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USING A STATISTIC APPROACH: AN APPLICATION FOR ASSESSING CONCENTRATIONS OF AIR POLLUTANTS

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ABSTRACT

In today's cities management, the primary challenges facing local decision-makers are climate change, population growth, pollution and the rising costs of energy. It must be noted that air pollution is one of the most complex ecological problems that the aforementioned decision-makers have to deal with nowadays. Given the limited financial means of most municipalities, the primary objective of this paper is to provide a less costly decision support model for the assessment of air pollutant concentrations, particularly SO_2. The Six Sigma approach, in its "analysis" section, allows the evaluation of the daily average of SO_2 concentrations measured during the period of one year in the city of Kenitra / Morocco. The application of statistical tests helps assess the conformity of this pollutant with the value limit required by the Moroccan standards for the protection of the environment.

Keywords: air pollutants, moroccan standards of the environment, kenitra, six sigma, normality tes, box-cox transformation, X-bar, superior capability.

1. INTRODUCTION

Given its paramount importance, clean air is deemed to be one of the chief sustainable development goals for the United Nations [1]. It is therefore necessary to take care of air quality in the cities to improve health and well-being of inhabitants. Air pollution is undoubtedly a critical environmental problem that cannot be overlooked. The World Health Organization's cancer agency, in its project entitled "Health Risks from Atmospheric Pollution in Europe", officially classified air pollution as a carcinogen for humans [2]. Due to the sustained urbanization in recent years, the levels of air pollutants in urban areas and megacities are becoming very high, which decreases the quality of the consumed air. Among the main sources of emission: road traffic, maritime transport emissions, industrial emissions [3], domestic heating and other anthropogenic actions.

The city of Kenitra has mushroomed enormously in recent years, from 292,457 in 1994 to nearly 450,000 today. As a result, the city has grown considerably. It is now confronted with major urban problems while the rate of motorization continues to increase, which poses grave ecological problems. In effect, the problems of pollution and congestion urge the need to change the management of the city and come up with new feasible and sustainable solutions to assess the concentrations of air pollutants, so as to meet the global requirements for the protection of the environment [4]. Therefore, the use of efficient and reliable estimation methods is mandatory.

In this article, we will explore a new path and build an expert system primarily based on the Six-Sigma approach [5] in order to analyze the concentrations of an atmospheric pollutant SO_2. The following questions will help establish a thorough understanding for the following factors: Which of the statistical tests is applicable to the assessment of air pollutants? And how can local authorities use the results obtained to ensure compliance with the regulations in force in order to comply with the requirements of environmental protection?

2. METHODOLOGIES

We adopt the IMRAD methodology. In the section "Results," we will begin by describing the problem of air pollution. Afterwards, we will present the Moroccan environment standards. Then, the main concepts of Approach Six Sigma are presented. In the case study part, we will try to verify the conformity with the Moroccan norms in force regarding the concentrations of the sulfur dioxide (SO_2) [6], a) by carrying out the test of normality, b) if the distribution of the data is not normal, a transform will ~~presents~~ the normal law with the indices, c) then, in the assessment of the conformity of the concentrations with the requirements in force, two tools will be used: the X-bar cards and the calculation of the higher capacity and g) one ends by the discussion of the results of the statistical evaluation (step "M": measures). In the "Conclusion" section, the merits and drawbacks of the proposed solutions will be presented, including perspectives.

3. RESULTS AND DISCUSSIONS

3.1 Notion of atmospheric pollution

The phrase "atmospheric pollution" is relatively old. It covers several phenomena driven by distinct processes and are sometimes coupled. They are presented as follows [7]:

- The additional greenhouse effect caused by the greenhouse effect (carbon dioxide, ...) and its consequences on the climate;

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- The destruction of stratospheric ozone (especially at the poles) by compounds such as chlorofluorocarbons (CFCs);
- Air quality with the problems of photochemical pollution (ozone, nitrogen oxide and volatile organic compounds) or particulates, acid rain (linked to sulfur dioxide and sulphate aerosols), more generally transboundary pollution multi-pollutant;
- The impacts of accidental releases (chemical, biological or nuclear) into the atmosphere.

Atmospheric pollution manifests itself in the form of a thick suffocating fog called smoke. Smoke is a mixture of air pollutants composed of ozone, particulates, carbon monoxide, nitrogen oxides and volatile organic compounds. It is a yellow-brown fog that is visibly present in large cities, but there are also high concentrations of smoke in the periphery and in the countryside, mainly because of the wind. Smoke irritates the eyes, the respiratory and cardiovascular systems, which exacerbates heart and lung diseases, as asthma damages the mucous membranes of the lungs. This can increase the risk of lung cancer and premature death. Seniors, children, asthmatics, people with lung diseases and heart problems, smokers, and people who exercise outdoors are even more sensitive to toxic gases forming the smoke.

3.2 Source of atmospheric pollution

The origin of atmospheric pollution is either anthropogenic (produced by human activities) or natural (emissions by vegetation, soil erosion, volcanoes, oceans, etc.). All sectors of human activity are likely to emit atmospheric pollutants: industrial activities, transport (road and non-road), domestic activities (heating in particular), agriculture, and forestry. They are emitted into the atmosphere as gases or particulates (PM) from different sources, then transported and / or processed in this compartment, and then removed by means of dry or wet deposition aerosols that are incorporated in rain or clouds. Pollutants observed in the atmosphere are not all emitted directly from these sources. They also result from physico-chemical reactions between chemical components, primary pollutants and other constituents of the atmosphere, governed by weather conditions. Table X shows the emission sources of the main air pollutants.

Table-1. Sources of air pollutants [8].

Pollutants	Emission sources
Nitrogen dioxide (NO_2)	NO_2 comes mainly from the combustion of fuels and incineration plants.
Ozone (O_3)	There are no sources of emission: ozone (O_3) is a secondary pollutant that is formed at a low altitude by chemical reactions produced under the effect of sunlight, from atmospheric pollutants - said precursors - such as nitrogen oxides (NOX) and volatile organic compounds (VOCs).
Sulphur dioxide (SO_2)	SO_2 comes mainly from the combustion of fuels and fuels containing sulfur (fuel oil, diesel, coal, etc.). Sulfur impurities in fossil fuels are oxidized by oxygen in the air (O_2) to sulfur dioxide (SO_2).
Carbon monoxide (CO)	CO is formed during the incomplete combustion of fuels. Traffic is responsible for most of the carbon monoxide emissions followed by industrial and domestic heating.
Primary Particles (PM)	The largest anthropogenic sources of particulate matter are road transport, energy production, agriculture, industrial combustion, non-road transportation, residential heating and industrial processes.

3.3 Presentation of the six sigma approach

The German physicist Johann Carl Friedrich Gauss (1777-1855) [8] laid the foundation stone of the Six Sigma method from its concept of normal distribution [9]. Walter A. Shewhart (1891-1967) developed statistical process control (SPC) around 1920. He kept the scientific basis he kept in his book, Economic Control of the Quality of Manufactured Product published in 1931. The pioneer of quality management, William Edwards Deming (1900-1993), created the process-oriented vision of a company's activities and tasks around 1940. Its development is now an integral part of quality standards and management lessons. Six Sigma has become today a philosophy of process improvement in five phases. It is based on the DMAIC [9] principle (Design, Measurement, Analysis, Improvement and Control):

- **Define:** Set the goal
- **Measure:** Measuring customer expectations
- **Analysis:** Analyze problems, strengths and weaknesses
- **Improve:** Differentiate, innovate
- **Control:** Guarantee long-term quality

This philosophy is aimed primarily at minimizing errors to achieve world-class performance (3.4 errors per

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million opportunities) that is usually expressed as a Six Sigma measurement or simply a Sigma value. For our study, we will only apply the "Measure" part of the six sigma approach.

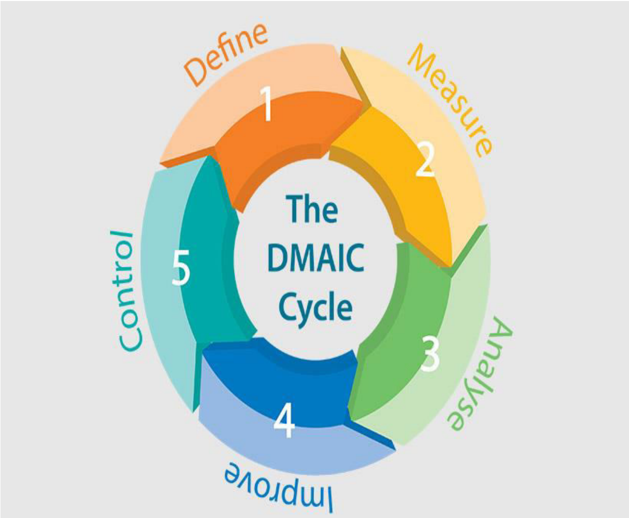

Figure-1. Principe DMAIC [9].

3.4 Moroccan standards on air quality

Morocco is paying conspicuous attention to the problems of air pollution, due to the accelerated industrial activities and heavy road traffic. This clearly has a direct and dangerous impact on the health of inhabitants, and in particular children. To remedy this situation, the government has decided to fight against the deterioration of air quality. It is in this context that the government has taken measures to monitor the quality of the air and reinforce the legal arsenal.

In accordance with the provisions of the law n°13-03 [10] relating to the fight against the air pollution, and its decree of application n ° 2-09-286 on December 8th, 2009 fixing the norms of air quality air monitoring modalities. A National Committee for Monitoring and Surveillance of Air Quality has been created, namely the secretariat and the chairmanship of which are provided by the Ministry of the Environment. This committee is very useful for federating and harmonizing air quality and monitoring actions, as well as strengthening measures to fight against air pollution. At the regional level and in accordance with Decree No. 2-09-286 on December 8^{th}, 2009, in each region where an air quality monitoring network is set up, and a permanent committee for the monitoring and surveillance of the quality of the air is instituted.

The air quality monitoring started in 1997 with the first campaigns of this kind in Morocco conducted by the Ministry Delegate for the Environment in the urban areas of Rabat, using a mobile laboratory. These campaigns have made it possible, on the one hand, to evaluate the extent and intensity of pollution in the city by comparing measured concentrations with different standards, and on the other hand, to make public authorities aware of the need to have fixed stations for continuous measurement of air quality.

3.5 Case study and discussion

The city of Kenitra is considered one of the most important cities in northwestern Morocco. It is located on the left bank of Oued Sebou, 12 km from its mouth on the Atlantic Ocean. It is a recent city whose creation dates back only 120 years. It occupies a privileged and strategic geographical position at the crossroads of the most important roads, Tangier-Tetouan in the North, Fez-Meknes in the East and Rabat-Casablanca in the South. Kenitra is an emerging city, which has experienced strong growth in terms of industrialization and investment. Hence, the need to take all necessary measures to ensure the protection, development and good management of environment is crucial and desirable.

Figure-2. The geograhic location of Kénitra [11].

The city of Kenitra has known a sustained population and urban growth with a population of 431.282 [12] (2014 RGPU General Population and Planning Census). Increasing urbanization places high demands on infrastructure, such as transportation. This causes the increase of different pollutants (CO, SO_2, NO, NO2, O3 and PM10) in the atmosphere [18]. In actuality, the city of Kenitra desperately demands more intelligent solutions in to control and inspect air quality. One should know tha the aim of this study is to use the six sigma approach in the evaluation of concentrations of atmospheric pollutants, in particular SO_2. The Six Sigma approach in its analysis section allows the evaluation of these concentrations by applying statistical tests [13].

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Kenitra city's air quality monitoring is carried out using a mobile unit whose mission is to collect the concentrations of the main pollutants. This mobile unit is submitted under the supervision of the team of the National Laboratory for Studies and Monitoring of Pollution (LNESP).

In this article, the most polluting air indicator, namely SO_2, is analyzed using the Six Sigma approach. Since the measured data are not available, observational data from an article on air pollution in the city of Istanbul/Turkey [14] are used. According to Moroccan standards, the annual average SO_2 limit value for air quality is 20 µg / m3. For the evaluation of these concentrations, the upper capability and the X-Bar control charts were used.

3.5.1 Normality test

This test verifies the normality of the data distribution according to two hypotheses:

Equality Assumption H_0, Actual Data Distribution Follows Normal Law

Difference Hypothesis H_1, Actual Data Distribution Does Not Follow Normal Law

P is the propensity to make the mistake of accepting the H1 difference hypothesis, which is wrong to consider a risk of $\alpha = 5\%$

- If P > 0,005: H_0 is correct, the data distribution is normal
- If P < 0,005: H_1 is correct, the data distribution is not normal

The probability density of the normal distribution is given by [15]:

$$P(x) = \frac{1}{\sqrt{2\pi\sigma}}\exp(\frac{1}{2}(\frac{x-\mu}{\sigma})^2 \quad (1)$$

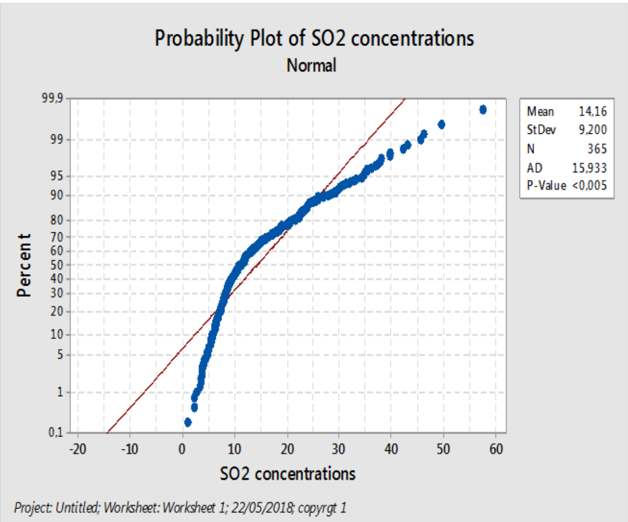

Figure-3. Probability plot of SO_2 concentration.

The value P < 0,005, H1 is correct; the actual distribution of the data is not normal.

3.5.2 Using X-bar cards for standardized data

The use of an X-Bar chart is to monitor the average of a process and determine its stability. It represents the average of the measurements in each subgroup. The center line indicates the average of all subgroup averages. The control limits, which are plotted at a distance of 3 standard deviations above and below the center line, show the expected variation in the means of the subgroups. The data is transformed using the Box-Cox Transformation [16] by the tools of statistical software.

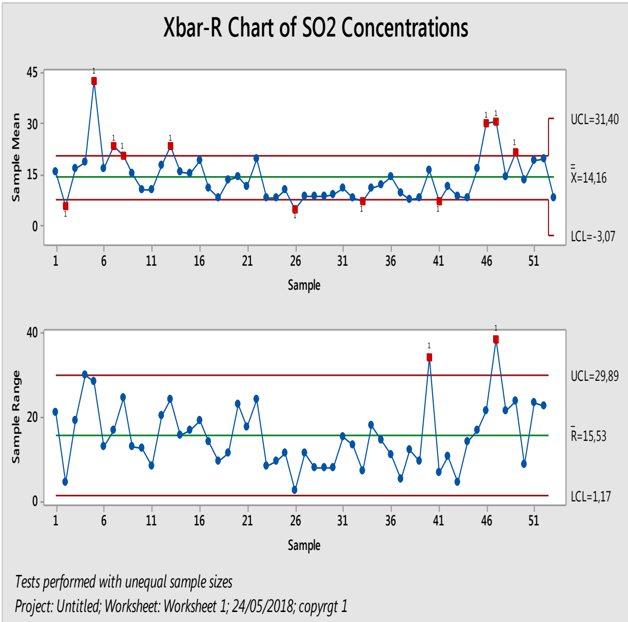

Figure-4. Chart for individual value.

Several points are beyond the control limits on the first graph while only 2 are beyond the limits on the second graph. These points indicate that the process cannot be stable. The process also does not respect these natural limits (+ 3σ, -3σ). It is then declared out of control at the 95% confidence Interval.

3.5.3 Capability calculation for standardized data

By following the capability $C_{p,upper}$ [17] which is calculated with respect to the upper limit. In our case the limit value is 20 µg /m^3 for SO_2 (Moroccan standards). Descriptive statistics have been determined for SO_2 values. These statistics are shown in Table-2. The capacity characteristics indicators are presented in Figure-5.

$$\text{Cp, upper} = \frac{UCL - \bar{x}}{3\sigma} \quad (2)$$

$$\sigma = \frac{1}{365}\sum_{i=1}^{365}(x1-\bar{x})(x1-\bar{x}) \quad (3)$$

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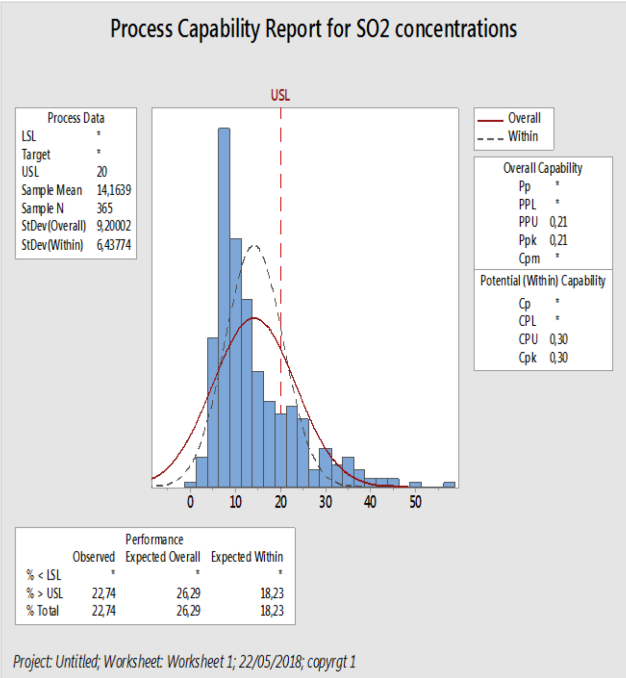

Figure-5. Capability for standardized data.

Table-2. Descriptive statistics.

Statistic	SO_2
USL	20
Sample Mean Sample N	14,1639 365
StDev (Overall) StDev (Within)	9.20002 6.43774
C_p	0,21
P_{pk}	0,21
C_{pk}	0,30

The capability index $C_{p,upper}$ is calculated to summarize the comparison of the adjusted distribution of ~~to~~ the specifications.

Since $C_{p,upper} = 0.21 < 1.33$, we can say that the process is decentralized. The same calculates give 26, 29%, which is ~~of~~ impossible to correspond to 93 overruns per year. This shows that it is not in conformity with the standards in force, and hence it does not allow any overtaking.

4. CONCLUSIONS

In this article, we presented the six-sigma approach. The SO_2 indicator is analyzed using superior capability and control charts. These analyses have shown that SO_2 concentrations in the air are very high. In the same way, other components of atmospheric pollutants can be analyzed by comparing them with the limit values fixed by the standards in force. Six-sigma is a structuring and very effective, but it can create concrete problems out of abstract ones. It should be known that the six-sigma approach allowed us to analyze the concentrations of the atmospheric pollutant SO_2 measured over a period of time, on a daily average. In a future study, we will use geographic information systems (GIS) to address the problems of atmospheric pollutants distribution in space.

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