2008:** 182.5

Table 4: Uncontrolled NOx Emission Factors for Different Kiln Types

CEMENT KILN TYPE	**HEAT INPUT REQUIREMENT MM Btu/ton of clinker)**	**NOx EMISSION RATE (lb/ton of clinker)**	**RANGE OF NOx EMISSIONS (lb/ton of clinker)**
Long wet kiln	6.0	9.7	3.6 - 19.5
Long dry kiln	4.5	8.6	6.1 - 10.5
Preheater kiln	3.8	5.9	2.5 – 11.7
Precalciner kiln	3.3	3.4	0.9 - 7.0

Note: The table shows the uncontrolled emission factors. This table also includes the heat input requirement for the different cement kiln types which indicates a good correlation with the NO emission rates.

Table 5: Achievable NOx Reductions with Various Control Technologies

Nox CONTROL TECHNOLOGY	**ACHIEVABLE NOx EMISSIONS REDUCTION (%)**
Process Modifications	25
Stayed Combustion in Precalciner	30-45
Conversion to Direct Firing	20-30
Conversion to Indirect Firing	20-40
Mid-Kiln Firing of Tires in Long Kilns	30-70
SNCR	80-90

Table 6: Capital and Annual Cost of NOx Control Technologies applicable for "MIKA-Cement" plant

	LOW NOx BURNER		MID_KILN FIRING	
Kiln type	**Kiln Capacity (tons clinker)**	**Capital Cost (AMD)**	**Annual Costs (AMD)**	**Capital Cost (AMD)**
Long Wet	30	492,000,000	98,700,000	215,400,000
Long Wet	50	654,000,000	126,900,000	224,400,000

		SCR	
Kiln type	**Kiln Capacity (tons clinker)**	**Capital Cost (10^6 AMD)**	**Annual Costs (10^6 AMD)**
Long Wet	30	3,600	9,000
Long Wet	50	5,100	1,200

Table 7: Capital and Annual Cost of NOx Control Technologies Applicable for "Ararat-Cement" Plant

		Low NOx Burner		Mid-Kiln Firing	
Kiln type	**Kiln Capacity (tons clinker)**	**Capital Cost (AMD)**	**Annual Costs (AMD)**	**Capital Cost (AMD)**	**Annual Costs (AMD)**
Long Dry	25	381,000,000	80,100,000	212,400,000	138,300,000
Long Dry	40	492,000,000	98,700,000	218,400,000	177,900,000

		SCR	
Kiln type	**Kiln Capacity (tons clinker)**	**Capital Cost (10^6 AMD)**	**Annual Costs (10^6 AMD)**
Long Dry	25	2,700,000,000	600,000,000
Long Dry	40	3,900,000,000	900,000,000

Table 8: Cost Effectiveness of NOx Control Technologies for "MIKA-Cement" Plant

		Low NOx Burner		Mid-Kiln Firing	
Kiln type	**Kiln Capacity (tons clinker)**	**NOx Removed (Tons/Yr)**	**Cost-Effectiveness (AMD/Tons NOx Removed)**	**NOx Removed (Tons/Yr)**	**Cost-Effectiveness (AMD/Tons NOx Removed)**
Long Wet	30	290	340,344	290	567,931
Long Wet	50	480	264,345	480	485,625

		SCR	
Kiln type	**Kiln Capacity (tons clinker/HR)**	**NOx Removed (Tons/Yr)**	**Cost-Effectiveness (AMD/Ton NOx Removed)**
Long Wet	30	930	9,677,419
Long Wet	50	17.4	68,965,517

Table 9: Cost Effectiveness of NOx Control Technologies for "Ararat-Cement" Plant

		Low NOx Burner		Mid-Kiln Firing	
Kiln type	**Kiln Capacity (tons clinker)**	**NOx Removed (Tons/Yr)**	**Cost-Effectiveness (AMD/Tons NOx Removed)**	**NOx Removed (Tons/Yr)**	**Cost-Effectiveness (AMD/Tons NOx Removed)**
Long Dry	25	210	381,428	210	658,571
Long Dry	40	340	290,294	340	523,235

		SCR	
Kiln type	**Kiln Capacity (tons clinker/HR)**	**NOx Removed (Tons/Yr)**	**Cost-Effectiveness (AMD/Ton NOx Removed)**
Long Dry	25	9.87	60,790,273
Long Dry	40	13.1	68,702,290