A thesis submitted to the Department of Environmental Sciences and Policy of Central European University in part fulfilment of the Degree of Master of Science

ENVIRONMENTAL QUALITY MONITORING, DATA DISSEMINATION AND USE: CASE STUDY ON ALAVERDI TOWN, ARMENIA

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No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:
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This thesis discusses the current statues of established water and air quality monitoring systems in Armenia. It also aims to analyse the issues related to monitoring data quality, data dissemination and interpretation, as well as it attempts to reveal the current situation of monitoring data utilization in environmental policy and decision-making process in the country. For this purpose, the case of Alaverdi town has been discussed as the most polluted town in Armenia.

The research is based on monitoring information collection, review of existing legal framework. It is also supported by the interviews conducted with the professionals involved in monitoring data collection and in policy making.

The research shows that there is a certain developed surface water quality monitoring in the country with extensively designed monitoring network, technical capabilities to measure a wide range of chemical and physical indicators and well-developed water quality classification system.

The case study on Alaverdi city shows that current atmospheric quality monitoring still remains information poor and monitoring data use is limited in the country.

Keywords: Armenia, monitoring, water quality, air quality, Alaverdi

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List of Abbreviations

AL	Armenian Law
ACP	Armenian Copper Program
ENPI	European Neighbourhood Partnership Instrument
EIA	European Environment Agency
MPC	Maximum Permissible Concentration

Introduction

As a former Soviet Union Republic, Armenia had an extensive monitoring system which was collecting a significant amount of information on the state of the environment. However, the common feature of the former monitoring system was that the environmental information was not accessible to public and other researchers and was kept only on the state level. Besides, collected information was hardly used in environmental policy and decision making (UNECE 2003).

The collapse of Soviet Union and followed severe economic crisis and other factors (the Nagorno-Karabakh War) significantly destroyed the country's environmental quality monitoring system; whereas as a country in economic transition, environmental quality monitoring is an essential tool for environmental policy and decision making.

However, over the last two decade, the reforms have been started taking place in order to improve environmental monitoring management in the country. The reforms have compassed from methodological and technical upgrading of existed monitoring system to policy and legal changes in the country by harmonizing them with EU standards (EEA 2011).

Considering the above-mentioned issues in the monitoring system, this study aims to answer the following questions:

- What is the present status of the environmental quality monitoring system in Armenia?
- How is the monitoring data disseminated?
- Is monitoring information used by various parties?

Literature review

Monitoring description

Environmental monitoring provides knowledge about how the environment changes through repeatable field-based measurements of chemical, physical and biological variables over the time (Lindenmayer *et al.* 2010). It is a fundamental component of environmental management, policy, and decision-making process due to the information collected and knowledge framed that are essential for assessing success or failures of implemented science-based policy or management activities (Biber 2013).

Lindenmayer *et al.* (2010) classify long-term monitoring into three groups which are curiosity-driven or passive monitoring, mandated monitoring and question-driven monitoring programs. Curiosity-driven or passive monitoring usually is not guided by research questions and provides limited information about environmental problems. Mandated monitoring is conducted according to governmental legislations and basically, it studies the trends of change of environmental conditions. Question driven monitoring is based on the "conceptual models" and "rigorous study design". In contrast to mandated monitoring, question driven monitorings usually have small scales and focus on the processes which can cause changes in environmental conditions (Lindenmayer *et al.* 2010).

If in the past, environmental monitoring was considered as a management activity, nowadays long-term monitoring is considered to be both science and research with clear defined research questions, (Hellawell 1991; Lovett *et al.* 2007). Monitoring data can be used in various scientific applications. In particular, long-term monitoring data can help to design short-term experiments and observations. The monitoring information on average and maximum concentrations of atmospheric ozone is necessary for experimenting its impacts on plants.

Nowadays, monitoring data are highly used in testing and developing atmospheric models (Lovett *et al.* 2007).

However, conducting effective monitoring projects and obtaining good quality monitoring data which can have a contribution to environmental science, policy and management can be challenging.

Successful monitoring programs

Good environmental monitoring consists of many stages (figure 1). First, as a science, the good monitoring should have well-defined research questions which should be able to address future environmental problems. This can be achieved if the monitoring projects are guided by strong understanding and foresight of the environmental system (Lovett *et al.* 2007).

Besides research question, a number of other factors have been identified that can effect on monitoring program effectiveness or even completely fail it. The most important drawbacks have been highlighted by several authors:

- Inadequate design, planning or unfocused monitoring (Bernhardt *et al.* 2005, Lindenmayer *et al.* 2009).
- Measurements of irrelevant indicators (Lindenmayer *et al.* 2009).
- Poor dissemination of monitoring data (Bernhardt *et al.* 2005).
- Lack of financial resources devoted to monitoring data management and quality control (Caughlan *et al.*. 2001).
- Monitoring without enrolment of science and scientific personals (Franklin *et al.* 1999).

The design of monitoring program includes selection of indicators, frequency and scale of measurements, statistical design of the project, sampling and measurement methods identification, analyzing and interpreting collected data, as well. All the mentioned components of monitoring program require a scientific approach which would ensure the collection of high-quality monitoring data (Franklin *et al.* 1999).

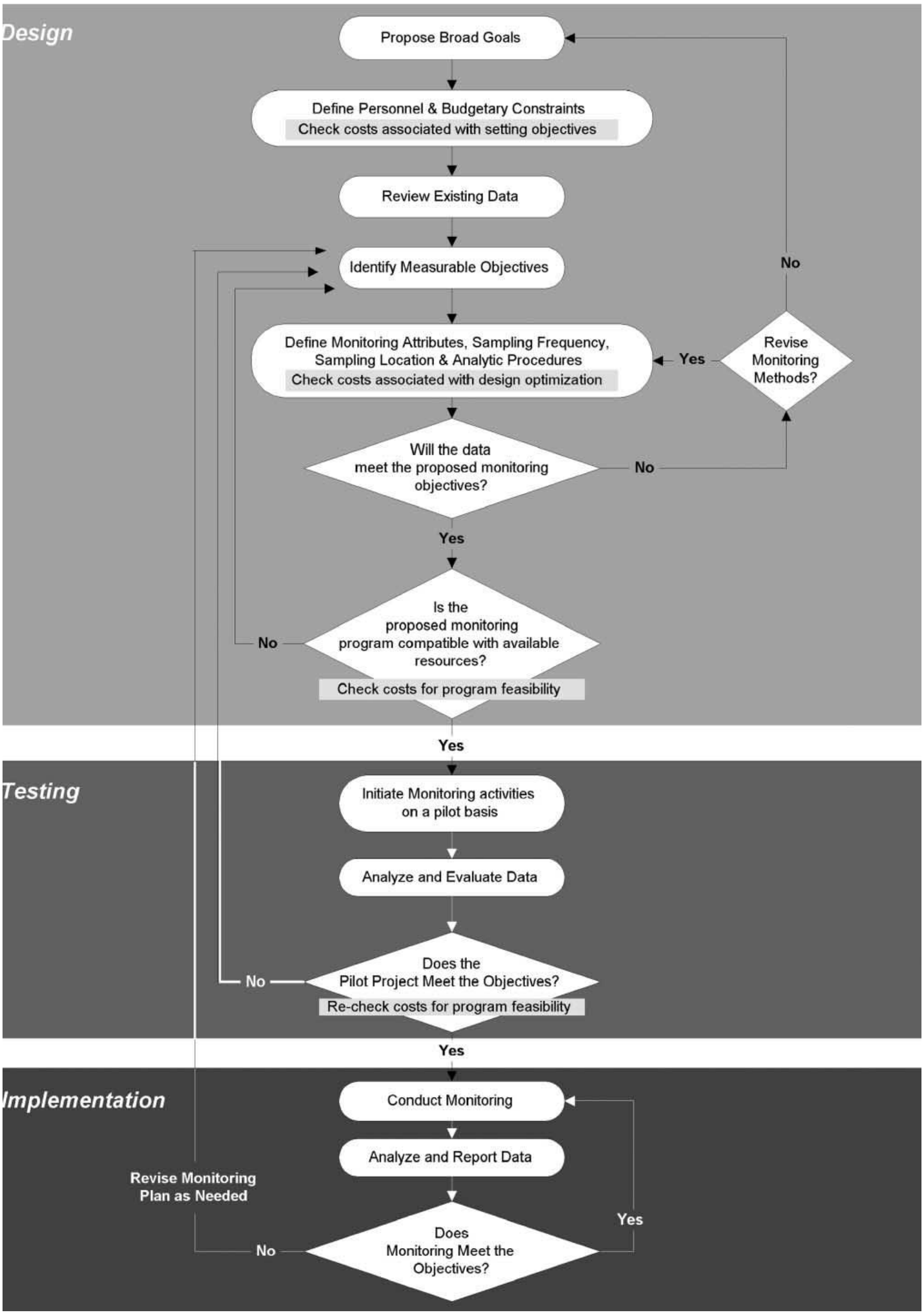


Figure 1. The conceptual diagram of development of monitoring process. Source (Caughlan *et al.* 2001).

However, science alone is not enough and monitoring information should be converted into a format which is understandable to managers and decision makers (King *et al.*. 2004). A Scientific approach to collect and analyze data is different from the politics that uses that information for decision making. This gap in "science-policy value" can be bridged by collaboration between the scientists and policy makers with certain defined roles (Engel-Cox *et. Al*. 2005).

Price (1965) defines the process of effective policy making as an interaction between different actors, such as scientists, leaders, administrators, and politicians. The role of scientists should be the interpretation of the results to other participants but they should not propose policy decisions (Steel *et al.*. 2004).

Engel-Cox et. Al (2005) have developed "data compact model" to describe the interactions between scientists and policy makers (figure 2). Initially, the model was developed to derive remote sensing information use in science and translation it into a policy. However, the model can be also used in other applications.

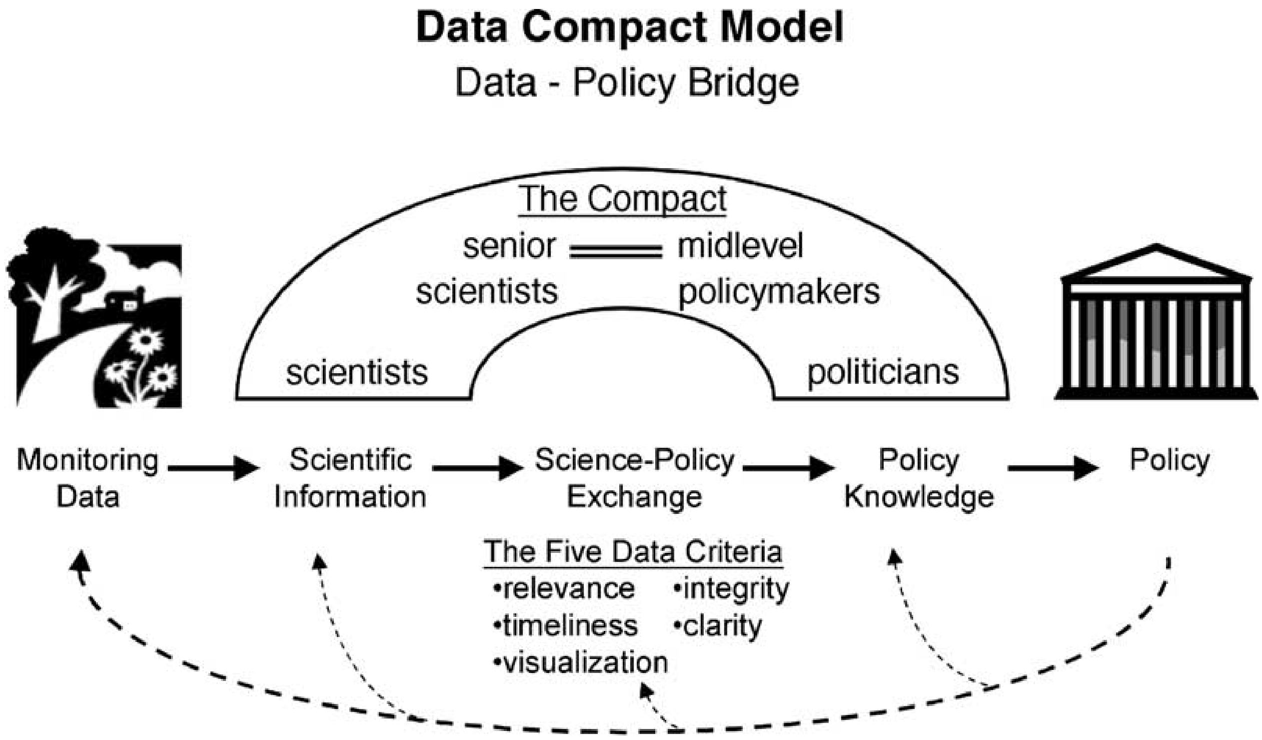


Figure 2. Conceptual representation of data compact model (Engel-Cox *et. al* 2005).

According to the model (figure 2), at the edge of the model are scientists, and in the middle of the model, senior scientist, and midlevel policymakers act. After framing scientific information from monitoring data, the information is translated by senior scientist to midlevel policymaker who later converts the information into policy-relevant knowledge. The information can be relevant for policy use, if it provides relevance, timeliness, visualization, integrity, and clarity.

Selection of the parameters

One of the challenges in environmental monitoring is to determine the range of indicators or parameters which can describe the change of ecological conditions. Moreover, measurement of some parameters can be challenging. Therefore, there can be cases when the collection of some parameters can be considered as impractical (Franklin *et al.* 1999).

On the other hand, there are monitoring programs that measure a wide range of indicators. The large list of indicators can have both disadvantages and advantages. One of the consequences can be related to the fewer efforts to define tractable and critical monitoring questions. Next, more time and financial resources are required for the wide range of indicators measurements which can directly impact on the collected monitoring data quality. On the other hand, it is also believed that wide list of indicators can be very useful as a startup for the project (Lindenmayer *et al.*. 2010).

The development of conceptual ecosystem model is highly encouraged to narrow down the range of the variables to be measured. Models will help to understand the behavior of the ecosystem which would allow to make predictions on condition changes and identify the list of indicators to be measured on the long-term basis (Lindenmayer *et al.* 2010).

Next stage of monitoring project is to determine the frequency of the measurements. Some ecosystems would require continuous or regular measurements (streamflow) while others (landslides and river channel changes) are examined on the event basis (Franklin *et al.* 1999).

After collection of monitoring information analysis and interpretation are following. Many programs tend to focus only on assessing the magnitude of ecological change. However, not only the degree of the ecological condition change is essential but also interpretations should provide comprehensive answers about the consequences, dynamic of the change and the rate of ecological reduction, as well (Franklin *et al.* 1999).

Ecological knowledge is framed after comprehensive interpretation of the collected monitoring information. Finally, monitoring data and knowledge should be available to all the interested parties in a timely and comprehensive basis. Nowadays existing modern technologies and modern society have made information accessible (Franklin *et al.* 1999).

The success of long-term monitoring program is determined by its progress to achieve set-up objectives. Indeed, each stage of monitoring program has its own cost which is likely to guide the pursuing goals. The information collected should justify the cost of resources spent on the project. On the other hand, the lack of financial resources would always pose limitations on the effectiveness of the monitoring project. Therefore, Caughlan *et al.* (2001) state that the final design of the project, including the selection of monitoring indicators and data collection and management, would always be impacted by the budget.

However, there is no clear answer what should be done in order to make monitoring program successful. Obviously, institutional and personal commitments are one thing that can promote to the success of monitoring programs. Particularly, the managers of monitoring program should ensure monitoring methods accessibility, data quality and program cost-effectiveness while policy makers, government and other financing agencies should have a commitment to the maintenance of long-term monitoring program and provide appropriate funding (Lovett *et al.* 2007).

The concept of adaptive monitoring has been proposed by Lindenmayer *et al.* (2009) which is believed to improve the quality of long-term monitoring data collection. The approach is based on the clear defined objectives and questions driving monitoring programs.

Therefore, similar to adaptive management practices, the adaptive approach which ensures interpretation and modification of monitoring plans should be conducted on the continuous basis and considered as an essential attribute to successful environmental monitoring practices (Franklin *et al.* 1999). For example, the approach can include changes in the frequency of measured variables, new research question formulation if the initial ones have been answered or using new state-of-art technologies and methods which can enhance the quality of collected environmental information (Lindenmayer *et al.* 2009).

However, if the existing literature highlights the need for science to design and implement effective monitoring program, EU water and air quality directives provides guidelines for the monitoring of each state of the environment. One of the advantages of such united approach of guided monitoring is that the information collection on the local regional or international level is harmonized.

Another important component of the successful monitoring program is a collaboration between people with different background, such as people from governmental and non-governmental organizations, research institutions and other organizations. The collaboration among various actors provide implementation of policy and management relevant monitoring projects with adequate data compliance. This partnership becomes successful among different parties when there is an environmental problem and people have shared responsibilities to propose solutions (Lindenmayer *et al.* 2010).

Besides the partnership, the success of monitoring project strongly depends on the leadership (Lovett *et al.* 2007; Strayer *et al.* 1986). Leadership is defined to have a vital role in all the stages of monitoring project that are discussed earlier: crafting questions and addressing new questions, developing tractable conceptual model, selecting parameters to be measured, analyzing and interpreting collected data, communicating the data to policy and decision makers, natural resources managers, scientists and other interested people (Lindenmayer *et al.* 2010).

The use of monitoring data

Several authors have highlighted the need for monitoring data in :

- Policy, decision-making and environmental legislation evaluation (Cowan 1993)
- Environmental baseline condition study (Keelings *et al.*.1995,1996)
- Development of ecological theory, computer simulation and modeling (Burgmen *et al.*. 1993)
- Scientific use and tracking new research question (Stelzer *et al.* 2006)

Among the different users of environmental monitoring data, environmental policy and decision making are most linked to environmental data, such as water quality, air quality, hazardous chemical contamination and etc. (Engel-Cox *et al.* 2005). Although being a fundamental element for policy and decision making, environmental monitoring information can also pose some risks to political decision making.

The lack of useful information can be desirable for policy makers because it would require extra efforts for additional environmental regulations. Besides, we should consider two outcomes of environmental decision makings. They can be beneficial for some parties, usually public or have negative impacts for those who pay for environmental protection or technological advancement (Biber 2013).

Research Methodology

This thesis presents qualitative research which is based on the literature review and interviews. The review of the literature has carried out for published and unpublished materials, legal documents, governmental decrees and the websites of representative institutions.

The interviewees have been chosen from the ministry representatives, governmental and non-governmental organizations, as well as independent experts with whom semi-structured and open-ended interviews have been held. The list of interviewed people is included in the appendix 1.

Chapter 1

Monitoring Institutions and Infrastructure

Monitoring Infrastructure

This chapter provides a review of currently established monitoring infrastructure in the country by providing their activities framework that is implemented in the field of environmental quality monitoring. In additions to state institutions, the chapter discusses academic institutions which carry out environmental research in the country.

Government Organizations

Armenian State Hydro-Meteorological and Monitoring Service (ASHMS)

ASHMS under the Ministry of Emergency Situation is the only organization in the country carrying out surface water quantity, weather, climate, ozone layer and observations and other hydro-meteorological monitoring and services in the country. Currently, water quantity monitoring network consists of 94 observation posts covering 7 river basins and 4 lakes and reservoirs in the country. The hydrological monitoring is conducted for the following parameters: water level, flow, water temperature, air temperature, and precipitation. Measurements are conducted twice a day. About 30 observations are conducted annually for river basin discharge at each observation posts.

44 meteorological posts are in operation in the country. Three stations (Yerevan, Sevan and Amasia) are included in the global atmospheric watch network and 16 stations are included in

the regional meteorological network. Meteorological observations are conducted 8 times a day.

The data are checked, processed and held in the united hydro-meteorological data bank and kept by the state fund. The data are also summarized in monthly reports and annual reference books. However, the organization does not have an electronic website. Therefore, the data on hydrometeorology are not available online. Moreover, according to the current policy of Ministry of Emergency Situation, the access to primary hydro-meteorological data is not free of charge.

Since the country independence, hydro-meteorological monitoring system has not been upgraded excluding participation in the projects between 2006-2008. The state financing is only sufficient for maintaining currently established service in the country. Meanwhile, the studies by the World Bank have shown that every unit of investment on technical modernization and development of the hydro-meteorological monitoring system would provide 12 units of economic efficiency in the country.

State Environmental Inspectorate (SEI)

The SEI under the Ministry of Nature Protection is responsible for supervising the implementation of norms and standards prescribed by the law in the field of environmental and natural resources protection. In the scope of environmental quality monitoring, the ASI is responsible for the inspection of the sets of permitted emission standards, as well as for carrying out the measurements of emitted atmospheric air pollutants.

As concerns water quality, the ASI monitors the quantity and the quality of harmful substances in wastewater. The control analysis of samples is conducted by the centralized laboratory of SEI which is not technically equipped enough to conduct periodically observations. For instance, the inspection and analysis of prioritized sources are conducted once a year while non-prioritized sources are observed on less frequency basis. Therefore, the monitoring of wastewater discharges is still considered to be weak and inadequate in the country (Yu *et al.* 2014).

Environmental Impact Monitoring Center (EIMC)

The EIMC under the Ministry of Nature Protection is state-none-commercial organization (SNCO) in charge of environmental pollution monitoring, evaluation and prediction programs in the country. Currently, the quality monitoring is conducted for surface water, atmospheric air and precipitation and partially for soil in the background city of Tsakhadzor. Besides the state monitoring and evaluation program, the center is participating in international and regional joint monitoring and information exchange projects. In particular, on a continuous basis the center is conducting joint Iranian-Armenian monitoring of the transboundary Ara(q)s River Basin in the country. Since 2008, the center has been taking part in European Monitoring and Evaluation Program (EMEP) under the convention of long-range transboundary of air pollutants.

The EIMC has been reorganized from the Hydro-meteorological department since 2003 according to the government decree of N 199 (2002) on the reforms of the state system of the Ministry of Nature Protection in Armenia. The central laboratory of the institution is located in the capital city of Yerevan and one regional laboratory exists in Vanadzor city. The central laboratory is carrying out total environmental quality monitoring programs of the country while the regional laboratory of Vandzor is responsible only for air quality observations and samples analysis of the cities of Vanadzor, Gyumri and Alaverdi.

After 1992, environmental quality monitoring was drastically decreased. The improvements have been started taking place since 2004 due to the state finance increase which was improved from 13 million Armenian drams (AMD) (US$ 32,000) in 2004 to 70 million drams (US$ 170,000) in 2013. In addition to financing, the laboratory did receive the state-of-art equipment by the donor organization, such as USAID and EU (Yu *et al*. 2014).

State Health Inspectorate

The SHI is SNCO under the Ministry of Healthcare in the country which was merged from the State Hygiene and Anti-Epidemiological Inspectorate of the Ministry of Health and the State Labor Inspectorate of the Ministry of Labor and Social Security in 2013. The sub-divisions of SHI are providing sanitary and hygienic safety control in the health care field. Particularly, the Reference Laboratory Center (RLC) is responsible for monitoring drinking water quality in the country. Additionally, according to laboratory activities framework, it should implement toxicological examinations on the state of the environment including determination of the trace constitutes of chemical substances in the ambient environment (soil, water, air).

State Hydrogeological Monitoring Center (SHMC)

The SHGMC is SNCO under the Ministry of Nature Protection aims to implement the quality and quantity monitoring of groundwater resources, as well as underground regime observations and exploration of insufficient underground water information in the country.

After 1993 the groundwater monitoring was also closed. The SHGMC was established in 2006 according to the government decree of number 1616N September 8th, 2005. Since the establishment, with the assistance of the United States Agency for International Development (USAID), monitoring network with 73 reference points has been developed which includes 49 natural springs, 22 borehole wells and 2 groundwater wells that cover 6 water basins of the country. The observations are conducted for the following parameters: water level, discharge and temperature. However, the collected data series and established monitoring network are estimated to be insufficient for investigating trends of various aquifers (Yu *et al.* 2014). The development and extension of the monitoring network and measured parameters can only be implemented in case of adequate financing.

As concerns water quality observations, the SHGMC does not have its own laboratory and the quality of groundwater samples are determined by the EIMC or by the Geological Laboratory (the Ministry of Energy). Moreover, the measured parameters only provide the basic information about the groundwater origin and incomplete picture of pollution without persistent organic pollutants constitutes.

Collected data are summarized in annual reports and are presented to the Ministry of Nature Protection. The data are not published or accessible online.

Scientific organizations

Center for Ecological Noosphere (CEN)

The center was found in 1993 and carries out a research in the field of ecology and environmental protection. Particularly, their studies are oriented to integrated assessments on terrestrial ecosystem and development of scientific-methodological based expertise and natural resources management optimization in the country. The center has problem-oriented laboratories and is technically equipped enough to conduct laboratory investigations using art-of-the-state methods, such as atomic-absorption, mass-spectrometric, gas-chromatographic, X-ray - fluorescent, spectro-photometric, radiometric, colorimetric, chemical and etc.

Institute of Hydroecology and Ichthyology, Scientific Center of Zoology and Hydroecology

The Institute of Hydrology and Itchyology was established as the fishery station of Sevan Lake in 1923. Since that time, the institute carries out hydro-ecological research of the lakes and reservoirs of the country. The institute has three scientific oriented departments of hydroecology, hydrobiology and ichthyology.

The institute is highly involved in the research on the Lake Sevan ecological problems. The institutes with the cooperation of EIMC is conducting the monitoring program of Savan Lake in the country. In the scope of cooperative monitoring, the Institute determines hydrophysical, hydrochemical and hydrobiological indicators while the EIMC is analyzing the chemical constitutes in Savan Lake's samples. The study findings are published in the form of articles and are reported to NAS RA (EEA 2015).

Center for Responsible Mining (AUA CRM)

Another research center currently contributing in the country's environmental information collection is the American University of Armenia Center for Responsible Mining. The center aims to advocate "socially, environmentally and economically responsible" mining practices in the country.

Through crowdfunding campaign and donor organization (OSCE), the CRM was able to equip its newly established laboratory with portable and stationary instruments which can be used to measure heavy metals constitutes in soil, water and blood samples. Recently, the CRM has reported its results on heavy metals constitutes in soil and drinking water samples taken from Kindergartens and Schools of Ararat City, Ararat Marz, Republic of Armenia (AUA 2016).

Chapter 2

Environmental Quality Monitoring

Water Quality Monitoring

Water quality monitoring has experienced dramatic changes during the last two decades. After 1992, surface water quality monitoring decreased drastically in the country. For instance, the total number of water samples taken in 1998 was 55 and 275 in 2004. The improvements in water quality monitoring system started taking place from 2003-2004. Between this period the surface water monitoring was conducted from 79-82 sampling points. Rehabilitation of monitoring system took place because of an increase in the state budget and getting the state-of-art equipment which was donated from the international organizations.

Current water quality monitoring network consists of 131 sampling points (appendix 2). This network includes 50 streams and rivers, 6 reservoirs and Lake Sevan. The sampling of water bodies is conducted usually once in a month or in some cases 7 times annually.

Technical Facilities

The facilities of EIMC central laboratory have been advanced after the donation of modern equipment by international organizations (EMEP, EU, USAID). Currently, the laboratory has advanced instruments which give an opportunity to carry out qualitative and quantitative analysis of chemical and physical variables in water samples. The equipment have been donated by international donor organizations.

- Induction coupled plasma mass spectrometer (ICP-MS) (Elan 9000) - capable to analyze 30 metals in water solution.

- Ion Chromatographic System (Dionex ICS 1000)- capable to analyze basic cations and anions constitutes in water solution.

- UV Spectrophotometers (Shimadzu UV 1650, Specord 205).

- Gas Chromatographic Systems (Perkin Elmer Clarus 400, Agilent Technologies 7890A and Varian 450) capable to analyse chloro-organic pesticides, petroleum hydrocarbon products.

- Total Organic Carbon Analyzer (TOC) (Vario TOC cube by Elementar)- capable to determine organically and inorganically bound carbon.

- Portable field measurement devices (YSI 556 և WTW 340i)

- Microscopes

Water quality indicators

Water sampling, field and laboratory analysis are mostly conducted according to ISO standards. In total, 65 parameters are determined which include hydro-chemical variables, heavy metals, chloro-organic compounds and etc. .

Although the center has facilities to conduct biological monitoring of surface water and bottom sediments, as it was mentioned before, at the moment biological monitoring component is missing from mandatory monitoring program in the country. According to deputy head on scientific matters (Ms. G. Shahnazaryan pers. comm.), biological monitoring of surface water has not approved by the government as a mandatory monitoring program because of the absence of adequate financing.

Data accuracy and reliability

Water quality monitoring data (sensitivity, accuracy and precision) has been significantly improved during the recent years as experts state (S. Minasyan and G. Shahnazaryan, pers. comm.), due to the use of modern equipment facilities, applied analytical methodologies and competent laboratory personal, as well.

At the moment, the central laboratory of EIMC does not have international or national accreditation. There is only a formal procedure of instrument testing by the National Institute of Metrology. However, the data accuracy and precision are provided by maintaining quality assurance practices developed by the center which includes regular calibration of analytical methods and their verification by quality control charts.

For verification and validation of water quality measurements, the laboratory actively participates in annual international inter-laboratory calibration process organized by national water Laboratory in Slovak.

Air Quality and Precipitation Monitoring

As water quality monitoring, air quality monitoring has also collapsed after 1992 in the country. Some air quality monitoring stations were closed in the 90's and monitoring was conducted in only four cities (Yerevan, Vanadzor, Alaversi and Ararat) in 1997-1998 for 11 parameters (Tonoyan 2011, UNECE 2004).

Currently, ten settlements (Yerevan, Gyumri, Vanadzor, Alaverdi, Ararat, Tsaghkadzor, Kapan, Qajaran, Hrazdan, Martuni,) are included in the air quality monitoring program (appendix 2). These cities are either largest or industrial cities. As a background town, monitoring works are also carried out in Tsaghakdzor town.

Ambient air quality monitoring network called “hybrid” is monitored by using three different sampling techniques: passive diffusive, active and automated analyzers. As passive sampling methods which is considered to be a cost effective air quality monitoring technics is used to scan nitrogen and sulfur dioxide constitutes in all the monitored settlements in the country. Current passive monitoring network consists of more than 250 sampling points in the country. The samples are exposed in weekly basis and provide pollutants weekly average concentrations.

Next, 24-hour active sampling is carrred out in stationary stations in the country. Currently, there are 17 stationary stations in operation, out of 7 are located in the capital city of Yerevan, 3 stations in Alaverdi and Vanadzor cities, and 1 station in Ararat, Tsahjkadzor, Hrazdan and Gyumri. 5 stationary stations (4 stations in Yerevan and 1 station in Alaverdi) also have automated monitoring instruments which are used to determine hourly concentrations of 4 pollutants (nitrogen oxides, carbon monoxide and sulfur dioxide).

Since 2008, under the convention of long-range transmission of air pollutants, air quality observations have been carried out in Amberd station in Armenia. The station is a regional station located at 2070 m above sea level on the slopes of Mount Aragats which is a representative site for such kind of monitoring work. Construction of the station including sampling and laboratory facilities used in the monitoring work was donated within the scope of EMEP.

Technical Facilities

The air quality monitoring system has experienced little improvement science the collapse. Although during the recent years, the number of monitoring stations have been increased and monitoring works have been supplemented by cost-effective passive sampling techniques, current existing sampling and analytical measurements capabilities does not allow to determine a wide range of list of air quality indicators. Besides, due to the outdated system, collected monitoring data quality remains poor.

Only the EMEP observatory in the country is armed by the latest instruments to conduct and provide the information on long range transmission of air pollutants.

Air quality indicators measured

In general, six main pollutants, such as sulphur dioxide, nitrogen oxides, carbon monoxide, ozone and total dust are determined in ambient air. However, these number of measurements varies for each above listed settlements in the country. Only air quality in the capital city of Yerevan is monitored for six pollutants. In majority of settlements, air quality observations are conducted for 3 air pollutants (nitrogen and sulphur dioxides, total dust).

In the EMEP station, the following compounds are determined: nitrogen and sulfur dioxide, ammonia, ozone and basic inorganic cation and anion constitutes of aerosols. Besides atmospheric pollutants, precipitation quality monitoring is also carried out at the Amberd site for major inorganic compounds, pH and conductivity. In the recent years, precipitation observations are carried out also in the background site of Tsaghkadzor.

Data accuracy and reliability

The quality of air monitoring data depends on sampling and analytical methodologies. This methods (sampling and analytical measurements methodologies) have been developed from the “GOST”s (state of standards of Soviet Union) and some ISO standards. However, according to the head of air quality division, despite all the efforts the quality of the data still remains poor because of the sampling technique (gas meters, air sampling pumps) and analytical methodologies which are mostly not appropriate to international standards. Therefore, the accuracy of the data is highly effected by technical factors. The data received by continues monitors are also questionable since the instruments are not calibrated because of financial and technical issues.

In the framework of operation of regional Amberd station, annual inter-comparison studies are conducted under the scope of EMEP program and Global, Atmosphere Watch.

Chapter 3

Case study on Alaverdi Town

Background

Alaverdi is considered to be the most polluted town in Armenia. The city is located in the north-eastern part of the Lory Province of Armenia and represents one of the largest industrial regions. Due to the industrial and mining activities carried out in the city, a number of hazardous substances are emitted into the atmosphere posing a risk not only to the surrounding ecosystem but also to people’s health.

Moreover, the complex topography of the city with full of mountain ridges and the gorge of the Debed River promote to this emission acceleration in the city (figure 3) (Nazaryan 2009).

Figure 3. The topography of Alaverdi. Source: Google Earth Program, 2016.

Environmental issues facing the city by the size and character can have serious ecological consequences not only for Armenian ecosystem but also for the South Caucasus region due to the transboundary Debed River passing though the city and the forests ecosystem which spread to the neighboring Georgia and Azerbejian (Nazaryan 2009).

Climate

The city is characterized by mild winters and hot and humid summers. The relative humidity is rarely below 60 %. The highest temperature recorded is within the range of +30 ÷ +35 ^{o}C and the lowest temperature records are between -17 ÷-18 ^{o}C. The annual precipitation is about 500-600 mm (Nazaryan 2009).

Industrial and mining activity

Copper mining is dating back to 18th century when copper smelter was built by Greeks in the city. Mining and industrial activates in the city have been started science the 1960's. In 1988-1989, the copper smelter plant was closed due to the earthquake and economic crisis in the country. Since 1997 the plant has been operated by "Manes and Vallex" cjsc which was renamed to "Armenian Copper Program" (ACP) in 2002. According to the GEO Alaverdi report (2009), 75 percent of the population is employed by the mining industry in the city.

Environmental Issues

Emissions by ACP are summarized in table 1. As we can see, number one issue in the city of Alaverdi is emissions of sulfur dioxide into the atmosphere by copper smelter plant. Metal ores have sulfide or other formation and copper smelting by ACP is conducted without any emission catchment mechanism.

Table 1. Emission by ACP Company (ENPI Project 2014).

Name of emitted substance	Emissions, tonnes/year	Daily MAC, mg/m^3
Sulfur dioxide	28166.6	0.05
Inorganic dust	115.3	0.15
Lead	6.1	0.0003
Zinc	9	0.05
Arsenium	6.1	0.003
Copper	11.9	0.002

The city is also facing heavy metal pollution issues, as it is highlighted by several authors. For instance, the pilot environmental study conducted in Alaverdi and in two other mining cities (Aghtala nad Shamlugh) of the Lori province in 2004 has revealed high lead concentrations in residential soil and dust samples. In particular, the samples taken from the closest sites of the smelter plant did contain higher level of lead concentrations (Petrosyan *et al.* 2004). According to the same study findings, lead concentrations in interior dust samples were exceeding the US Environmental Protection Agency standards on interior lead content.

Besides lead contamination, there was the evidence of contamination by other heavy metals in the city. In particular, arsenic concentrations similar to lead showed significant correlation with the geographical proximity of emission source in the city (Akopyan *et al.* 2015; Petrosyan *et al.* 2004).

Moreover, the climate of the city was estimated to impact on resuspension and dispersion of contaminated soil-dust into the atmosphere, thus creating a favorable conditions for human exposure (Kurkjian *et al*. 2002). For instance, the first comparative blood lead level (BLL) study which selected children (4-6 years old) both living in polluted (Alaverdi and Akhtala) and less polluted cities (Yerevan) suggested that the children living in the polluted environment of Alaverdi and Akhtala had equal BLL which is significantly higher than the

BLL detected among the children living in less polluted city of Yerevan (Petrosyan *et al.* 2014).

It is worth to mention that the studies on lead and other heavy metals were conducted, in 2002-2004 when the smelter plant was in operation at about 30 % of its capacity (Petrosyan *et al.* 2004). Considering this fact, it is likely that current contamination in the city of Alaverdi is much severe, as no research on heavy metal contamination levels has been carried out since that time.

Temporary solution of environmental problems

Among several environmental solutions to reduce emissions of harmful substances into the atmosphere, the APC Company has decided to build a new chimney which provides emissions removal from the higher position. Currently emissions removal takes place from the absolute height of 1078 m which is about 218 m above the see level compared to the old chimney (Armenpress 2011). It was expected that the new chimney would reduce gases concentration by 10 times in the city due to the effectiveness of emission dispersion into the atmosphere (Azaturtyun 2011). The chimney was built in 2011 and the total cost of related environmental measures was accounted to be 2 million US dollars.

Analysis of current air quality monitoring in the city

Current ambient air quality monitoring is conducted in Alaverdi town and in its neighboring 8 communities (Odzun, Haghpat, Akori, Hagvi, Madan, Akner, Kachachkut and Sanahin). In the neighboring communities, ambient air quality observations have been started since 2013 in order to estimate pollutants dispersion effect from the new built chimney of the copper smelter plant in the town. Table 2 presents the characteristics of air quality monitoring program in the city.

Table 2, The summary of air quality monitoring methods, parameters and frequency of measurements in Alaverdi and its neighboring communities.

Name	Sampling methods	Number of stationary stations	Parameters Measured	Measurements Frequency
Alaverdi	passive	18	nitrogen dioxide, sulfur dioxide	weekly
	active	3	nitrogen dioxide, sulfur dioxide, total dust	daily
	automatic	1	carbon monoxide, nitrogen oxides	hourly
Communities	passive	20	nitrogen dioxide, sulfur dioxide	weekly

In total, atmospheric concentrations of five pollutants are monitored in the city of Alaverdy and two pollutants in the affected communities. Thus, current monitoring program does not monitor lead and provide information about heavy metal contents in Alaverdi's environment despite the issue highlighted by several authors.

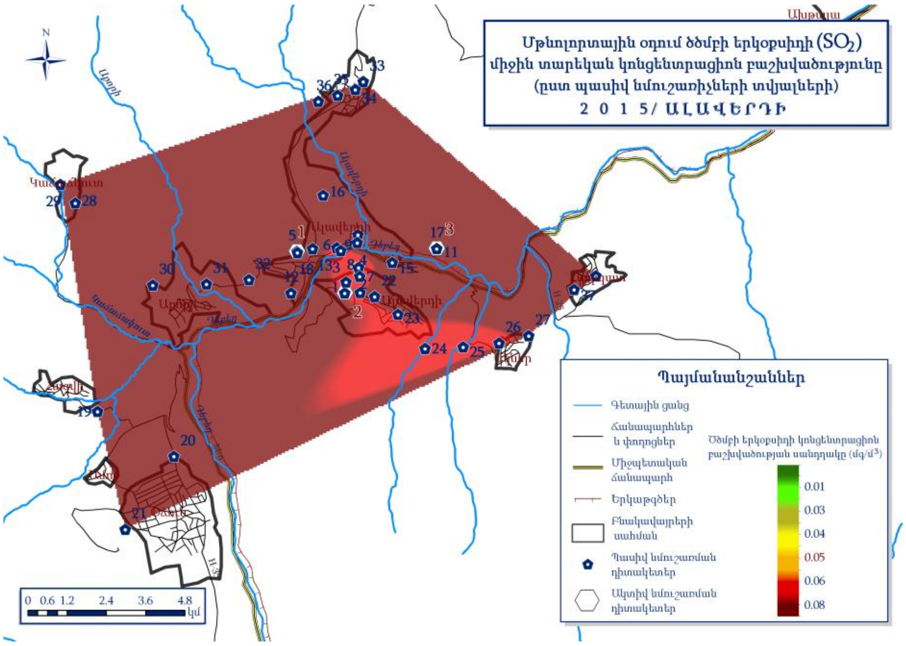
As it was revealed from the interviews (A. Gabrielyan pers. comm.), current air quality monitoring measures the list of variables which was approved by the government and has not updated during the recent years. One of the obstacles of updating the list of monitoring variables is relates to budgetary issues and changes referring to cost of program is not approved by the authorities.

Secondly, wide range of parameters determination requires technically and methodological capabilities that is still limited in case of ambient air quality monitoring.

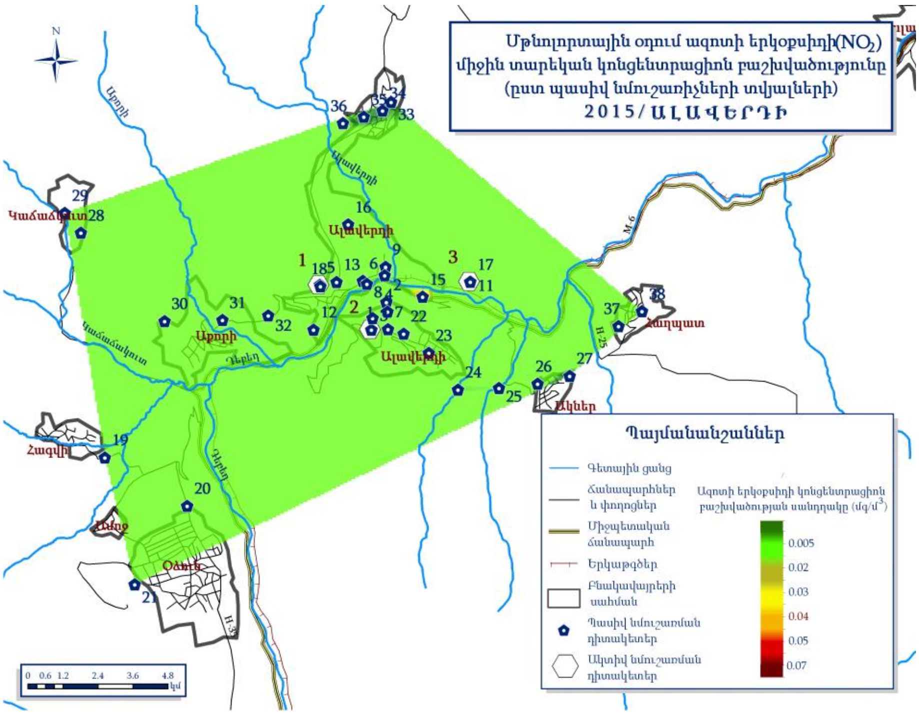
Data analysis

The monitoring data collected from Alaverdi are presented in monthly and annual reports which are accessible through an online database of the EIMC and MNP website. The data analysis includes basic elements, such as comparisons with established air quality norms, graphical representations of trends, as well as distribution of nitrogen and sulfur dioxide constitutes are visualized by maps. (figure 4).

Interviews conducted show that the way how monitoring information is presented and reported is understandable for policy makers and other users (NGO's). Although the specialists involved in monitoring data production and analysis identify the lack of modern technologies and professional skills for data analysis and interpretations. Furthermore, due to the lack of meteorological variables, (wind speed and direction, humidity, etc.) comprehensive analysis of air pollution distribution is practically not implemented.



(a) Sulfur dioxide annual average concentration distribution in 2015, Alaverdi.



(b) Nitrogen dioxide annual average concentration distribution in 2015, Alaverdi.

Ակտիվ նմուշառման եղանակով դիտարկումների արդյունքները Ալավերդի քաղաքում:
Monitoring data collected by active sampling method in Alaverdi.

Որոշվող միացություն (դիտակայանի քանակ)/ Monitored compound (the number of station)	Դիտարկված առավելագույն կոնցենտրացիա, մգ/$մ^3$ (դիտակայանի համար) / Max concentration, mg/m^3 (station numbering)	ՍԹԿ-ից գերազանցումների քանակ		Միջին տարեկան կոնցենտրացիա, մգ/$մ^3$ / average Annual concentration, mg/m^3	ՍԹԿ միջին օրական, մգ/$մ^3$ / MPC daily average, mg/m^3
		>1 ՍԹԿ/ MPC	>5 ՍԹԿ/ MPC		
Ծծմբի երկօքսիդ (3) Sulfur Dioxide	0.122 (դիտ. N3 / station N3)	58	1	0.019	0.05
Ազոտի երկօքսիդ (3) Nitrogen Dioxide	0.178 (դիտ. N1 / Station N1)	8	0	0.010	0.04
Փոշի (2) Dust	0.291 (դիտ. N2 / Station N2)	69	0	0.069	0.15

(c) data analysis.

Figure 4. The ways of monitoring results presentation. Pollutants distribution maps (a), (b) and (c) tabular representations. Source: Annual Report on monitoring results (EIMC 2015).

Monitoring data quality and data interpretation problem

The monitoring of ambient air concentrations of sulfur dioxide is done by using different methodologies. The concentrations of sulfur dioxide determined by online monitor and passive sampling are compared to understand the credibility of monitoring (Figure 5). Online monitoring of sulfur constitutes is carried out since 2008 at one of the stationary stations which has the closest location to the copper smelter plant in Alaverdi. Passive sampling of sulfur dioxide has been started since the end of 2009. However, for having complete annual averages of the concentration, the annual average of 2010 is used to compare the concentration difference within two monitoring methods. The data have been provided by the EIMC res air quality monitoring program in the country.

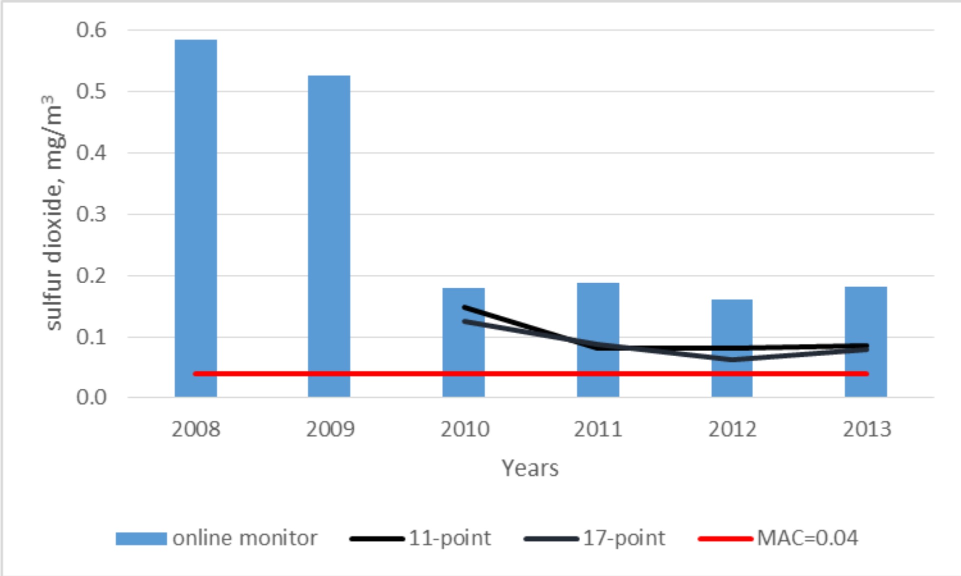


Figure 5. Comparison of sulfur dioxide annual average concentrations determined by two monitoring methods (online monitoring and passive sampling of gaseous) at a stationary station and collocated passive monitoring sites (11-point and 17-point) in Alaverdi between 2008 and 2013. MAC: Maximum Allowable Concentration.

According to figure 2, the recorded concentrations of sulfur dioxide in 2008-2009 years were around 0.59÷0.53 mg/m^3 which is approximately14÷13 times higher than the national standard of MPC (0.04 mg/m^3). In the following period of 2010 - 2013, the annual concentrations of sulfur dioxide decrease significantly and are equal to 0.18 mg/m^3.

Sulfur dioxide concentration reduction cannot be linked to the positive impact of the oprations of the new constructed chimney because the construction work began in 2010 while the operation has took place since September 2011 (Pepanyan, M. 2011.). It is clear that there is no noticeable reduction of atmospheric sulfur dioxide concentrations after chimney operation and removal of harmful gases from the higher height after the year of 2011.

Taking into account the calibration problem of automated analyzers, an attempt is made to compare sulfur dioxide concentrations which was received from two different measurement methodologies (figure 4). For this purpose, two collocated passive sampling sites data is used to compare with the results received from automated analyzer.

It is clear from the figure 4 that there is a significant difference between the data received from the different measurements. Except for 2010, the bias between two methodologies is accounted to be about 50 percent. This bias casts doubt up on the credibility of collected data quality. However, the reduction of concentrations which is likely connected to the monitoring data quality was manipulated as a positive effect of environmental measures devoted to pollution reduction in the city; particularly, to the emissions release from the new constructed chimney. Such kind of error also reveals the luck of communications between the company management personal, policymakers, monitoring specialists and scientists, as well.

Air quality governance in the country

Air quality governance and national policy in the country is based on the Law of Atmospheric Air Protection (1994) and on the legal acts which provide the regulation of the mentioned law. The Law of Atmospheric Air Protection defines the role of state and terrestrial administration bodies in atmospheric air quality governance and in the regulations of harmful substances emission. Based on the article 36 of Atmospheric Protection Law, which defines the emissions recording, the government adopted the decree N 259 (April 24th, 1999) which confirms the state recording procedures of emissions of harmful substances in the country. According to this decree, the subject for state recording are all stationary sources if their annual “Used Value of Air” UVA is between 200 million to 2 milliard cubic meters per year. The concept of “used value of air” is defined by the following equation (N 1673-Ն decree);

$$UVA = \sum Ei/MPC$$

Where E i is the emission of the i component and MPC is the maximum permissible concentration.

The organizations are obliged to carry out their emission calculations (N 259 decree) and present their annual reports to the Ministry of Nature protection. The emission permits are issued by Ministry of Nature Protection based on the exemination of introduced reports.

According to N 1673 decree, if the annual emissions are within the above mentioned range, the emission limit is determined by the reported factual value of emission. Otherwise, if emissions from stationary sources exceeds above mentioned value of 2 milliard cubic meters, the emission values are detained by so called “limits of permissible emission”.

Next, “the limit of permissible level of substances” polluting atmosphere is regulated by N1673 decree (December 27th, 2012). This decree defines the concept of “background concentration”, the content and structure of approval of emission limits. The limits of permissible concentrations of harmful substances is issued by the same N1673 decree for about 400 substances which were mainly adopted from former Soviet Union standards. Currently the state governance of atmospheric air quality is based on emission permissions and on the control of mechanisms of the issued emission norms.

Environmental monitoring is discussed as a tool for quality control in settlements and the monitoring results as a measure for policy interventions (N-67 decree).

Current policy against emission reduction

As it was discussed above, the current policy of protecting ambient air quality is based on emission restriction. According to current emission regulations, for five years, the APC company is provided temporary emission quotas which exceed established emissions limits.

For exceeding emission standards, according to Armenian law on Nature Protection and Nature Utilization payment (1998), the APC pays environmental to the State budget fees for environmental pollution. From the generated funds, the government provides subsidies to the effected communities.

Therefore, the established mechanism of emissions regulation provides privileges to emitters and financial benefits for pollution effected communities, at the same time it ignores air quality problems that the city is facing and related information use.

Comparison with EU policy

In contrast to Armenian legislation, the EU emission policy of permissions and restrictions of emission is based on the best available technologies (EC 2010). The policy covers energy and industrial sectors, including metals and minerals production.

EU member states are using the following provisions to minimize environmental impact that is the

- best available technologies to prevent environmental pollution (the provision is missing in our legislation)
- Reuse of generated waste
- Energy efficiency
- Measures are taken to avoid accidents and their impacts (missing provision)

Thus, the Armenian legislation does not provide sufficient provision to regulate the field. The case of Alaverdi shows that instead of giving technology based solutions, emissions are regulated o by their value which is not linked to the used technology.

Additionally, according to EU legeslation, periodic expertise takes place by authorized body which is done by unexpected inspections whereas such kind of inspections are practically missing in the country due to the lack of technical capabilities .

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Appendix 1

The list of interviewees.

Name	*Position*
Gayane Shahnazaryan	Deputy head on scientific matters, Environmental Impact Monitoring Center
Arpine Gabrielyan	Head of air quality devision
Hamlet Melqonyan	Deputy head, State Hydrogeological Monitoring Center
Asya Muradyan	Head of the department of protection policy of climate change and atmosphere, Ministry of Nature Protection
Inga Zarafyan	President, “EcoLur” Informational NGO
Seyran Minasyan	Independent expert (former deputy head on scientific matters of the environmental impact monitoring center)
Ailita Sargsyan	Healthcare Specialist
Martiros Tsarukyan	Indipendent expert (former Head of the department of protection policy of climate change and atmosphere, Ministry of Nature Protection)

Appendix 2

Water quality and air monitoring network. Source: (EIMC 2015).