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An overview and assessment of potential correlations to sewage system overflows in Córdoba

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EXECUTIVE SUMMARY

One of the challenges to achieve sustainable development is to provide adequate access to sanitation and water treatment, which is considered a human right. The latter implies that there are binding obligations and people with the ability to claim against others with a duty to respond. The city of Córdoba, Argentina, today faces many problems with water pollution and sanitation. An important problem is represented by the existence of overflows in the public sewage networks, which currently provides service to 50.5% of households (National Census INDEC 2010). The presence of sewage overflows in the streets of the city generates a series of adverse impacts and exposes more than one million three hundred thousand people to significant health risks. This issue has been present for more than a decade and has even been getting worse year by year. In this context, the present study is proposed whose objectives are: 1) To identify and organize sewage overflows claims (considered as representative indicators of the damage, for which there are no fully systematized records), and 2) Describe and quantify associations between the number of claims and potentially linked factors: water consumption, level of precipitation, atmospheric temperature, population and cases of diarrhea. The research study took place in the city of Córdoba, whose population exceeds 1,300,000. The monthly data for the period 2010-2014 were provided by the Municipality of Córdoba, the National Weather Service, the Department of Provincial Epidemiology, Aguas Cordobesas and the National Institute of Statistics and Census. Analyses showed that during the 5-year period sewage overflow claims increased by 28%. In addition, number of claims varied by month (59 months) and this variation seems to follow an annual pattern, where the first increase occurs in March and May, with intermediate saddle points and the peak reached in July-August, and then decreases until the minimum number is reached during summer months (Nov. - Feb.). It was determined that 17 boroughs (representing 22% of the population of the city) accumulate 58% of total claims, being Alberdi, Centro, Alta Cordoba, San Vicente and Alto Alberdi the most disadvantaged boroughs, in that order. Specific locations were identified, scattered in the city where claims accumulated from 12 to 30 times in five years. In each of the boroughs analyzed the apparent monthly water supply showed negative correlation with the corresponding amount of claims, and many of them were statistically significant with medium effect size. The total number of claims per month in the city ($\Omega$) showed significant negative linear correlation (medium effect size) with the monthly volume of rainfall. The $\Omega$ index showed significant negative linear correlation with a medium effect size with the average monthly temperature. In each of the boroughs analyzed the average monthly temperature showed negative correlation with the corresponding amount of claims and in Centro, Alta Cordoba, Alto Alberdi, Paraisos and Zumarán were statistically significant with medium and large effect size. The $\Omega$ index showed no significant linear correlation with the monthly number of reported cases of diarrhea. This is only a general indicator, as diarrhea can be caused by many factors, and does not imply absence of health risk. Population density and the growth rate in areas of major overflows showed
no significant correlations with annual claims in 2010. However, the annual number of sewage overflow claims in disadvantaged boroughs did show significant positive linear correlation with large effect size, with their population in 2010, which means that in boroughs with the highest number of inhabitants, higher (linearly proportional) was the amount of annual claims for failure sewerage networks in 2010. During the period 2010-2014, in most of the problematic areas (e.g. Alta Córdoba, San Vicente and General Bustos) correlations of their estimated populations and monthly claims were significant and negative, which means that claims increased as its population decreased. These results show a complex and heterogeneous relationship between claims and demographic indices. Nueva Córdoba has the highest population density in the city, as well as the greatest population growth, however, the results obtained in this case suggest that the number of people or population density would have no linear relationship to the number of claims. Still, more studies involving larger ranges of time and amount of data are needed for a more complete understanding of the situation.

A possible interpretation of these results is that the pipes of the sewage network system are strongly affected by accumulation of fats, oils and grease (FOG), in fact, this is the main reason of overflows in the systems of the United States. Hence the temperature has such an important role because it can promote the solidification or increase fluidity of FOG, as the system gets cold or warm, respectively, by influencing the viscosity of the components. Moreover, elevated air temperatures are associated with higher rates of rainfall and water consumption, which contributes to higher flow rates and a "wash-out" of the pipes. The increasing number of claims could be interpreted as an increase in functional abnormalities in the sewers, whose causes are beyond the scope of this work. Still, it can be inferred that this phenomenon is subject to multiple factors, including the user and the ways in which the sewage system functions, the technical and construction criteria, even meteorological variables, demographic and cultural habits. This implies that there should be planification and execution of comprehensive solutions based on thorough research with reliable references and impartial criteria and suggestions.
RESUMEN

Uno de los desafíos para alcanzar el desarrollo sustentable es brindar acceso adecuado a sistemas sanitarios y de tratamiento de agua, considerado como un derecho humano. Lo último implica que existen obligaciones exigibles y sujetos con capacidad de reclamar frente a otros con deber de responder. La Ciudad de Córdoba, Argentina, se enfrenta hoy a diversos problemas en torno a la contaminación del agua y el saneamiento. Uno de los más importantes lo representa la existencia de desbordes en las redes sanitarias públicas, que actualmente brindan servicio al 50.5% de los hogares (Censo Nacional INDEC 2010). La presencia de fluidos cloacales en las vías públicas de la urbe genera una serie de impactos adversos y expone a más de un millón trescientos mil habitantes a riesgos sanitarios importantes. Esta problemática está vigente desde hace más de una década e incluso se ha venido incrementando año a año. En este contexto se plantea el presente estudio que tiene por objetivos: 1) identificar y organizar los reclamos sobre desbordes cloacales (considerados como indicadores representativos de los desperfectos, sobre los cuales no existen registros completamente sistematizados), y 2) describir y cuantificar las asociaciones entre el número de reclamos y diferentes factores potencialmente vinculados: consumo de agua, nivel de precipitaciones, temperatura atmosférica, número de habitantes y casos de diarreas. La investigación tuvo lugar en la Ciudad de Córdoba cuya población excede 1 300 000 habitantes. Los datos mensuales del período 2010-2014 fueron brindados por la Municipalidad de Córdoba, el Servicio Meteorológico Nacional, el Área de Epidemiología Provincial, Aguas Cordobesas y el Instituto Nacional de Estadística y Censos. Los análisis mostraron que en el período de 5 años los reclamos aumentaron en un 28%. Además, los reclamos variaron según los meses (59 meses), y esa variación parece seguir un patrón anual donde los primeros incrementos se dan en marzo y en mayo, con depresiones intermedias y el pico se alcanza en julio-agosto, para luego decrecer hasta el mínimo en verano. Se determinó que 17 barrios (que representan un 22% de la población de la Ciudad) acumulan el 58% del total de reclamos, siendo Alberdi, Centro, Alta Córdoba, San Vicente y Alto Alberdi los más desfavorecidos, en ese orden. Se identificaron puntos específicos dispersos en la ciudad donde los reclamos se acumulan desde 12 a 30 veces en los cinco años. En cada uno de los barrios analizados la dotación aparente mensual de agua mostró correlación negativa con la correspondiente cantidad de reclamos, y en muchos de ellos fue estadísticamente significativa con tamaño de efecto medio. El número de reclamos total en la Ciudad por mes (Ω) mostró correlación lineal negativa significativa (tamaño del efecto medio) con el volumen mensual de precipitaciones. El índice Ω mostró correlación lineal significativa negativa con un tamaño del efecto medio con la temperatura media mensual. En cada uno de los barrios analizados la temperatura media mensual mostró correlación negativa con la correspondiente cantidad de reclamos, y en Centro, Alta Córdoba, Alto Alberdi, Los paraísos y Zumarán fueron estadísticamente significativas con tamaños de efecto medio y grande. El índice Ω no mostró correlación lineal significativa con la cantidad mensual de casos reportados de diarreas. Este es solamente un indicador general, ya que las diarreas
pueden ser ocasionadas por muchos factores, y que no implica ausencia de riesgo sanitario. La densidad poblacional y el índice de crecimiento en zonas de mayores fallos no mostraron correlaciones significativas con los reclamos anuales en 2010. No obstante, el número anual de reclamos en cada barrio más desfavorecido sí mostró correlación lineal positiva significativa y un tamaño del efecto grande con su respectiva población en 2010, lo que implica que en los barrios con mayor número de habitantes, mayor fue (linealmente proporcional) la cantidad de reclamos anuales por fallos en las redes cloacales en el año 2010. A lo largo del período 2010-2014, en la mayoría de los barrios más problemáticos (ej. Alta Córdoba, San Vicente y General Bustos) las correlaciones de sus poblaciones estimadas y los reclamos mensuales fueron significativas y negativas, lo que implica que los reclamos aumentaban conforme disminuía su población. Estos resultados evidencian una compleja y heterogénea relación entre los reclamos y los índices demográficos. Nueva Córdoba tiene la máxima población y densidad en la Ciudad, además de haber tenido el mayor crecimiento demográfico, sin embargo, los resultados obtenidos en este caso sugieren que la cantidad de habitantes o la densidad poblacional no tendrían relación lineal con el número de reclamos. Aun así, se necesitan más estudios que abarquen mayores rangos de tiempo y cantidad de datos para una comprensión más acabada de la situación.

Una posible interpretación de estos resultados es que las cañerías del sistema cloacal son afectadas fuertemente por acumulación de grasas, aceites y ceras (GAC), de hecho, esta es la principal razón de las obstrucciones en los sistemas sanitarios de los Estados Unidos. De aquí que la temperatura tenga un rol tan importante, ya que puede favorecer la solidificación de GAC o bien, aumentar la fluidez, según el frío o el calor respectivamente, al influir en la viscosidad de los componentes. Más aun, temperaturas atmosféricas elevadas están asociadas con mayores índices de precipitaciones y consumo de agua, que de alguna manera contribuirían a mayores caudales de circulación y a un “lavado” de cañerías. El creciente aumento de reclamos podría interpretarse como un incremento en las anomalías funcionales en las redes cloacales, cuyas causas escapan al alcance de este trabajo. Aun así, se puede inferir que este fenómeno está sujeto a múltiples factores, que incluyen tanto al usuario y las formas en que se utiliza el servicio cloacal, como a cuestiones técnico-constructivas e incluso variables de orden meteorológico, demográfico y cultural. Ello implica que se deberían planificar y ejecutar soluciones integrales, sustentadas en investigaciones que brinden referencias, criterios y sugerencias fiables e imparciales.
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APPENDIX
1. Introduction

South America has vast historical events where people fought for a brighter future in this continent. In the present many countries in South America are growing (economically, politically, socially) at a fast pace. As each country grows it is important to have sustainable growth, especially for the new generation. Learning from the past while making discoveries and planning in the present will be vital for a sustainable South America.

Córdoba, Argentina has a rich history and is home to top universities such as Universidad Nacional de Córdoba, founded in 1613, and Universidad Tecnológica Nacional, with a total that exceeds 130,000 students. It is undergoing rapid urbanization and is experiencing a growth in population. Critical to growth of any city is its underlying infrastructure, which needs to be updated and maintained properly. -Infrastructure is the physical or structural backbone of the city. It includes transportation systems (roads, bridges, highways, public transportation), utility systems (gas, electricity, water treatment and delivery), and buildings (schools, court houses, sports facilities, and its public and private housing developments). A critical component of urban infrastructure that is often less focused on is the sewer system.

Despite past efforts to mitigate sewage overflows, it is still very much a problem for the city, especially as the full range of impacts are not noticeable in the immediate term. The extent of human health and environmental impacts caused by sanitary sewer overflows are difficult to quantify, including the location of such impacts, and the volume of pollutants discharged. Members of the municipal and provincial government, city council, local universities, and other entities are working to mitigate this problem of sewage overflows. However, the resources to do so are limited. In this context, the goal of our study is to investigate potential causes of sewage overflows in the existing wastewater network in Córdoba, Argentina.

Aiming to contribute to finding a solution, this study will analyze various factors that contribute to sewer overflows, based on information provided by the Municipality of Córdoba. This study will then find correlations using the data provided by different government organizations to quantify which factors contribute most to the overflows in the city. While inhabitants of the city acknowledge that there is a problem, there is no study that we are aware of that has holistically quantified this issue. It is our hope that this study helps to address at least some parts of the issue of sewage overflows in Córdoba, and serves as a basis for future analyses of the topic.

1.1 Problem

The city of Córdoba has highly frequent occurrences of sewerage system overflows throughout. In our interviews with a variety of subjects, it was noted often that this has been an issue for many years and has been worsening. This situation generates sanitary and environmental risks, as well as socio-economic impacts. Though 58% of the city's population is connected to the sewerage network (censo INDEC 2010), the overflows create undesired consequences that affect the entire population of Córdoba, directly and indirectly. The presence of sewage overflows generates adverse environmental impacts and severe sanitary risks. Specially, when the problem of overflows increases in magnitude year after year.

1.2 Significance of the Study

This study seeks to determine potential weak points in the wastewater infrastructure that currently supports the city of Córdoba’s 1.3 million inhabitants (censo INDEC 2010). Access to adequate sanitary systems is fundamental to human dignity (Bautista, 2013). Per a report commissioned by the United Nations Economic Commission for Latin America and the
Caribbean (ECLAC) on human rights to water and sanitation, the primary requirement of sanitary systems is that they are secure with respect to hygiene. Given these claims, it makes sense to prioritize civilian protection from excreta and wastewater. To our knowledge, this will be the first study to quantify and identify the associated factors that contribute the most to the problematic of sewage overflow even though the issue has been affecting the city for more than a decade.

1.3 Hypothesis, Research Focus, and Objectives of Study

This study’s main research question is as follows: In the city of Córdoba between 2010 and 2014, what associations exist between the number of sewer overflow claims and the following factors?

- Water consumption
- Rainfall levels
- Meteorological temperature
- Cases of gastroenteric diseases
- Population growth

To address this research question, the following general objectives were proposed:

- Identify and organize sewer overflow claims.
- Describe and quantify the associations between the number of claims and the variables stated above.
2. Background

2.1 Weather, Geography, and Economy of the City of Córdoba

The city of Córdoba is located at the heart of Córdoba Province, Argentina. Founded in 1537 as the capital of the country, it is now Argentina’s second largest city. The city of Córdoba is sprawling. The population of Córdoba is about 1.3 million over an area of 576 km². It has a rich history of being a university town, and includes the oldest university in Argentina and the second oldest in Latin America, UNC. The city is located at the foothills of the Sierras Chicas along the Río Suquía and in the center of Argentina.

The biggest economic sectors in Córdoba are automobile, railway, and aircraft manufacturing, as well as satellite and electronic technology industries. Areas around Córdoba produce a range of agricultural products.

The temperature in the city varies between 5° and 29° Celsius (41° to 84° Fahrenheit). The warm season is from November 14 to March 14 and the cold season is from May 21 to August 14. The probability of rain ranges from 16% in the winter to 47% in the summer—it typically drizzles in the winter and rains harder in the summer. Thunderstorms are common; 49% of the days it rains, it thunderstorms. This number increases to 66% during the summer.1

2.2 Río Suquía

The Suquía River originates in the valley of Punilla from the union of several streams and rivers. It meets the Cosquín River and several smaller rivers at the San Roque Reservoir, and then passes through the center of Córdoba from West to East. In Córdoba the river meets La Cañada, a canal built through the downtown area. Finally, it feeds into the Mar Chiquita Lake. The river is 200 kilometers long and 200 meters wide.

2.3 Sewage Treatment in the City of Córdoba

The city of Córdoba’s main treatment plant, Bajo Grande, was constructed in 1985. It has a treatment capacity of 10,000 m³/h. The planned expansion of the plant is set to double its treatment capacity to 20,000 m³/h (Plan de redes sanitarias 2016-2019). The project is estimated to cost US$164M, with an expected completion date of 2019 (BN Americas 2016).

The current plant includes primary sedimentation, pumped to sludge bio-digesters, to percolators on granite rocks, to circulation tracks for percolators, then to clarifiers for secondary sedimentation, chlorination for a residence time of about 30 minutes, and discharge into the Suquía River. The outputs from the sludge bio-digesters are methane and solid waste, which are taken to drying beds and then transported off-site.

The plant is designed for an intake biochemical oxygen demand (BOD) of 250 mg/L (a measure of organic matter in the water) and falls on the lower end of the typical BOD range of 230–560 mg/L. This could be due to the high water consumption rates in Córdoba. The plant is also designed for total suspended solids (TSS) intake of 240 mg/L, a measure of solid materials in the water. This too falls on the lower end of the average, with typical raw municipal wastewater TSS in the range of 250–600 mg/L (Henze & Comeau, 2008). Under normal operation, the wastewater is treated to a BOD of 40 mg/L and TSS of 30 mg/L when it exits the plant.

1 https://weatherspark.com/averages/33324/Córdoba-Córdoba-Argentina
During peak rain, the plant receives about 1.3 times the flow it is designed to handle\(^2\), and relies on the use of a bypass. Via the bypass, excess flow is taken straight to chlorination before being released into the river. Most reports regarding the Bajo Grande treatment plant mention that it is operating over capacity.

2.4 Areas with No Sewage Network

The sewerage system in the city of Córdoba covers 58 percent of the population\(^3\), and is largely limited to the city’s center. The other half of the population uses either non-network alternatives or clandestine connections. Common non-network alternatives include a residence-specific septic tank, which contains solid waste and is periodically cleaned out, and a *pozo negro* (literal translation “black well”), the colloquial name for a hole dug into the ground used to discharge liquid waste into the groundwater system. The chart below shows the number of households using each type of sewage discharge.

<table>
<thead>
<tr>
<th>Census 2010 Sewage Info</th>
<th>Connected to Housing</th>
<th>Outside the House</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Households</td>
<td>396,524</td>
<td>15,424</td>
</tr>
<tr>
<td>Public Network (Sewer)</td>
<td>207,098</td>
<td>1,981</td>
</tr>
<tr>
<td>A Septic Tank and a Pozo Negro</td>
<td>160,073</td>
<td>5,424</td>
</tr>
<tr>
<td>Only a Pozo Negro</td>
<td>26,166</td>
<td>5,335</td>
</tr>
<tr>
<td>Hole, dug in the ground</td>
<td>1,074</td>
<td>442</td>
</tr>
<tr>
<td>No Toilet</td>
<td>2,113</td>
<td>2,242</td>
</tr>
</tbody>
</table>


Table 2.4 - Sewage information of the City of Córdoba, Census 2010.

\(^2\) Ing. Gabriel Rustan, EDAR Plant engineering manager - Meeting on Friday September 19th 2016.

\(^3\) Municipality of Córdoba, Sewage and Gas Networks: Plan de redes sanitarias para la ciudad de Córdoba (2016-2019).
In certain barrios, the water table reaches almost to surface level, causing pozos negros to be emptied directly into the street. The elevated water tables also pose issues of mold and compromised structures in these barrios neighborhoods. In outlying areas of the city, there are allegations of raw sewage discharges directly into surface streams. The Municipality of Córdoba has plans for a US$225M network expansion to unconnected neighborhoods and a AR$580M pesos upgrade of the Bajo Grande treatment plant to handle current demand, with a target completion date in 2019.  

Source: Municipalidad, Ciudad de Córdoba, Plan de Redes Sanitarias Córdoba.

Fig. 2.4 - 1 Zones that are connected to the sewage network

2.5 Public and Private Investments in Water and Wastewater

According to World Bank’s Private Participation in Infrastructure database, across Argentina there has been no private investment in water and wastewater in the last decade. The charts below show the amounts of private investment and number of projects in the water and wastewater sectors as they compare to other Latin American countries, according to the data of the World Bank.  


Fig. 2.5 - 1 Investment amounts and number of projects in the water and wastewater sectors, Argentina

Fig. 2.5 - 2 Investment amounts and number of projects in the water and wastewater sectors, Chile

Fig. 2.5 - 3 Investment amounts and number of projects in the water and wastewater sectors, Mexico
In the City of Córdoba, there has been no private investment in the wastewater network to date.

The city’s current budget for sewerage expansion is US$225M, managed by Córdoba’s finance and investment agency. The agency gave out five bids in mid-2016 for work to expand the sewerage network access to 100 percent of the city’s inhabitants. The committee established payment mechanisms to reward developers for delivering ahead of schedule.

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6 BN Americas. 20/05/2016. Argentina’s Córdoba sees 5 bids for US$225mn sewage tender.
7 Ibid.
3 Framework

3.1 Urban Wastewater Characteristics

This section presents a summary of the article “Aspectos Sanitarios del Estudio de las Aguas” (Sanitary Aspects of the Study of Water) by Espigares García and Pérez López (1985).

3.1.1 Physical Characteristics

The physical characteristics of urban wastewater include temperature, turbidity, color, solids, and smell.

Urban wastewater temperature ranges from 10-21ºC, with a mean of 15ºC, caused by the discharge of hot water used in cleaning and household chores.

The turbidity, or opacity, of urban wastewater refers to the amount of light that passes through the water. This can influence the productivity of primary decomposers, who are more productive when more light filters through. Causes for higher turbidity are further explained in the subsections on the chemical and biological characteristics of urban wastewater.

The color of urban wastewater can range from gray to black. Color is mainly determined by anaerobic biological processes.

Solids found in urban wastewater can be classified as:

- **Total**: still present after an hour of evaporation at 130ºC.
- **Fixed**: still present after evaporation and carbonization at 600ºC for a few minutes.
- **Volatile**: in between total and fixed, and subclassified into dissolved and colloidal—the former with a diameter smaller than a thousandth of a micrometer, and the latter between a thousandth of a micrometer and a micrometer, and having a gel-like consistency, removable via coagulation.
- **Suspended**: of diameter larger than a micrometer, removable by simple physical processes like decantation. Those that fall to the bottom of a cylinder with specified height within an hour are called settleable.

The smell of urban wastewater changes with time. Recently discharged urban wastewater has a tolerable smell. However, as time passes, anaerobic microorganisms begin to reduce sulfates and sulfites into sulfurs, which causes the bad smell characteristic of septic waters. Bad-smelling gasses are also produced via anaerobic fermentation.

3.1.2 Chemical Characteristics

In order to understand and characterized wastewater, it is necessary to investigate what are the chemical characteristics of urban wastewater: organic and inorganic matter.

Organic Matter

The organic matter found in urban wastewater can be broken down as follows: 40 to 60 percent proteins, 25 to 50 percent carbohydrates, and 10 percent fats and oils. Urea, the organic compound found in urine, is one of the principal sources of nitrogen, which has an important role in fueling eutrophication. Organic matter also contributes sulfur, iron, and phosphorus. The majority of natural amino acids that are found in urban wastewater as a result of protein decomposition.

The Biochemical Oxygen Demand (BOD) and the Chemical Oxygen Demand (COD) are the measurements used to traditionally measure organic matter, which are the most significant...
constituents in domestic wastewater. These materials change depending on how long they
are in the system and the temperature as shown in Figure 3.1.2. Wastewater for
inhabitants is often expressed in the unit population equivalent (PE), and it is expressed in
water volume or BOD.

\[
\begin{array}{|c|c|c|c|c|}
\hline
\text{BOD} & \text{BOD}_{20} & \text{BOD}_{12} & \text{BOD}_{25} & \text{COD} \\
\hline
40 & 100 & 115 & 150 & 210 \\
200 & 500 & 575 & 759 & 1,100 \\
\hline
\end{array}
\]

Fig. 3.1.2. The BOD analysis result depends on both test length and temperature.
Standard is 20ºC and 5 days (Henze et al., 2001).

**Inorganic Matter**

The three most important components of the inorganic matter found in urban wastewater are
nitrogen, phosphorus, and sulfur.

Nitrogen is essential for the growth of microorganisms and plants. When found in high
concentrations in urban wastewater, often the result of high concentrations of agricultural
fertilizers, it causes *eutrophication*: an excessive richness of nutrients in a body of water that
causes a dense growth of plant life and the death of animal life due to lack of oxygen. Urea
and proteinaceous material, when decomposed by bacteria, produce ammonia. Ammonia is
therefore the best indirect chemical indicator of recent fecal contamination.

Phosphorus is also essential for the growth of organisms, and is found in urban wastewater
in the form of phosphates. Like nitrogen, phosphorus contributes to the process of
eutrophication. Because it is needed by living things in much smaller quantities than
nitrogen, it can have a larger impact on eutrophication, and is therefore more strictly
regulated. Phosphates are found in detergents.

Sulfur is required for the synthesis of proteins and is released when they decompose. Most
microorganisms use sulfates as a source of sulfur. The resulting sulfuric compounds are
important in determining the level of sanitation of urban wastewater. SH2 can be oxidized
into a sulfate that corrodes sewer pipes, and can cause gastrointestinal disorders in children
if it contaminates drinking water.

Other inorganic matter found in urban wastewater includes heavy metals like copper,
chrome, boron, lead, silver, and arsenic, among others, all of which are toxic. Metals like
nickel and manganese are also found in urban wastewater, and are essential to biological
life.

Gases are another important component of inorganic matter. Dissolved oxygen is necessary
of all aerobic organisms, and as mentioned above, can be exhausted via eutrophication. The
presence of dissolved oxygen prevents anaerobic processes that produce bad-smelling gases, and the level of dissolved oxygen is thereby an indicator of water quality. The quantity of dissolved oxygen in water depends on atmospheric pressure, temperature, and water characteristics like salinity and the amount of suspended solids. Methane is another important gas found in urban wastewater, and is the principal byproduct of anaerobic decomposition.

### Wastewater Constituents Summary

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>Pathogenic bacteria, viruses and worm eggs</th>
<th>Risk when bathing and eating shellfish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodegradable organic materials</td>
<td>Oxygen depletion in rivers, lakes and oceans</td>
<td>Fish death, odours</td>
</tr>
<tr>
<td>Other organic materials</td>
<td>Detergents, pesticides, fat, oil and grease, coloring, solvents, phenols, cyanide</td>
<td>Toxic effect, aesthetic inconveniences, bio-accumulation in the food chain</td>
</tr>
<tr>
<td>Nutrients</td>
<td>Nitrogen, phosphorus, ammonium</td>
<td>Eutrophication, oxygen depletion, toxic effect</td>
</tr>
<tr>
<td>Metals</td>
<td>Hg, Pb, Cd, Cr, Cu, Ni</td>
<td>Toxic effect, bioaccumulation</td>
</tr>
<tr>
<td>Other inorganic materials</td>
<td>Acids, for example hydrogen sulphide, bases</td>
<td>Corrosion, toxic effect</td>
</tr>
<tr>
<td>Thermal effects</td>
<td>Hydrogen sulphide</td>
<td>Aesthetic inconveniences, toxic effect</td>
</tr>
<tr>
<td>Odour (and taste)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.1.2 -1. Constituents present in domestic wastewater (based on Henze et al., 2001)

### 3.1.3 Biological Characteristics

#### Bacteria

Urban wastewater contains fecal bacteria as well as bacteria involved in the process of biodegradation. Coliform bacteria are an indicator of human waste.

#### Viruses

Viruses come from the excrement of infected humans and animals. Viruses attach themselves to solid fecal matter and other particulate matter in order to survive for a prolonged time in urban wastewater. Viruses often remain alive in the mud extracted from wastewater during the treatment process, and can be a danger if mud is used as fertilizer without prior treatment.

#### Algae

Algae are the primary plant life involved in the exhaustion of dissolved oxygen in water during eutrophication. Algae is more likely to be found in water high in phosphorus and nitrogen.

#### Protozoa

The most common protozoa found in urban wastewater are amoebas. Protozoa can eliminate bacteria suspended in wastewater, preventing cloudy effluents.
Fungi
Fungi are often present in the mud generated by the water treatment process, and can inhibit proper treatment of the mud.

3.1.4 General Characteristics of Urban Wastewater
From a sanitary and water treatment standpoint, the three most important characteristics of wastewater are:
- Large quantity of solids present.
- Abundance of biodegradable substances (food for microorganisms).
- Large quantity of microorganisms.
Having described the characteristics of urban wastewater, it is important to keep wastewater underground out of the reach of people and have a proper treatment.

3.2 Overflows
Here Sewer Sanitary Systems (SSSs) are defined as the municipal wastewater collection system that conveys domestic, commercial, and industrial wastewater, and limited amounts of infiltrated groundwater and rainwater, to a treatment plant. Sewer Sanitary Overflows (SSOs) are defined as untreated discharges (overflows) from SSSs.

3.2.1 Descriptives of overflows in the City of Córdoba
There are no accurate records of the numbers of failures that occur in the sewers of the city of Córdoba, nor the causes of the failures (or at least we did not have access to that information) However, the number of claims regarding the problems in sewerage networks was provided by the Sewage and Gas Networks office. The following chart was constructed from the database provided by the Subsecretary of Sewage and Gas Networks. It can be observed that the claims have increased over the period of 2010-2014 at a rate of 28%, with an average growth rate of 6.33% per year.

![Total claims per year chart]

Fig. 3.2.1 - 1 Total SSOs claims per year
Also, the data provided for this study was the total claims per month of the years 2010-2014 in the City of Córdoba, represented in the figure below. It is noted here that the overall curve has a seasonal variation. It starts with relatively low values in January and slightly grows until March then there is a slight decrease in April, and so on. The maximum values appear in July and August, followed by a nearly constant decrease until December.

![Total claims in Córdoba per month](image1)

**Fig. 3.2.1 - 2 Total SSOs claims (2010-2014) in the City of Córdoba per month.**

![Total Overflow Claims in Córdoba 2010-2014](image2)

**Fig. 3.2.1 - 3 Total SSOs claims in the City of Córdoba per month year by year.**
The bar chart shows the total claims during the 5 years period (2010-2014) in the most disadvantaged barrios. As can be seen from this graph, the distribution of claims is very heterogeneous across the whole city.

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>Total Claims</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALBERDI</td>
<td>3033</td>
</tr>
<tr>
<td>CENTRO</td>
<td>2870</td>
</tr>
<tr>
<td>ALTA CABA</td>
<td>2395</td>
</tr>
<tr>
<td>SAN VICENTE</td>
<td>1886</td>
</tr>
<tr>
<td>ARO ALBERDI</td>
<td>1861</td>
</tr>
<tr>
<td>GENERAL BLANCO</td>
<td>1488</td>
</tr>
<tr>
<td>SAN MARTIN</td>
<td>1392</td>
</tr>
<tr>
<td>LAS LOMAS</td>
<td>1378</td>
</tr>
<tr>
<td>PUEYREDON</td>
<td>1094</td>
</tr>
<tr>
<td>ZAMORA</td>
<td>1091</td>
</tr>
<tr>
<td>TAPIYU</td>
<td>1063</td>
</tr>
<tr>
<td>NUEVA CORDOBA</td>
<td>1037</td>
</tr>
<tr>
<td>VILLA FRAS</td>
<td>851</td>
</tr>
<tr>
<td>MILLER</td>
<td>772</td>
</tr>
<tr>
<td>GLENES</td>
<td>707</td>
</tr>
<tr>
<td>VILLA CABRA</td>
<td>704</td>
</tr>
<tr>
<td>ULICA</td>
<td>640</td>
</tr>
<tr>
<td>ULICA</td>
<td>617</td>
</tr>
</tbody>
</table>

Fig. 3.2.1 - 4 Total SSOs claims per barrio for the period 2010-2014.

Fig. 3.2.1 - 5 Illustrative map of City of Córdoba showing overflow locations.
Illustrative map of disadvantaged barrios, with their accumulated overflows between 2010 and 2014 and locations where recurrent claims of overflow were registered. The following table shows information about the approximate locations where there was recurrent claims of overflows:

<table>
<thead>
<tr>
<th>Nº claims 2010-2014</th>
<th>location</th>
<th>barrio</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>Loreto 339</td>
<td>Yapeyú</td>
</tr>
<tr>
<td>26</td>
<td>Lulio 3488</td>
<td>Zumarán</td>
</tr>
<tr>
<td>26</td>
<td>Pedro Goyena 64</td>
<td>Alberdi</td>
</tr>
<tr>
<td>24</td>
<td>Pedro Arata 2041</td>
<td>Villa Paez</td>
</tr>
<tr>
<td>24</td>
<td>12 de octubre 1960</td>
<td>Alberdi</td>
</tr>
<tr>
<td>24</td>
<td>Maipu 151</td>
<td>Centro</td>
</tr>
<tr>
<td>19</td>
<td>Otero 1081</td>
<td>Urca</td>
</tr>
<tr>
<td>12</td>
<td>Mariano Larra 3700</td>
<td>Urca</td>
</tr>
</tbody>
</table>

3.2.2 Demographics and Urban Characteristics of the City of Córdoba

The city of Córdoba, Argentina, founded in 1573, is the country’s second largest city by population, with approximately 1.3 million inhabitants. Córdoba is home to several universities and attracts students from across the country. The city has experienced significant population growth in recent years, led by the resettlement of residents from other regions of Argentina and immigrants from Peru, Bolivia, and Paraguay. Córdoba occupies approximately 576 km$^2$ and is densely populated in the center, but much less so at its peripheries. As such, it has a relatively low population density of 2,308 inhabitants per km$^2$, compared to 13,680 inhabitants per km$^2$ in Buenos Aires proper.

According to national census data, the population density of Córdoba's barrios (borough) has fluctuated significantly over the last 25 years. While the city experienced an increase in population since 1992, this was reflected in only a few centrally located barrios. In fact, most barrios have undergone an overall negative growth in population. This phenomenon of regionalized shrinkage and growth of density within the city may be an effect of the 2001 economic collapse, 2008 global recession, or the inflation and stagnated growth of the Argentine economy over the past 5 years. The phenomenon may be more directly explained by the resettlement of city residents to countryside barrios outside the city limits or by internal migration within the city to barrios with high growth. Regardless, while the city’s population is growing overall, high rates of growth are concentrated to a select few barrios. For example, the centrally located neighborhood of Nueva Córdoba, the only area in the city to experience such dramatic growth of population and density, nearly 57% from 2001 to 2010. Located near the National University of Córdoba’s campus, the barrio has grown from single family homes to multi-story apartment complexes to house local students. The barrios

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8 Dirección General de Estadística y Censos, 2010 Census
9 Patterns of density interpreted from population and area per barrio from 2001 census data
10 Estimations with source data from INDEC
12 See Figure 3.2.2 -1
of Nueva Córdoba, El Centro, Alberdi, and Guemes are some of the city’s most populous and dense barrios.

The rapid increase of population density in the city is a common speculation for the source of Córdoba’s sewage system overflow. Many interview subjects are of the opinion that the current sewage system may be overwhelmed by increased sewage flow from newly built, high density buildings once they are integrated into the pre-existing network. This network, which is up to 60 years old in some regions, was originally planned for lower density barrios according to the College of Civil Engineers of Córdoba. Thus, the speculation that it is overwhelmed by rapid population growth is a hypothesis we would like to explore further in this report.

![Córdoba Population Growth in High Overflow Neighborhoods](image)

Fig. 3.2.2 - 1 Population growth in Córdoba’s barrios with highest overflow rates per population. Made with data from 2010 National Census

### 3.2.3 Water Consumption

The drinking water system was bid as a 30-year concession awarded in 1997. It was initially owned by Suez France and Sociedad General Aguas de Barcelona of Spain, but in 2006 Argentine infrastructure firm Roggio acquired a 51% stake in Aguas Córdobesas. The provision of drinking water services falls under the provincial government. Córdoba’s wastewater, however, falls under the municipality’s authority. There is this divide between the authorities responsible for potable water and those responsible for wastewater.

We have compiled water consumption data from Aguas Córdobesas, collected by month since 2005. The following figures shows the average monthly water consumption, and the consumption per person per day over time (l/p/d), respectively. We can see that there is an overall decrease in water consumption over time. The water consumption average of past 12 months (September 2015–August 2016) for Córdoba is 290 l/p/d, which is on the higher end of water consumption for developed countries. According to Aguas Córdobesas, this average is denominated as “apparent allocation” which is calculated as a function of water

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14 BN Americas. 04/07/2016. Argentina’s Córdoba opens 5 bids for wastewater project.
supplied to the network, distributed by the total population and the industrial use and runoffs are not taken into consideration. We can also see that peak consumption occurs during the summer months of January–March.

**Water Consumption from 2005–2016 (Aguas Cordobesas)**

![Water Consumption Graph](image)

**Average Monthly Consumption 2005–2016 (Aguas Cordobesas)**

![Average Monthly Consumption Chart](image)

Fig. 3.2.3 - 1 Water Consumption in the city of Córdoba

Fig. 3.2.3 - 2 Average monthly water consumption in the City of Córdoba
3.2.4. Rainfall

Sanitary sewer and stormwater systems in Córdoba are theoretically completely independent and carry water with very different characteristics. When rainwater is allowed to infiltrate sewage system not designed to process it, overflows can occur. Sewage has a relatively constant flow that shouldn’t be altered, while rainwater is sporadic and uneven. Sewage is transported through pipes to a treatment plant; rainwater is taken directly to a body of water, often superficially.

A report on the sewage system in Nordelta, Argentina, published by Asociación Vecinal Nordelta (AVN), explains the effects of rainwater infiltrating the sewage system. Nordelta also has a network that attempts to keep rainwater and sewage separate. Rainwater draining into the sewer can produce a large increase in the volume of water in the system which can result in sewage overflowing into the stormwater system. For example, a common amount of rainfall is 30mm. If that falls on a house with a terrace of 100 m², there will be a contribution of 3,000 liters of water. If the house does not have a proper stormwater drainage system, this amount could be added directly to the sewage system. A Nordelta house usually contributes 100 liters to the sewer during a peak hour. If this empties into the sewer instead of the storm drain this causes the sewer to take in 30 times the normal volume from that house. If this issue is happening continuously, the network will not be able to handle that amount of flow. Excess water in the system can also come from illegal connections of sewer pipes. Depending on soil conditions and rain intensity, rainfall can infiltrate a sewage system from the ground through leaky sewage pipes. Rainwater in the sewage network also forces the treatment plant to handle more volume, which minimizes its purification capacity.

3.2.5 Temperature and its Influence inside the Sewer System

In order to understand how the temperatures changes the flow inside a pipe, first is necessary to understand the solid and liquid wastes that flow through the sewers. The kind

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15 Asociación Vecinal Nordelta Report
of waste produced in the sewer is characterized by household behavior, lifestyle, and standard of living, as well as the technical and juridical surroundings.

**Influence of pluvial waters due change in temperature**

Córdoba’s infrastructure of sewer and pluvial waters were designed as two different entities. However, due to the overgrowth of population and other factors, many of the pluvial waters are being re-directed into the sewer system. This has several possible consequences: from the current sewer system not being able to support the extra load, to different composition of materials being added to the system. Therefore, it is necessary to account for the constituents that come with pluvial and waste water when examining temperature’s influence in Córdoba’s sewer system.

**Importance and Consequence of Temperature Changes in the Materials that flow in the Sewer System**

Some of the daily waste include fats, oils and grease which are one of the biggest restrictions to the flow in a household, and these produce major sewage back-ups and overflow in the system. As temperature changes from low to high and vice versa, the materials properties, called the thermal-elastic properties, change as well. For instance, during colder months such as June and July, fats, oils and grease solidify in the sewer making it very hard, costly and difficult to remove in the case of a blockage. Therefore variations in temperature affect the flow of the sewer system. There are three temperature regimes: the mesophilic, the thermophilic, and the psychotropic (see table 3.2.5 - 1). These are important because temperature changes increase bacterial activity. When air bubbles come entrapped in secretions, the settling rate of secondary solids decreases. Consequently, wastewater at a warmer temperature may be useful in preventing settleability problems and loss of solids (Eckenfelder & Wesley, 2000).

<table>
<thead>
<tr>
<th>Temperature Regimes</th>
<th>Ranges</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>mesophilic</td>
<td>4 to 39°C [39.2 to 102.2°F]</td>
<td>most aerobic biological treatment processes operate in the mesophilic</td>
</tr>
<tr>
<td>thermophilic</td>
<td>55°C [131°F]</td>
<td>temperature drops to about methane-producing bacteria become quite inactive</td>
</tr>
<tr>
<td>psychotropic</td>
<td>below 4°C [39.2°F]</td>
<td></td>
</tr>
</tbody>
</table>

Table. 3.2.5 - 1 Temperature regimes that affect flow in the sewer system (Gerardi, 2002)

In order to see the efficiency of the pipes it is necessary to approximate what and how much flows through the pipes. Moreover, it is necessary to understand the thickness of what flows vs weight. In other words, viscosity measures the thickness of a liquid or a solid and how it behaves when in contact with a different surface, whereas density is a measure of the liquid’s weight regardless of surface contact. Table 3.2.5 - 1 shows typical characteristics for domestic sewage. Here, we are not considering any commercial entities which are held to different standards since their production volume and necessities are much higher than domestic entities. In the case of fat, oil, and grease, when temperature changes their viscosity changes, by either concentration or composition. Sewage system’s viscosity traditionally are measured by “apparent viscosity”, which varies with shear rate due to the shear-dependent deformation of the flocculant solids (Yang et al 2009). Since the flux

17 https://www.niagarafalls.ca/city-hall/municipal-works/fat-oil-grease.aspx
depends on shear rate, meaning the contact between the solid and the material that it is
 carrying the fluid, as the temperatures changes the shear rate changes as well. The change
 in the viscosity of water is about 0.995 mPa-s when temperatures are between 5 and 35°C.
 Below is the most simplified formula for computing viscosity linearly:

\[ \mu_w = 5.829 \times 10^{-5} T^2 - 4.868 \times 10^{-2} T + 0.00174 \]

As the material properties of the solid changes, it is necessary to account for this, the most
adequate formula is given by Yang, where \( R_g \) is the universal gas constant (8.316 J/(mol.kg))
and \( E \) the activation energy for viscosity, 9.217 kJ/mol.

\[ \mu_s = 0.0126 \text{MLSS}^{1.644} e^\frac{E}{(R_g(T+273.15))} \]

<table>
<thead>
<tr>
<th>Sewage Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constituent</strong></td>
</tr>
<tr>
<td>Total Suspended Solids (TSS)</td>
</tr>
<tr>
<td>Biochemical Oxygen Demand (BOD)</td>
</tr>
<tr>
<td>Chemical Oxygen Demand (COD)</td>
</tr>
<tr>
<td>Nitrogen (total as N)</td>
</tr>
<tr>
<td>Phosphorus (total as P)</td>
</tr>
<tr>
<td>Fats, Oil, Grease (FOG)</td>
</tr>
</tbody>
</table>

Table 3.2.5 -2

For our current study it is not possible to quantify or even estimate what the current solid
waste amount is at our starting point. to evaluate how different fluids behave, see Table.
3.2.5 -3.

<table>
<thead>
<tr>
<th>Fluids</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newtonian fluids</td>
<td>it does not matter how fast they move or how much you agitate them, they flow the same</td>
</tr>
<tr>
<td>water, oil, alcohol and paint thinner</td>
<td></td>
</tr>
<tr>
<td>Dilatant fluids</td>
<td>whose viscosity increases with agitation until they become almost solid - they are impossible to pump in standard centrifugal pumps and require special measures to move them</td>
</tr>
<tr>
<td>cream and butte</td>
<td></td>
</tr>
<tr>
<td>Plastic fluids</td>
<td>have a yield value (the point of resistance) that must be exceeded before they can start flowing</td>
</tr>
<tr>
<td>ketchup</td>
<td></td>
</tr>
<tr>
<td>Thixotropic fluids</td>
<td>These fluids are viscous (thick) when standing still, but will become less viscous (thinner) over time with constant agitation.</td>
</tr>
<tr>
<td>Glues, non-drip paint, greases, cellulose compounds, soaps, starches and tar</td>
<td></td>
</tr>
</tbody>
</table>

Table. 3.2.5 - 3 Different fluids and its characteristics

Based on the table above, most fluids are temperature dependent. Temperature affects the
performance of the flux in the sewage, and that is why in many places that experience extreme changes in temperature, the main contribution of sewer blockages is correlated with a change of climate.

\(^{18}\) http://www.water-wastewater.com/
3.2.6. Misuse of the sewage network

There are many causes of sewage system overflows, including bad weather, system/network failure, or blockages within the pipes. According to a Report to Congress by the Environmental Protection Agency, in the United States, nearly 74% of sanitary sewer overflow (SSO) events are caused by partial or complete blockage of the pipes (Chapter 4, Environmental Protection Agency, 2004), followed by wet weather and inflow and infiltration, which cause 14% of overflows events. The primary cause of these blockages is grease, which implies misuse of the sewage system is a big problem. Grease in the sewage system can solidify and eventually block the pipes (2004, 4-28). When people knowingly or unknowingly pour grease down their drain it can clog the system. The buildup of this grease can eventually lead to large blockages when it solidifies. Overflows are more common in the winter when it is colder, which would make more grease solidify in the pipes. They are also more common during times when less water is used, potentially because blockages occur when the grease is flowing more slowly and thus more likely to solidify.19

Through interviews and literary research we have found two main forms of potential network misuse. The first form of misuse is dumping directly into the network. According to interviews with the municipality, manhole covers get stolen often, making it easier for things to fall directly into the pipes or be thrown into the sewers. The second form is the discharge of waste into the sewer system that the system is not designed to handle, like grease. Furthermore, members of the College of Civil Engineers said in interviews that disposal of non-sewage waste into the sewage system is more likely to block sewers in individual buildings than in public sewer lines that run under the street. As the focus of this work is street overflows, the civil engineers' opinions suggest that non-sewage waste is unlikely to be a significant cause of street sewage spills. It is difficult to determine the individual impact of each form of misuse because there is very little data available to analyze. However, it is clear that blockages are at least in part caused by misuse. To look at images of the unexpected items found in Sewers and removal process, refer to section Appendix 10.1.

3.2.7 Flow Relationship with Respect to Other Factors

To evaluate human impacts that can compromise the current sewer system in Córdoba because of rapid population growth, a rough evaluation of the city’s current sewer pipe system was investigated for this report. Specifically, we aimed to shed more light on the link between urbanization, public health, and population growth by better understanding connections between the population growth and the installation of the three different generations of piping that form the current system. Cordoba's actual coverage serves about 58% of their population, and to evaluate if their current sewer can sustain all these users, we completed a rough quantification and examination of its usage rate and sustainability. First,

![Fig. 3.2.6 - 1 Causes for overflows according to EPA, 2004](image)

CAUSES OF SSO EVENTS

<table>
<thead>
<tr>
<th>Causes of SSO Events</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blockages</td>
<td>74%</td>
</tr>
<tr>
<td>Wet weather and i/l</td>
<td>14%</td>
</tr>
<tr>
<td>Line breaks</td>
<td>7%</td>
</tr>
<tr>
<td>Mechanical or power failures</td>
<td>3%</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100%</td>
</tr>
</tbody>
</table>

See section 3.2.5 for influence of temperature in grease
however, we provide some necessary background about the construction and materials used in the city’s sewer system.

**Overview of Sewer System Materials**

According to Director of Sewage and Gas Networks Daniel Bardagi, when Cordoba’s sewer system was first planned the risk of a disease transfer and outbreak due to overflow was not well understood. As the need for better infrastructure increased, and knowledge about new materials and lower cost sewer piping were discovered, the municipality implemented ordinances to use different pipes all together. There were a total of three different generations of sewer piping installed in Córdoba from 1950 to 1980, and all of them were designed to exclusively carry domestic wastewater. The system was limited to only domestic wastewater because it was believed at the time to provide the most benefits and the lowest long-term costs compared to other disposal options. Cordoba’s sewer system is a centralized water-carriage system, modeled after the system used in Buenos Aires, and works by gravity. The system was first constructed using vitrified clay pipe, which still remains today in what is now the innermost ring of the city’s sewer system. Vitrified clay was chosen because it could be constructed with small diameter and in different shapes. In the 1960s, engineers identified the basic information about the area’s topography and population density, and it was then decided to use concrete instead of clay in expanding the sewer system. In the third generation of expansion during the late 1980s, the city switched to polyvinyl chloride (PVC) piping, as it had been discovered that concrete was sensitive to hydrogen sulfide (H2S) gas.

**Factors contributing to pipe deterioration**

Since the overall flow of a sewer system highly depends on the efficiency of the pipe, it is important to know the factors which contribute to the deterioration of the pipe. The performance of a pipe depends on a variety of factors such as material, soil and its characteristics, construction process, organic and inorganic chemical deposits, installation and maintenance. Moreover, as pipes age, other factors affecting performance emerge—as was the case with the corrosion of the concrete pipes caused by hydrogen sulfide gas. Production of H2S can create low velocities in a sewer line, and according to the American Society of Civil Engineers (ASCE), corrosion of this kind is one of the major failures in pipes, causing them to break in little as 10 years. Another major factor that could significantly impact the uneven flow of sewer pipes is infiltration by groundwater that enters sewer pipes through cracks, joints and unrepaired leaks (Burian et al., 2000). Since we performed our calculations by assuming that pipes work well, an efficiency factor should be introduced at the end of our calculations to account for the problems mentioned above. Table 3.2.7 summarizes the different pipes, as well as some limitations and problems that contribute to the deterioration of the performance of the pipes.

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20 Information provided by Cordoba’s municipality Eng. Daniel Bardagi on August 16, 2016
22 Water System and Its Deterioration by EPA, U.S.A
Table 3.2.7-1 Different type of pipes and its limitations

<table>
<thead>
<tr>
<th>Material and approximately year of installation</th>
<th>Approximation Diameter Ranges Installed in Córdoba [1]</th>
<th>Range Lifespan</th>
<th>Known Problems by using these pipes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay Pipe 1950</td>
<td>0.15m to 1.20 m</td>
<td>50 - 100 years</td>
<td>Stress concentration on pipe</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Easier Cracked (due to improper installations)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Very brittle</td>
</tr>
<tr>
<td>Concrete 1970’s</td>
<td>1.40 m to 2m</td>
<td>10 - 50 years</td>
<td>Extremely vulnerable to H2S,</td>
</tr>
<tr>
<td>PVC (Polyvinyl chloride) 1980’s - Present</td>
<td>1.40 m and up</td>
<td>50 - 500 years</td>
<td>Thermosets gradual falloff</td>
</tr>
</tbody>
</table>

Statistical Analysis Models

In a traditional way the use of water per person is calculated in the following matter:

\[
Q_m = \frac{p \times d}{24,000}
\]

\[
Q_d = Q_m \times \frac{24h}{1\text{dia}}
\]

Where \( p \) is the population and \( d \) is the consumption of water per person. Figure 3.2.7-1 shows the growth in water consumption with growth in population.

The flow of each generation of sewer piping is shown in Figure 3.2.7-2, using the formula below for calculating flow:

\[
Q_d = Q_m \times \frac{24h}{1\text{dia}}
\]

The specific parameters to the city of Córdoba are as follows:

\[ Q = v \times A = \text{caudal máximo de conducción} \]

\[ v = r^{1/2} \times R^{2/3} / n = \text{velocidad de conducción según Manning} \]

\[ i = \text{pendiente de la cañería} \]

\[ R_n = A / X = \text{Radio hidráulico} \]

\[ n = \text{coeficiente de Manning} \]

Manning equation:

\[ Q(h) = \frac{1}{n} AR(h)^{2/3} \sqrt{S} \] (using units of m and m/s)

n = friction coefficient
A = area filled with water
R = wetted perimeter
S = slope
D = diameter

We evaluated flow with respect to population growth in order to evaluate the performance of the three different pipes and see whether rapid population growth could be a cause for the increase in sewer overflows. As our calculations show, the current sewer systems were not planned to accommodate a rapid population increase. For example, the smaller diameter
found in the clay pipes, which are located in the central section of city, did not accounted for the dense population that is currently there. We will explain the areas where most of the overflows occurred in section 3.2 and compare how the three generations of piping contribute to the overflows.

### 3.2.8 Technical Issues – Sewer Overflows

Sanitary sewer overflows including those that do not reach the receiving waters tend to be an indication of improper operation and maintenance of the sewer system. Causes of sewer overflows include: blockages, insufficient conveyance capacity, collapsed or broken sewer pipes, vandalism (deliberate blockages), high levels of inflow (water leaking into manholes) and infiltration (groundwater leaking into sewers), and structural and mechanical failures. The principal pollutants in sewer overflows are microbial pathogens, oxygen depleting substances, total suspended solids (TSS), toxics, nutrients, and floatables.

In 2014, there were about 10,000 overflow events in Córdoba (1.3 million population). In the U.S. (318.9 million population), the threshold for high frequency overflows is about 100 overflows per year. The most common causes of sewage overflow events are: blockages (75%), inflow and infiltration from wet weather (14%), line breaks (7%), mechanical or power failure (3%), other (2%) (EPA, 2004). Grease is the most common cause of blockages causing about 47% of the blockage events. Grit, rock, and other debris cause 27%, and roots cause 22% (EPA, 2004).

Cordoba’s sewer system is a gravity system. Typically, gravity sewer systems are designed for a 0.6 m/s to 0.9 m/s flow rate so as to avoid settling and clogging of the pipes. A flow exceeding about 3m/s would cause scouring. The flow rate depends on the slope, diameter, and material of the pipes. If the slope is too shallow, clogging is more likely. And if the flow is too steep, scouring is more likely. The system is typically designed for flow at 60% with max flow at 90%\(^\text{24}\). Gravity sewers are not designed to be operated under pressure (which happens when the flow is 100%).

### 3.3 Sanitary Risks

Health is a precious, intangible commodity that is often taken for granted especially when it comes down to sanitary health risks. It is important to mention microbial pathogens, fats-oils-grease (FOG) and toxics, such as heavy metals and synthetic organic compounds that are present in wastewater when assessing the sanity risks on humans that are in contact with the waste (EPA, 2004). Microbial pathogens that exist in wastewater include bacteria, virus, and parasites. These pathogens are a threat to human health. It is critical to keep raw sewage out of the environment and away from people. Sewage pathogens have been linked to many illnesses, ranging from mild flu-like symptoms to serious disease. The types of organisms that may be present in wastewater, and the potential health effects associated with each, are described in Figure 3.3-1.

People get exposed to pathogens by ingestion. Pathogens can be ingested by means of drinking contaminated water or eating contaminated food, such as fish that are caught in contaminated water. Once people contract a pathogen-borne disease, they become carriers of the disease and can infect others through the fecal to oral route (NAS, 1993). Protozoan cryptosporidium parvum causes cryptosporidiosis, a gastrointestinal disease that affects people and animals. Upon infection, this protozoan resides principally in the gastrointestinal tract and goes through its life stages as an intracellular parasite. In the intestines, it forms oocytes that are exfoliated in feces, which is the source of infection (Gennaccaro et al, 2003). It is believed that viruses are contracted through direct contact with sewage, and are responsible for gastroenteritis, hepatitis, respiratory illness, and other health problems.

---

(Bittion, G et al. 1980). Common illnesses caused by viruses are viral gastroenteritis, acute nonbacterial gastroenteritis, food poisoning, and food infection.

Bacteria in sewage, such as Escherichia coli and enterococci, can cause diseases and illnesses. Enterococci are bacteria that normally live in the intestines and digestive system of humans. The bacteria help to break down wastes in the body, but can cause urinary tract infections, wound infections and blood infections if they get out of their normal/natural environment (WHO 2003). New strains of the bacteria, called Vancomycin Resistant Enterococcus (VRE), have developed a resistance gene to vast antibiotics, becoming super-bacteria. Since enterococci are found normally in the intestines, every time an antibiotic is taken, the bacteria are exposed. This resistance gene makes it very difficult for doctors to treat patients with VRE [Siegel, Jane D., et al. 2007].

<table>
<thead>
<tr>
<th>Organism</th>
<th>Health Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td></td>
</tr>
<tr>
<td>such as Escherischia Coli</td>
<td>Salmonelosis</td>
</tr>
<tr>
<td></td>
<td>Cholera</td>
</tr>
<tr>
<td></td>
<td>Food Poisoning</td>
</tr>
<tr>
<td></td>
<td>Acute Diarrhea</td>
</tr>
<tr>
<td></td>
<td>Typhoid Fever</td>
</tr>
<tr>
<td>Protozoa</td>
<td></td>
</tr>
<tr>
<td>such as Cryptosporidium</td>
<td>Abdominal Cramps</td>
</tr>
<tr>
<td></td>
<td>Intestinal Parasites</td>
</tr>
<tr>
<td></td>
<td>Acute Diarrhea</td>
</tr>
<tr>
<td></td>
<td>Ulcers</td>
</tr>
<tr>
<td>Viruses</td>
<td></td>
</tr>
<tr>
<td>such as Enterovirus</td>
<td>Diarrhea</td>
</tr>
<tr>
<td></td>
<td>Gastroenteritis</td>
</tr>
<tr>
<td></td>
<td>Hepatitis A</td>
</tr>
<tr>
<td></td>
<td>Meningitis</td>
</tr>
<tr>
<td></td>
<td>Pneumonia</td>
</tr>
<tr>
<td></td>
<td>Respiratory infections</td>
</tr>
<tr>
<td>Helminths (worms)</td>
<td>Anemia</td>
</tr>
<tr>
<td></td>
<td>Chest Pain</td>
</tr>
<tr>
<td></td>
<td>Digestive Problems</td>
</tr>
<tr>
<td></td>
<td>Fever</td>
</tr>
<tr>
<td></td>
<td>Insomnia</td>
</tr>
<tr>
<td></td>
<td>Muscle Aches</td>
</tr>
<tr>
<td></td>
<td>Vomiting</td>
</tr>
</tbody>
</table>

Table 3.3 -1 Potential health effects when in contact with sewage

3.3.1 Case Study of bacteria count in Córdoba

Cordoba’s current bacteria count. Sample of overflows at different locations within the city were tested at Centro de Quimica Aplicada (CEQUIMAP), report N° 16041821/01-16041821/03. Data sample was taken to CEQUIMAP, April 24 2016.

Limits as stated in CEQUIMAP’s report are Fecal coliforms 1,000 [NMP/100mL] and Total coliforms 5,000 [NMP/100mL]. Table 3.3.1 -1 shows that in the sewage overflows at different areas in Córdoba there are high levels of coliforms. More studies need to be performed in many more barrios to be able to quantify the total risk factor by the bacteria on humans and the environment.
There are a number of things that can contaminate wastewater that are not organic. These mainly consist of heavy metals and chemicals, which are usually from industrial runoff or illegal dumping of waste. Other inorganic materials can include alkaline, chloride, nitrogen, PH, phosphorus, sulfur, hydrogenated sulfide, methane, oxygen and more (Solórzano Ochoa, 1983). The consequences of this toxic waste include sanitary and public health risks, impact on the local agricultural industry and environment.

Heavy metals, which usually come from industrial runoff, have been found in the Río Suquía (Merlo et al., 2011). Clandestine connections from local factories could be inputting this pollution. There have been claims that factories are dumping waste into the river and that these chemicals contribute to the death of the local agriculture ecosystem. More research is necessary to confirm if pollution from factories is a significant cause of pollution in the river.

3.4 Socio-Economic Impacts

Our group witnessed many overflows throughout our time in the city. They are a part of daily life in Córdoba and many people do not know that the water in their streets is sewage water. Open sewage is a safety hazard because it can carry many bacteria and viruses. Needing medical attention or being unable to work due to sickness can have a large socioeconomic impact on people in the city. If the problem is not dealt with it will worsen and lead to many potential problems for Córdoba. This might cause property values to decrease and drastically affect the standard of living in the city. The results of a overflows in a sewage system may affect economic and commercial activity in Córdoba and decrease the city’s touristic appeal. The longer the problem is left unattended the worse it will get and the more expensive repairs and legal fees will become. Sewage systems are imperative in order for the city to function and develop.

There are many socioeconomic impacts that come from an inadequate sewage system. Many areas are not connected to the sewage network at all and face many serious health and safety issues because of this. Both Villa Libertador and Chacra de la Merced are economically disadvantaged neighborhoods, and hence the concentration of health impacts in these regions poses significant equity concerns which are beyond the scope of this report. For example, people cannot afford to move from deeply polluted areas such as Villa Libertador and Chacra de la Merced. Living in polluted areas can lead to negative health effects and a lower quality of life. In Villa Libertador there are subsidence issues caused...
from an elevated water table, interviewed residents and community workers claimed was
due largely to liquid waste from pozos negros, but UNC faculty claimed was attributable to
recent rainfall. Since the subsidence issues largely surfaced this year, while the existing
sewage disposal methods have been in place for decades, the latter opinion is at
substantiated by a very cursory glance at evidence. People interviewed cannot afford to
maintain their homes or develop a new sewage system that would have less impact on their
environment. In Chacra de la Merced, people can no longer farm or sustain themselves
economically because pollution has made their crops impermissibly contaminated with fecal
matter and may have decreased their ability to support themselves. Both of these communities
and many others are severely disadvantaged because of their lack of proper
sewage networks.

3.5 Environmental Impact of Overflows

In addition to more easily quantifiable costs of sewage overflows, there are environmental
costs to sewage overflows in the network itself. This section is divided into two subsections:
firstly an anticipatory review of potential impacts of sewer overflows using government
reports from Australia and the United States and secondly an overview of ecological studies
of the Río Suquía and an assessment of which contamination issues might be partially
dependent on sewage overflows within the City of Córdoba.

3.5.1 Potential Environmental Impacts

As a motivation for controlling the number and volume of sewage overflows, Australia’s
Natural Resource Management Ministerial Council (2004) enumerated the primary
constituents of sewage overflows, which was previously discussed in section 3.1.4. Similarly,
EPA (2004) identified the principal pollutants as:

1. Microbial pathogens
2. Oxygen depleting substances
3. Total Suspended Solids
4. Toxics
5. Nutrients
6. Floatables

EPA (2004) found that based on the 43% of sewage-only wastewater systems in the United
States, liquid in the system had the following amounts of principal contaminants (4.3):

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Amount</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fecal Chloroform</td>
<td>1,000,000-1,000,000,000</td>
<td>colonies/100mL</td>
</tr>
<tr>
<td>BOD</td>
<td>89-451</td>
<td>mg/L</td>
</tr>
<tr>
<td>TSS</td>
<td>118-457</td>
<td>mg/L</td>
</tr>
<tr>
<td>Toxins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>.1-101</td>
<td>ug/L</td>
</tr>
<tr>
<td>Copper</td>
<td>1.8-332</td>
<td>ug/L</td>
</tr>
<tr>
<td>Lead</td>
<td>0.5-250</td>
<td>ug/L</td>
</tr>
<tr>
<td>Zinc</td>
<td>9.7-1850</td>
<td>ug/L</td>
</tr>
<tr>
<td>Nutrients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>1.3-15.7</td>
<td>mg/L</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>11.4-16.1</td>
<td>mg/L</td>
</tr>
</tbody>
</table>

Table 3.5.1 -2. Potential environmental impacts of sewer overflows
They further noted that for rivers and streams, like the environment of Córdoba and the Río Suquía, the most important stressors generally are:

1. Pathogens
2. Siltation
3. Habitat Alteration
4. Oxygen Depleting Substances

3.5.2 Córdoba-Specific studies

This section outlines the scientific studies which have been performed on the Río Suquía and preliminarily assesses whether a better control of sewage overflows in the city network might decrease these environmental impacts. The studies are divided into three main classes, those that have to do with the pollution of the river generally, those that have to do with levels of human disease, and finally a biological indicators to assess the impact of pollution on the overall non-human ecosystem.

3.5.2.1 Pollution of the River

Merlo et al. (2011) retrieved sediment and water samples from four sites along the Río Suquía in August 2008 during low flow season and March 2009 during high flow season. Because of the sites chosen, any indicator which spikes at Site 2 (Córdoba City) could be attributed in part to the effect of sewage system overflows.

During low flow, the City seemed to be the main source of conductivity, nitrate, in the water samples and nitrate, organic carbon content, silt, clay, E coli and fecal coliforms in the sediment samples. During high flow, Site 2 seemed to be the primary source of E. Coli in the water samples and clay in the sediment samples.

Bonansea et al. (2013) tested pesticide levels at four points along the Río Suquía in July and November of 2010 and April and June of 2011. Since the second sample point is below both the Bajo Grande Treatment plant and the city, it is unclear if any spikes in pesticide levels observed at site 2 can be attributed to overflows from the sewage system or simply incomplete treatment at the Plant. However, this is a moot point, as no significant increases in any of the tested pesticides were discovered between la Calera and Villa Corazón de María (Bonansea et al., 2013).
5.3.1.2 Viral Infections

Sosa et al. (2012) tested 60 samples from February 2009 to July 2011 at the Bajo Grande Plant inlet for Polyomavirus BK. 87% of those samples tested positive. While BK virus transmission mode is unknown, it may be due to bodily fluid contamination, in which case sewage overflows in the urban area could pose a substantial transmission risk. The current sewage treatment system is unlikely to destroy BK viral particles, and therefore communities downstream of the Río Suquía will likely remain at risk under most feasible schemes.

Martinez et al. (2014) took water samples monthly at eight points on the Río Suquía and at the Bajo Grande treatment plant in 2007 and 2009-2011 and tested them for Hepatitis E antibodies, along with population samples and raw sewage samples within the City.

The study found Anti-HEV IgG in 6.3% of raw sewage samples, 3.2% of riverine samples in most areas, and 4.4% of the population. Since Hepatitis E is primarily transmitted by drinking fecally contaminated water, exposure to the Río Suquía contaminated with sewage overflow is a potential mode of Hepatitis E transmission for downstream communities (Wassaf et al., 2014).
5.3.1.3 Ecosystem Indicators

Hued et al. (2013) proposed the usage of biological indicators to combine all types of river contamination into a single indicator. For their purposes, they chose to examine liver and testicular tissue from male *J. multidenta* fish. They took samples from La Calera and Villa Corazón de María, so much like the results from Bonansea et al., we are not in a position to deconvolute the effects of incomplete treatment at the Bajo Grande plant and sewage overflows in the City.

![Map showing locations of sampling sites](image)

Fig. 3.5.2.3 -1 Map showing locations of sampling sites (Hued et al., 2013).

Downstream organisms showed disordered liver and testicular tissue, with potential implications for reproductive health. The downstream organisms were also shorter, weighed less, and had suppressed secondary sexual characteristics. This generally affirms that the environment downstream of the Bajo Grande treatment plant is inferior, though whether reductions in sewage overflows would improve this general biological indicator remains uncertain (Hued, Lo Nostro, Wunderlin, & Bistoni, 2013).
## 4 Method

### 4.1 Data Collection

During the first few weeks of the project we met with many different organizations and departments. In these meetings, we received a wide range of perspectives, however no supporting documentation nor bibliography was given to us. This chart summarizes the opinions and perspectives we received during each of our meetings.

<table>
<thead>
<tr>
<th>Meeting</th>
<th>Broad perspectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipalidad de Córdoba&lt;br&gt;&lt;strong&gt;Ing. Daniel Andres Bardagi&lt;/strong&gt;, Subdirector of Sanitary Networks and Gas, Municipality of Córdoba</td>
<td>• Data on current sewage system&lt;br&gt;• Information on Bajo Grande capacity&lt;br&gt;• Plan to expand sewage network and treatment plant capacity&lt;br&gt;• How breakages are dealt with&lt;br&gt;• Potential Solutions</td>
</tr>
<tr>
<td>Movimiento ADN&lt;br&gt;&lt;strong&gt;Ing. Andrés Méndez&lt;/strong&gt;, Agricultural Engineer&lt;br&gt;&lt;strong&gt;Natalia Herrera&lt;/strong&gt;, Urban Planner&lt;br&gt;&lt;strong&gt;Soledad Gómez&lt;/strong&gt;, Architect&lt;br&gt;&lt;strong&gt;Raúl Gimenez&lt;/strong&gt;, Doctor</td>
<td>• Causes of sewage problems&lt;br&gt;• Health and environmental effects&lt;br&gt;• Attempted solutions</td>
</tr>
<tr>
<td>Colegio de Ingenieros Civiles&lt;br&gt;&lt;strong&gt;Ing. Civil Teresa Inés Pereyra&lt;/strong&gt;, President of the Capital Region Board&lt;br&gt;&lt;strong&gt;Ing. Civil Luis Braceras&lt;/strong&gt;, Coordinator of the Transport Commission</td>
<td>• Problems with the sewer system&lt;br&gt;• How the sewer system works&lt;br&gt;• How sewage and gas is planned&lt;br&gt;• Population&lt;br&gt;• Pipe regulations&lt;br&gt;• Opinions about problems/solutions</td>
</tr>
<tr>
<td>Club De Derecho&lt;br&gt;&lt;strong&gt;Federico Macciocchi&lt;/strong&gt; - Lawyer, President of Club de Derecho</td>
<td>• Monsanto lawsuit&lt;br&gt;• Problems with the sewage system</td>
</tr>
<tr>
<td>CEDHA&lt;br&gt;&lt;strong&gt;Juan Miguel Picolotti&lt;/strong&gt; - Lawyer and Prosecutor</td>
<td>• 2001-2002 Well water analysis&lt;br&gt;• Solutions to drinking water problem&lt;br&gt;• Universidad Nacional de Córdoba&lt;br&gt;• Pending lawsuit information&lt;br&gt;• Issues with treatment plant expansion</td>
</tr>
<tr>
<td>EDAR&lt;br&gt;&lt;strong&gt;Ing. Gabriel Rustan&lt;/strong&gt;, Plant subdirector Depuradora de Aguas Residuales</td>
<td>• How the plant works&lt;br&gt;• Treatment process&lt;br&gt;• Plant capacity&lt;br&gt;• Issues with the last expansion of the plant</td>
</tr>
<tr>
<td>Las OMAS&lt;br&gt;&lt;strong&gt;Maria Weht&lt;/strong&gt;, President of NGO</td>
<td>• History of Chacra de la Merced&lt;br&gt;• Town medical center&lt;br&gt;• Coca-Cola water plant&lt;br&gt;• Injunctions from the town&lt;br&gt;• Water connection information&lt;br&gt;• Information about the NGO and the families in the area</td>
</tr>
<tr>
<td>Villa Libertador&lt;br&gt;Local organizing committee members of barrio</td>
<td>• Information about lawsuit over sewage conditions&lt;br&gt;• Municipalities efforts to help and study the sewage issue in Villa Libertador&lt;br&gt;• Medical Centers</td>
</tr>
</tbody>
</table>
| Universidad Nacional de Córdoba, Mgtr. Ing. Pablo Recabarren, Dean of the Faculty of Exact, Physical, and Natural Sciences | ● Bacteria content of water in the street and canal  
● Napa flooding  
● Septic tanks  
● Housing issues |
| --- | --- |
| Provincial Secretary of the Environment Dr. Javier Britch, Secretary of Environment and Climate Change | ● Problems with the sewage system  
● Current sewage pipe regulations  
● Information on wastewater wells  
● Immediate and long term solutions  
● Vandalism issues  
● Problems: lack of coverage and lack of capacity of the existing system |
| Universidad Libre del Ambiente Lic. Darío Gómez Pucheta, Lic. in Social Work | ● New environmental reforms  
● Responsibilities of the municipality and the provincial government  
● Problem: municipality doesn’t have any plans for the sewage system  
● Issues with the sewage system, treatment plant and contaminated river |
| Comisión de Ambiente Lic. Lucas Balian, City Counsellor | ● General plan for the city for water  
● Issues with misuse and capacity of the sewage system  
● Sewage system in the northern area of Córdoba  
● Villa Libertador  
● Plans to create new treatment plant and expand the sewage network  
● Collaboration with the National, Provincial and Municipal governments |
5 Analysis and Results

5.1 Statistical tests Computing

5.1.1 Number of overflows (Ω) ↔ Water consumption

Research question: Is there an association between the number of claims and the water consumption per person?

Objective: To describe and quantify the relation between the number of monthly claims and the monthly averaged water consumption per person.

Hypothesis: There exists significative correlation between the number of monthly claims and the monthly averaged water consumption per person.

To carry out with the proposed objective, a calculation of the linear bivariate correlation by the Pearson coefficient between the values of each variable was completed. The total number of claims in the City (Ω) showed a significant negative linear correlation with medium effect size, with the water consumption per person per month, $r (59) = -0.385, p < 0.05$. This means that the null hypothesis is rejected and the claims have a higher level to lower water consumption. In other words, there is a probabilistic trend that explains: for a lower average water consumption per person per month, there will be a higher (linearly proportional) total number of claims for failure of sewage networks. While this information is useful, not all barrios have the same number of claims, in fact there are a few barrios that accumulate a large majority of claims, so it is necessary to analyze these cases.

Research question: Is there an association between the number of claims and water consumption in barrios that have more claims in the City of Córdoba?

Objective: To describe and quantify the relationship between the number of monthly claims and the monthly water consumption in barrios that have more claims in the City of Córdoba.

Hypothesis: There is significant correlation between the number of claims and monthly water consumption in barrios that have more claims in the city of Córdoba.

As shown in the table, in barrios Alberdi, Alta Córdoba, Centro, Los Paraísos, Pueyrredón and Guemes, there were significant and negative correlations with medium effect size. This means that there is a probabilistic trend in which the higher water consumption per person in these barrios, the lower (linearly proportional) the number of claims for failure of sewage networks there.
5.1.2 Ω ↔ Rainfall

Research question: Is there association between the number of claims and the rainfall?

Objective: To describe and quantify the relation between the number of monthly claims and the volume of rainfall per month.\(^{25}\)

Hypothesis: There are significative correlations between the number of monthly claims and the volume of rainfall per month.

The total number of claims in the City (Ω) showed significant negative linear correlation with medium effect size (according to Cohen’s approach, 1988), with the rainfall per month, \(r (59) = -.260, \ p < 0.05\). This means that the null hypothesis is rejected and the claims have a lower level to higher rates of rainfall. In other words, there is a probabilistic trend that explains: for a higher volume of average rainfall per month, there will be lower (linearly proportional) total number of claims for failure of sewage networks. While this information is useful, not all barrios have the same number of claims, in fact there are a few barrios that accumulate the large majority of claims, so it is necessary to analyze these cases.

\(^{25}\) The data of monthly rainfall was provided by the Servicio Meteorológico Nacional de Argentina.
Correlations

<table>
<thead>
<tr>
<th>Claim</th>
<th>Pearson Correlation</th>
<th>Sig. (2-tailed)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALBERDI</td>
<td>-.060</td>
<td>.652</td>
<td>59</td>
</tr>
<tr>
<td>CENTRO</td>
<td>-.366**</td>
<td>.004</td>
<td>59</td>
</tr>
<tr>
<td>ALTA CBA</td>
<td>-.255</td>
<td>.051</td>
<td>59</td>
</tr>
<tr>
<td>S VICENTE</td>
<td>-.129</td>
<td>.329</td>
<td>59</td>
</tr>
<tr>
<td>A. Alberdi</td>
<td>-.054</td>
<td>.684</td>
<td>59</td>
</tr>
<tr>
<td>G. Bustos</td>
<td>.089</td>
<td>.502</td>
<td>59</td>
</tr>
<tr>
<td>San Martin</td>
<td>.025</td>
<td>.850</td>
<td>59</td>
</tr>
<tr>
<td>Grl. Paz</td>
<td>-.138</td>
<td>.296</td>
<td>59</td>
</tr>
<tr>
<td>Paraisos</td>
<td>-.401**</td>
<td>.002</td>
<td>59</td>
</tr>
<tr>
<td>Pueyrredon</td>
<td>-.137</td>
<td>.301</td>
<td>59</td>
</tr>
<tr>
<td>Zumaran</td>
<td>-.272</td>
<td>.037</td>
<td>59</td>
</tr>
<tr>
<td>Yapeyu</td>
<td>-.094</td>
<td>.477</td>
<td>59</td>
</tr>
<tr>
<td>Nva Cba</td>
<td>.016</td>
<td>.905</td>
<td>59</td>
</tr>
<tr>
<td>Guemes</td>
<td>-.010</td>
<td>.942</td>
<td>59</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

As seen in the table, in barrios Centro, Los Paraisos and Zumarán, the correlations were significant and negative with medium effect size. This means that there is a probabilistic trend in which the higher rainfall in these barrios, the lower (linearly proportional) the number of claims for failure of sewage networks there.

5.1.3 Ω ↔ Temperature (average, max, min)

5.1.3.1 Average Temperature

Research question: Is there an association between the number of claims and the meteorological average temperature?

Objective: To describe and quantify the relation between the number of monthly claims and the monthly meteorological average temperature.

Hypothesis: There is significant correlation between the total number of monthly claims and the monthly meteorological average temperature.

The total number of claims in the City (Ω) showed significant negative linear correlation with medium effect size with the monthly average temperature, \( r (59) = -0.399, p < 0.05 \). This means that the null hypothesis is rejected and the claims have a lower level to higher meteorologic average temperatures. In other words, there is a probabilistic trend which

26 All the data of temperatures were provided by the Servicio Meteorológico Nacional de Argentina.
explains: for a lower meteorological average temperature per month, there will be a higher (linearly proportional) total number of claims for failure in sewage networks. While this information is useful, not all barrios have the same number of claims, in fact there are a few barrios that accumulate a large majority of claims, so it is necessary to analyze these cases.

As seen in the table barrios Centro, Alta Cordoba, Alto Alberdi, Los Paraísos and Zumarán, the correlations were significant and negative with medium and large effect size. This means that there is a probabilistic trend in which at lower meteoritical average temperatures in these barrios, the higher (linearly proportional) the number of claims for failure of sewage networks there.

5.1.3.2 Maximum Temperature
Research question: Is there an association between the number of claims and the meteorological maximum temperature?
Objective: To describe and quantify the relation between the number of monthly claims and the monthly averaged meteorological maximum temperature.

Hypothesis: There is significant correlation between the total number of monthly claims and the monthly averaged meteorological maximum temperature.

The total number of claims in the City (Ω) showed significant negative linear correlation with medium effect size, with the monthly averaged maximum temperature, \( r (59) = -0.41, p < 0.01 \). This means that the null hypothesis is rejected and the claims have a lower level to a higher meteorological maximum temperature. In other words, there is a probabilistic trend which explains: for a lower meteorological maximum temperature averaged per month, there will be a higher (linearly proportional) total number of claims for failure of sewage networks. While this information is useful, not all barrios have the same number of claims, in fact there are a few barrios that accumulate a large majority of claims, so it is necessary to analyze these cases.

<table>
<thead>
<tr>
<th>Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Claim ALBERDI</strong></td>
</tr>
<tr>
<td><strong>Claim CENTRO</strong></td>
</tr>
<tr>
<td><strong>Claim ALTA CBA</strong></td>
</tr>
<tr>
<td><strong>Claim S VICENTE</strong></td>
</tr>
<tr>
<td><strong>Claim A. Alberdi</strong></td>
</tr>
<tr>
<td><strong>Claim G. Bustos</strong></td>
</tr>
<tr>
<td><strong>Claim San Martin</strong></td>
</tr>
<tr>
<td><strong>Claim Grl. Paz</strong></td>
</tr>
<tr>
<td><strong>Claim Paraisos</strong></td>
</tr>
<tr>
<td><strong>Claim Pueyrredon</strong></td>
</tr>
<tr>
<td><strong>Claim Zumaran</strong></td>
</tr>
<tr>
<td><strong>Claim Yapeyu</strong></td>
</tr>
<tr>
<td><strong>Claim Nva Cba</strong></td>
</tr>
<tr>
<td><strong>Claim Guemes</strong></td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
As shown in the table barrios Centro, Alberdi, Alta Cordoba, San Martin, Los Paraísos, Pueyrredón and Zumarán, the correlations were significant and negative with medium effect size. This means that there is a probabilistic trend which at lower monthly averaged meteorological maximum temperatures in those barrios, the higher (linearly proportional) the number of claims for failure of sewage networks there.

5.1.3.1 Minimum Temperature

Research question: Is there an association between the number of claims and the meteorological minimum temperature?

Objective: To describe and quantify the relation between the number of monthly claims and the monthly averaged meteorological minimum temperature.

Hypothesis: There is significant correlation between the total number of monthly claims and the monthly averaged meteorological minimum temperature.

<table>
<thead>
<tr>
<th>Correlations</th>
<th>Pearson Correlation</th>
<th>Sig. (2-tailed)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
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<td>.048</td>
<td>50</td>
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<tr>
<td>Claim CENTRO</td>
<td>-.371**</td>
<td>.008</td>
<td>50</td>
</tr>
<tr>
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<td>-.278</td>
<td>.050</td>
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<tr>
<td>Claim S VICENTE</td>
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<td>.080</td>
<td>50</td>
</tr>
<tr>
<td>Claim A. Alberdi</td>
<td>-.329*</td>
<td>.020</td>
<td>50</td>
</tr>
<tr>
<td>Claim G. Bustos</td>
<td>.259</td>
<td>.070</td>
<td>50</td>
</tr>
<tr>
<td>Claim San Martin</td>
<td>-.213</td>
<td>.137</td>
<td>50</td>
</tr>
<tr>
<td>Claim Grl. Paz</td>
<td>-.046</td>
<td>.753</td>
<td>50</td>
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<tr>
<td>Claim Paraisos</td>
<td>-.622**</td>
<td>.000</td>
<td>50</td>
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<tr>
<td>Claim Pueyrredon</td>
<td>-.298*</td>
<td>.035</td>
<td>50</td>
</tr>
<tr>
<td>Claim Zumaran</td>
<td>-.342*</td>
<td>.015</td>
<td>50</td>
</tr>
<tr>
<td>Claim Yapeyu</td>
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<td>.153</td>
<td>50</td>
</tr>
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<td>Claim Nva Cba</td>
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<td>.742</td>
<td>50</td>
</tr>
<tr>
<td>Claim Guemes</td>
<td>-.081</td>
<td>.574</td>
<td>50</td>
</tr>
</tbody>
</table>
The total number of claims in the City (Ω) showed significant negative linear correlation with medium effect size, with monthly averaged minimum temperature, $r (50) = -0.434$, $p < 0.05$. This means that the null hypothesis is rejected and the claims have a lower level to higher meteorological minimum temperature. In other words, there is a probabilistic trend which explains: for a lower monthly averaged minimum temperature, there will be a higher (linearly proportional) total number of claims for failure of sewage networks. While this information is useful, not all barrios have the same number of claims, in fact there are a few barrios that accumulate a large majority of claims, so it is necessary to analyze these cases.

As shown in the table barrios Centro, Alberdi, Alto Alberdi, Los Paraíso, Pueyrredón and Zumarán, the correlations were significant and negative with medium and large effect size (Los Paraíso). This means that there is a probabilistic trend which at lower monthly averaged meteorological minimum temperatures in those barrios, the higher (linearly proportional) the number of claims for failure of sewage networks there.

### 5.1.4 Ω ↔ Disease cases

#### 5.2.4.1 Diarrhea

**Research question:** Is there an association between the number of claims and cases of diarrhea?

**Objective:** To describe and quantify the relationship between the number of monthly claims and the monthly amount of reported cases of diarrhea.

**Hypothesis:** There is significant correlation between the number of monthly claims and the number of reported cases of diarrhea per month.

The total number of claims in the City (Ω) showed no significant linear correlation with the monthly number of reported cases of diarrhea, $r (59) = -0.031$, $p > 0.05$. This means that the null hypothesis is accepted and the claims have no relation to the number of reported cases of diarrhea. In other words, there is no probabilistic trend to explain a linearly proportional relationship between the number of reported cases of diarrhea and the total number of claims for failure of sewerage networks in the City of Córdoba.

#### 5.1.4.1 Acute Bloody Diarrhea

**Research question:** Is there an association between the number of claims and cases of acute bloody diarrhea

**Objective:** To describe and quantify the relationship between the number of monthly claims and the monthly amount of reported cases of acute bloody diarrhea.

**Hypothesis:** There is significant correlation between the number of monthly claims and the number of reported cases of acute bloody diarrhea per month.

The total number of claims in the City (Ω) showed no significant linear correlation with the monthly number of reported cases of acute bloody diarrhea, $r (59) = 0.112$, $p > 0.05$. This means that the null hypothesis is accepted and the claims have no relation to the number of reported cases of acute bloody diarrhea. In other words, there is no probabilistic trend to explain a linearly proportional relationship between the number of reported cases of acute bloody diarrhea and the total number of claims for failure of sewerage networks in the city of Córdoba.
5.1.5 Number of overflows (Ω) ↔ Population

Research question: Is there an association between the number of claims and the total population of the municipality of Córdoba?

Objective: To describe and quantify the relationship between the number of monthly claims and the total population of the municipality of Córdoba.

Hypothesis: There is significant correlation between the number of monthly claims and the total population of the municipality of Córdoba.

The population in the city of Córdoba has experienced a notable almost linear and steady growth from 1947 to 2001. Since 2001, growth has been slow in the 9 subsequent years, from 1,284,582 to 1,329,604 inhabitants.

To obtain the monthly population of the years after 2010, a linear and logarithmic estimation was made, taking as reference data from the last four census that account for a period of 19 years. Both the linear as the logarithmic function have an excellent degree of representation of the original curve of growth since 1991, with an index of $R^2 = 0.96$. The latter was chosen because it has a similar trend as the trend since the middle of the previous century.
Having mentioned this, the monthly estimates are shown in the following table.

### Estimated population by month and year in the city of Córdoba

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>1332902</td>
<td>1340488</td>
<td>1348072</td>
<td>1355651</td>
<td>1363227</td>
</tr>
<tr>
<td>2011</td>
<td>1333534</td>
<td>1341121</td>
<td>1348703</td>
<td>1356283</td>
<td>1363858</td>
</tr>
<tr>
<td>2012</td>
<td>1334166</td>
<td>1341753</td>
<td>1349335</td>
<td>1356914</td>
<td>1364489</td>
</tr>
<tr>
<td>2013</td>
<td>1334799</td>
<td>1342385</td>
<td>1349967</td>
<td>1357545</td>
<td>1365120</td>
</tr>
<tr>
<td>2014</td>
<td>1335431</td>
<td>1343017</td>
<td>1350599</td>
<td>1358177</td>
<td>1365751</td>
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<td>1336063</td>
<td>1343649</td>
<td>1351230</td>
<td>1358808</td>
<td>1366382</td>
</tr>
<tr>
<td></td>
<td>1336695</td>
<td>1344281</td>
<td>1351862</td>
<td>1359439</td>
<td>1367013</td>
</tr>
<tr>
<td></td>
<td>1337328</td>
<td>1344912</td>
<td>1352493</td>
<td>1360071</td>
<td>1367644</td>
</tr>
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<td></td>
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<td>1345544</td>
<td>1353125</td>
<td>1360702</td>
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</tr>
<tr>
<td></td>
<td>1338592</td>
<td>1346176</td>
<td>1353757</td>
<td>1361333</td>
<td>1368906</td>
</tr>
<tr>
<td></td>
<td>1339224</td>
<td>1346808</td>
<td>1354388</td>
<td>1361964</td>
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<tr>
<td></td>
<td>1339856</td>
<td>1347440</td>
<td>1355020</td>
<td>1362596</td>
<td>1370168</td>
</tr>
</tbody>
</table>

To carry out the proposed objective, a calculation of the linear bivariate correlation by the Pearson coefficient between the arithmetic mean of each variable was completed. The total number of claims in the City (Ω) showed significant positive linear correlation with a very large effect size, with the total population of the city of Córdoba, $r (59) = .632, p < 0.01$. This means that the null hypothesis is rejected and the claims have a higher level as the population increases. In other words, there is a probabilistic trend which explains: for a greater total number of population in the city, there will be a higher (linearly proportional) number of claims for failure of sewage networks. It is important to keep in mind that for this analysis the total population was used, including that which has no connection to sewage networks, so there is a certain level of error and serves only for illustration purposes.

While this information is useful, not all barrios have the same number of claims, in fact there are a few barrios that accumulate a large majority of claims, so it is necessary to analyze these cases.

#### 5.1.5.1 Population by barrio

Research question: Is there an association between the number of claims and the population in barrios that have more claims in the City of Córdoba?

Objective: To describe and quantify the relationship between the number of monthly claims and the population in barrios that have more claims in the City of Córdoba.

Hypothesis: There is significant correlation between the number of monthly claims and the population in barrios that have more claims in the City of Córdoba.
## Population in barrios per year

<table>
<thead>
<tr>
<th>Barrio</th>
<th>1991</th>
<th>2001</th>
<th>2008</th>
<th>2010</th>
<th>Surface (km²)</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nueva Córdoba</td>
<td>23533</td>
<td>29412</td>
<td>37231</td>
<td>37055</td>
<td>1.23</td>
<td>30028</td>
</tr>
<tr>
<td>Alta Córdoba</td>
<td>39401</td>
<td>34828</td>
<td>34894</td>
<td>34575</td>
<td>4.69</td>
<td>7365</td>
</tr>
<tr>
<td>ALBERDI</td>
<td>32404</td>
<td>31594</td>
<td>33758</td>
<td>32729</td>
<td>2.45</td>
<td>13337</td>
</tr>
<tr>
<td>Alto Alberdi</td>
<td>37147</td>
<td>30584</td>
<td>31198</td>
<td>30472</td>
<td>3.81</td>
<td>7992</td>
</tr>
<tr>
<td>CENTRO</td>
<td>34873</td>
<td>28949</td>
<td>29561</td>
<td>28200</td>
<td>2.89</td>
<td>9768</td>
</tr>
<tr>
<td>General Pueyrredón</td>
<td>21888</td>
<td>21598</td>
<td>21947</td>
<td>24021</td>
<td>2.99</td>
<td>8039</td>
</tr>
<tr>
<td>San Vicente</td>
<td>21129</td>
<td>19058</td>
<td>18448</td>
<td>18145</td>
<td>2.50</td>
<td>7267</td>
</tr>
<tr>
<td>General Bustos</td>
<td>18166</td>
<td>15978</td>
<td>15662</td>
<td>15659</td>
<td>1.72</td>
<td>9101</td>
</tr>
<tr>
<td>San Martín</td>
<td>14199</td>
<td>13748</td>
<td>12324</td>
<td>13157</td>
<td>1.49</td>
<td>8812</td>
</tr>
<tr>
<td>Güemes</td>
<td>13725</td>
<td>11679</td>
<td>11479</td>
<td>11588</td>
<td>1.00</td>
<td>11588</td>
</tr>
<tr>
<td>General Paz</td>
<td>9021</td>
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<td>8598</td>
<td>9524</td>
<td>1.15</td>
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<tr>
<td>Yapeyú</td>
<td>8941</td>
<td>8338</td>
<td>8019</td>
<td>8373</td>
<td>0.75</td>
<td>11096</td>
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<tr>
<td>Observatorio</td>
<td>8230</td>
<td>7352</td>
<td>6735</td>
<td>6616</td>
<td>0.82</td>
<td>8118</td>
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<tr>
<td>Müller</td>
<td>6989</td>
<td>5771</td>
<td>6009</td>
<td>5734</td>
<td>0.72</td>
<td>8020</td>
</tr>
<tr>
<td>Los ParaísoS</td>
<td>5709</td>
<td>5236</td>
<td>5223</td>
<td>5079</td>
<td>0.50</td>
<td>10197</td>
</tr>
<tr>
<td>Urca</td>
<td>4401</td>
<td>3652</td>
<td>3353</td>
<td>3308</td>
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<td>5162</td>
</tr>
<tr>
<td>Zumarán</td>
<td>4098</td>
<td>3749</td>
<td>3646</td>
<td>3542</td>
<td>0.39</td>
<td>9047</td>
</tr>
</tbody>
</table>


The sum of the population of these 17 barrios represents only 22% (287,777) of the total population of the City of Córdoba, however these accumulate 58% (4416) of the total amount of claims in the year 2010, as can be seen on the pie charts:
The exact population data from Census INDEC are available only until 2010. To estimate the population growth for the period 2010-2014, a polynomial function of the third degree was used, taking into reference the sum of population of these disadvantaged barrios from the census years (1991, 2001, 2008 and 2010).

The number of claims in disadvantaged barrios ($\Omega_{\text{barrios}}$) showed significant positive linear correlation with a large effect size to the total population of these barrios, $r (59) = .527$, $p < 0.01$. This means that the null hypothesis is rejected and there is a probabilistic trend which explains: For a higher total number of inhabitants in disadvantaged neighborhoods, there will be higher (linearly proportional) number of claims for failure of sewerage networks in those areas. Keep in mind that this calculation was done with an estimate, which may be subject to errors of accuracy, because we have no precise ways of knowing what happens to the population after 2010.

For a detailed analysis, barrio by barrio, we start with, Nueva Córdoba, which has experienced the highest population growth in the last 15 years and has the highest population density of the city. The same procedure was followed as with the total population of the city and then correlation tests were applied with the following result.

The number of claims in the barrio of Nueva Córdoba showed no significant linear correlation (and medium effect size), with the number of people in this barrio, $r (59) = .255$, $p > 0.05$. This means that the null hypothesis is accepted and the claims have no relation to the number of people. In other words, there is no probabilistic trend to explain a linearly proportional relationship between the estimated number of people and the number of claims for failure of sewerage networks for the period 2010-2014 in this barrio.
As shown in Fig. 5.1.5.1 -1, the growth linear profile estimation gives a slope of (84.75°) in New Córdoba, which is less than the total remaining linear profile slope of (88.35°). Still, the average annual growth of claims was 8.21% for the period.
population growth in Centro

\[ y = -318.45x + 668092.33 \]
\[ R^2 = 0.81 \]

\[ y = -637338.18 \ln(x) + 4875532.87 \]
\[ R^2 = 0.81 \]

population growth in Alta Córdoba

\[ y = -244.90x + 526346.72 \]
\[ R^2 = 0.82 \]

\[ y = -490173.12 \ln(x) + 3762291.50 \]
\[ R^2 = 0.82 \]
population growth in San Vicente

\[ y = -153.93x + 327444.08 \]
\[ R^2 = 0.97 \]

\[ y = -307987.73\ln(x) + 2360562.29 \]
\[ R^2 = 0.97 \]

population growth in Alto Alberdi

\[ y = -330.03x + 693243.21 \]
\[ R^2 = 0.78 \]
population growth in General Bustos

\[ y = -132.55x + 281788.11 \]
\[ R^2 = 0.89 \]

population growth in Alberdi

\[ y = 50.2239819005x - 67952.2737556561 \]
\[ R^2 = 0.2316720679 \]
### Correlations

<table>
<thead>
<tr>
<th>Claim</th>
<th>Hab Alberdi</th>
<th>Hab Nva Cba</th>
<th>Hab Centro</th>
<th>Hab Alta Cba</th>
<th>Hab San Vicente</th>
<th>Hab Alto Alberdi</th>
<th>Hab Gral Bustos</th>
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</thead>
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</tr>
<tr>
<td></td>
<td>N</td>
<td>59</td>
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<td><strong>Claim G. Bustos</strong></td>
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<td>Sig. (2-tailed)</td>
<td>.000</td>
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<td></td>
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<tr>
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</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.052</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As shown in the table barrios Alta Cordoba, San Vicente and General Bustos, there were significant and negative correlations with large and medium effect size. This means that
there is a probabilistic trend in which for a larger number of population in these barrios, the lower (linearly proportional) the number of claims for failure of sewage networks.

To have more indicators on possible associations with the population, a test of correlation was made between the number of claims in the 17 barrios with more claims and the density of population in these barrios during the year 2010 (data showed in the following table).

<table>
<thead>
<tr>
<th>Barrio</th>
<th>Density 2010 (habs/km²)</th>
<th>Claims 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nueva Córdoba</td>
<td>30028</td>
<td>145</td>
</tr>
<tr>
<td>Alta Córdoba</td>
<td>7365</td>
<td>435</td>
</tr>
<tr>
<td>ALBERDI</td>
<td>13337</td>
<td>519</td>
</tr>
<tr>
<td>Alto Alberdi</td>
<td>7992</td>
<td>388</td>
</tr>
<tr>
<td>CENTRO</td>
<td>9768</td>
<td>598</td>
</tr>
<tr>
<td>General Pueyrredón</td>
<td>8039</td>
<td>213</td>
</tr>
<tr>
<td>San Vicente</td>
<td>7267</td>
<td>342</td>
</tr>
<tr>
<td>General Bustos</td>
<td>9101</td>
<td>230</td>
</tr>
<tr>
<td>San Martin</td>
<td>8812</td>
<td>250</td>
</tr>
<tr>
<td>Güemes</td>
<td>11588</td>
<td>149</td>
</tr>
<tr>
<td>General Paz</td>
<td>8272</td>
<td>241</td>
</tr>
<tr>
<td>Yapeyú</td>
<td>11096</td>
<td>164</td>
</tr>
<tr>
<td>Observatorio</td>
<td>8118</td>
<td>109</td>
</tr>
<tr>
<td>Müller</td>
<td>8020</td>
<td>148</td>
</tr>
<tr>
<td>Los Paraísos</td>
<td>10197</td>
<td>220</td>
</tr>
<tr>
<td>Urca</td>
<td>5162</td>
<td>81</td>
</tr>
<tr>
<td>Ana María Zumarán</td>
<td>9047</td>
<td>184</td>
</tr>
</tbody>
</table>

The number of claims in the 17 barrios with the most claims showed no significant linear correlation (and very small effect size) with the density of population of these barrios during the year 2010: $r_s(17) = -0.010$, $p > 0.05$. This means that the null hypothesis is accepted and the claims have no relation to population density. In other words, there is no probabilistic trend to explain a linearly proportional relationship between population density and the number of claims for failure of sewerage networks in these barrios during the year 2010.

In addition, a calculation of correlations between claims in 2010 of each barrio and their growing ratios of population between 1991 and 2010 was made.
<table>
<thead>
<tr>
<th>Barrio</th>
<th>Growing ratio 2010/1991</th>
<th>Claims in 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centro</td>
<td>0.8086485</td>
<td>598</td>
</tr>
<tr>
<td>Alberdi</td>
<td>1.0100296</td>
<td>519</td>
</tr>
<tr>
<td>Alta Córdoba</td>
<td>0.8775158</td>
<td>435</td>
</tr>
<tr>
<td>Alto Alberdi</td>
<td>0.8203085</td>
<td>388</td>
</tr>
<tr>
<td>San Vicente</td>
<td>0.8587723</td>
<td>342</td>
</tr>
<tr>
<td>San Martin</td>
<td>0.9266146</td>
<td>250</td>
</tr>
<tr>
<td>General Paz</td>
<td>1.0557588</td>
<td>241</td>
</tr>
<tr>
<td>General Bustos</td>
<td>0.8619949</td>
<td>230</td>
</tr>
<tr>
<td>Los Paraisos</td>
<td>0.8896479</td>
<td>220</td>
</tr>
<tr>
<td>Pueyrredón</td>
<td>1.0974507</td>
<td>213</td>
</tr>
<tr>
<td>Yapeyu</td>
<td>0.9364724</td>
<td>164</td>
</tr>
<tr>
<td>Güemes</td>
<td>0.8442987</td>
<td>149</td>
</tr>
<tr>
<td>Müller</td>
<td>0.8204321</td>
<td>148</td>
</tr>
<tr>
<td>Nueva Córdoba</td>
<td>1.5745974</td>
<td>145</td>
</tr>
<tr>
<td>Observatorio</td>
<td>0.8038882</td>
<td>109</td>
</tr>
</tbody>
</table>

As a result, no significant linear correlation was found. \( r_s (15) = -.064, p > 0.05. \) This means that the null hypothesis is accepted and there is no probabilistic trend to explain a linearly proportional relationship between the demographic growth rate (1991-2010) and the number of claims for failure of sewerage networks in these barrios during 2010.

Finally, a calculation of correlations between the annual claims made in each barrio, with most claims in 2010 and the corresponding population in that year.
The total annual number of claims in each disadvantaged barrios did show significant positive linear correlation with a large effect size to their respective numbers in 2010, \( r_s (17) = .586, p <0.05 \). This means that the null hypothesis is rejected and there is a probabilistic trend which explains: in barrios with the highest number of inhabitants, higher (linearly proportional) was the amount of annual claims for failure of the sewerage networks in 2010. Still, as shown in the bar graph, Nueva Córdoba, home to the largest number of inhabitants, is far from being among the most disadvantaged barrios. In fact, as an example, barrio Zumarán, with less than one-tenth of the population of New Cordoba, had 27% more claims than Nueva Cordoba.
Graph in log scale for claims and hab per barrio

- Nueva Cordoba
- Alta Cordoba
- ALBDEL
- ALTO
- CENTRO
- San Vicente
- General Basset
- San Martin
- General Paz
- Franz Mi
- General C.
- Muller
- Las Pintado
- Ulick
- Zumeta

claims 2010
habitaciones 2010
6 Discussion

6.1 Implications of the results

Many of our correlations do not necessarily equate to causation. In other words, just because two events are correlated did not mean one caused the other. However, in this section we will try our best to offer possible explanations for significant results.

Water Consumption
Significant and negative correlation between water consumption and overflows (overall, and most disadvantaged barrios - as seen in table 5.1.1-1). This might be because more water in the system means grease gets washed out. Also more water could help mobilize other sources of trash. In addition, a spurious correlation between water consumption and the atmospheric temperatures associated with seasonal periods is highly possible.

Rain
We found an overall negative correlation between rain and breakages. One possible explanation for this is that grease is clogging the pipes, and more water means said grease gets washed out. More water flowing through the pipes could also help mobilize other sources of trash. More rain could mean that people don’t notice breakages as much, and so there are fewer reported incidents. The rainy season is also in the summer when it is warm, and the temperature could be affecting the amount of breakages as well.

Monthly Averaged, Average Temperature
Average monthly temperature showed a negative correlation with sewage overflows, meaning as the maximum temperature increased, overflow counts went down. During hotter months, the city’s daily water consumption increases, which means more water is entering the sewerage system. Increased sewer flow could help mobilize trash and other blockage-causing materials. In particular, warmer temperatures could help mobilize grease and oil, the build-up of which is a principal cause for sewer blockages in the US (EPA, 2004). Another explanation for the decrease in blockages with higher temperatures is that hotter months tend to have more rainfall. This is another cause for more water entering the sewerage system, resulting in the same increased flow to clear out blockage-prone materials. It should be noted, however, that while both rainfall and average temperature have a negative correlation with blockages, temperature is more strongly correlated.

Monthly Averaged, Maximum Temperature
Maximum daily temperature, averaged by month, showed a negative correlation with sewage overflows. Possible explanations are the same as for average temperature.

Monthly Averaged, Minimum Temperature
Minimum daily temperature, averaged by month, showed a positive correlation with sewage overflows. Possible explanations are that lower temperatures produce the opposite effects described for higher temperatures above. Colder months coincide with lower daily water consumption, and less rainfall. As such, it is possible that a lower water flow in the sewer pipes allows for blockage-causing materials to accumulate.

Gastroenteric Disease Diagnoses
There was a slight negative correlation between diagnoses of gastroenteric diseases and overflows. This correlation was weak and likely is unrelated, thus we cannot make any definitive statements using this data. However, diarrhea is a symptom that can be caused by many irritants and can only serve as a general indicator. The fact that there is no correlation
with sewer overflows, does not mean that there is no risk of getting sick with gastroenteric diseases.

Population

As observed in demographic charts between 1991 and 2010, there has been no drastic or sudden changes in population, with the exception of Nueva Córdoba which grew by 63% in its population. Interestingly, the monthly claims in that barrio showed no significant correlation with its estimated population\(^{27}\) and despite having the highest density and population of the city, it is far from producing the most claims of overflows. Moreover, the population density and the growth rate in barrios with most overflows claims did not showed significant correlations with annual claims in 2010. However, the annual number of claims in each disadvantaged barrio did show significant positive linear correlation with a large effect size with their respective numbers in 2010, which means that in barrios with the highest number of inhabitants, higher (linearly proportional) was the amount of annual claims for failure sewerage networks in 2010. Throughout the period 2010-2014, most of the most problematic barrios (eg, Alta Córdoba, San Vicente and General Bustos) correlations of their estimated populations and monthly claims were significant and negative, which means that claims increased as its population decreased. Why this should be correlated to a fewer overflows is an open question.

These results show a complex and heterogeneous relationship between claims and demographic indices. The case of New Cordoba is perhaps the most important for having the highest population density, in addition to having the highest population growth, and therefore the various agents referenced it as the example of the growth associated with increased overflows. However, the results obtained in this case suggest that the number of people or population density would have no linear relationship to the number of claims. In fact, any of the districts with smaller population than New Córdoba, exceed the number of claims in the latter. For example, Zumarán with less than one-tenth of the population of Nueva Córdoba, exceeds the number of claims in Nueva Córdoba by 27%. Still, more studies involving larger ranges of time and amount of data for a more complete understanding of the situation are needed.

Increase in Overflows Per Year

Upon observation of total system overflows per month from 2010 to 2014, there seems to be a general trend of increasing number of overflows each year, independent of seasonal variation. Observe Fig. 3.2.1 - 3 to see that from 2010 - 2014, each year’s graphed overflows roughly follow a similar curve throughout the year, and that each sequential year, the curve is maintained while the number of overflows trend an increase. One possible explanation is that grease and oil may be accumulating annually in the system, and if left uncleared, may result in greater propensity to overflow each year. However, if this theory was correct, we would expect to see a correlation between the age of a part of the system and the number of overflows per barrio, which we could not prove due to the lack of technical information about the sewers network. Therefore, we have no confident explanation of this trend.

6.2 Technical Recommendations

There are a number of technical recommendations that can be taken from this report that could help with achieving a lower number of breakages in the city. Most of these recommendations revolve around collecting more detailed information on breakages and how they happen. We recommend the assessment of the extent to which grease, oils and

\(^{27}\) Note: Keep in mind that this linear estimate is not absolutely precise.
fats are the cause of blockages. We also recommend investigating specific locations where multiple breakages occur multiple times a year, why those are problematic areas, and how to better provide long-term maintenance in those areas.

Gathering more information on clandestine connections, when/how manhole covers get stolen, and causes of individual information would also be useful in pinpointing the exact problem. For example, keeping track of how maintenance was performed and observations at site (i.e. what they saw/extracted from the pipe) and other more in depth data captured in the field would be invaluable information. Improved interagency data sharing would also help future parties trying to solve the problem.

Once it is more clear what is causing the problem, it will be easier to decide on an effective solution. If the problem is mainly due to misuse of the system, an awareness campaign on what should go in the sewer and what should not would be effective. Or perhaps a change to how maintenance is done would improve the occurrence of multiple breakages. Limits on solid waste may be another viable solution. Most likely, there will need to be multiple different solutions to solve the problem.

6.3 Limitations of the Study

This study is limited by several factors:

Population extrapolation: Our correlations with population are based on National Census (INDEC) data from 1991, 2001, 2008, and 2010 extrapolated in linear and logarithmic forms from 2010 to 2014. While the data remains barrio-specific, we are extending the fits to years where we have no data. The correlations between overflow events and population were obtained with population data that actually spans the range when we have overflow data, which means a level of error.

Limitations of diseases data: data received were for years 2010 to 2015 that was recorded by hospitals reporting the patient diagnosis. Information about actual location of contamination was not obtained, people tend to work, live and attend hospitals in different barrios. Diarrhea is a symptom that can be caused by many irritants and can only serve as a general indicator. The fact that there is no correlation with sewer overflows, does not mean that there is no risk of getting sick with gastroenteric diseases.

Ambiguity in overflow data claims: Data set of daily sewage network repair claims were unclear in parts. Claims could be a repair on an overflowing pipe, or just an amplification of the network pipes at that location. We assumed all entries to be an overflow or malfunction of the system, which may result in an overestimate of the overflows. However, the entries in the overflow data set were often ambiguous (ex: missing location of the claim, missing the date of the claim, or a combination of other important data points per claim), which may suggest data reporting is not always thorough or accurate. Claims may be underreported by workers or citizens (particularly in historically disenfranchised barrios), or misreported, further affecting our analyses correlating overflows/system malfunction with other data sets.

Limitations of water consumption data: the water consumption data are presented by month for the City of Córdoba in average liters per person person. However, the numbers represent not only domestic usage but an aggregate of domestic, governmental, industrial, and leakage, titled “dotación aparente”. The data are not provided per barrio which also limits our correlation to the city level rather than the barrio level.

Lack of information on the condition of the sewerage network: we have very limited data on the condition of the pipelines and have not been able to obtain information from the operators who address the overflows on the usual causes. We know generally the mix of
pipeline materials and the typical causes of overflows based on studies done elsewhere. It would greatly improve our analysis to have some data on the conditions of the pipes, the materials, diameters, and frequent causes of overflows.

In this study, we have operated statistically only with associations tests. These associations outcomes mean potential influences or relationships and should not be confused with causality. As the matter of fact, an association is a relationship between concepts, ideas, variables, etc., meaning the variables are related by something in common.

6.4 Difficulties

We faced several difficulties in the research process for this study:

*Difficult to Access Data:* The attainment of empirical data was more difficult than expected, mostly due to the data not being easily accessible to the public. Most data could only be acquired by directly asking the Municipality or other government organizations, whom were often slow to respond to our requests, or would deny our access to the information for reasons we can only speculate. One very likely possibility for this lack of data is that the Municipality, in fact, does not empirically track the data we requested.

*Disorganized data:* The data we received from the Municipality of Córdoba was notably disorganized and it is a potential indicator of lack of appropriate recording. Adapt the database to make it more accurate for our objectives within the required timeframe.

*Statistically Unverified Statements in Public Discourse:* Interviewers from all parties made sweeping statements on the state of the sewage system and the causes of blockages, tending to highlight personal experience or individual examples to illustrate their point. An understanding of the importance of statistical verification of these claims does not seem common amongst any of the stakeholders interviewed.

*Political Image Use:* There appears to be no expectation that pictures taken of a private group remain the property of that group and can only be used with permission. As such, future groups are strongly advised to make clear any expectations of politically neutral use of images with each individual photo-taker. This is particularly important when students anticipate relying on political adversaries of photo-takers for information to complete their project. Opposition groups and affiliated NGO’s have an inherent interest in making municipal issues seem as severe as possible and attributing them to the Municipality. The presence of Stanford engineering students can play into this narrative, to the detriment of long and medium term access to information. In order to gather data from opposing sources, it may be helpful to remind all interviewees of the technical/engineering focus of the project, and the need to situate it in a complete political context.

*Requesting data sooner/More time for data analysis:* It took us two or three weeks to figure out what data we wanted and who we were going to ask to give us that data. This left us with less than two weeks to sort through the data we obtained, decide what was important, and do analysis. It would have been helpful to figure out what types of data we were going to ask for and who we wanted to meet with, to our best ability, before coming to Argentina. There were a few activities/meetings we figured out would have been useful, but didn’t have the time for them. Getting our hands on some type of data and reaching the analysis stage sooner may have helped guide our research and schedule.

Lack of access to digital data: information is a critical tool in resource management, regional planning and economic development. It is unfortunate that Córdoba is hampered by the lack of accurate and detailed spatial of demographic data, water consumption, and many other data sets that governmental agencies should provide relatively easy and well organized access to. Because of the lack of these resources, it was difficult to collect, verify and
typically validate the data that was used in this report. Therefore, we had to relay in verbal sources, and work with the inclusion of the data we had access to.

*Extreme politicization of problem:* This project was made even more complex because it a political hot topic. The current government, their opposition, and groups that work with them such as the *Movimiento ADN*, all had their own agendas and wanted to work with us/use us to further those agendas. It’s very difficult to get access to data or hard facts because everyone is very opinionated and most of the information people give us is just opinions. Many of our meetings were just about different people’s opinions and unfounded claims. It is difficult for people to give objective perspective because there are two very drastic extremes and almost everyone is biased on the topic. There was a big push from ADN for us to work and look at Villa Libertador because it is currently in the news and a popular topic politically. It is very difficult for anything to actually get done because everyone has political alliances.

*Time Frame:* One of the things that made this project really difficult was the time frame. We were only in Córdoba for 5 weeks which is hardly enough time to cover a problem this complex and create real solutions for it. Getting access to data and information is difficult because it takes a long time to email government officials and people with information. Processes and politics are slow and we were crammed on time in many ways. We had enough time to learn about the problem and get a deep understanding of the issue but not enough time to really think of a solution. It is necessary to get a better understanding of the project and its direction during the spring quarter class in order to maximize time in country. Hopefully the research we did can be the foundation for future years so the next groups can jump more directly into the engineering and solution part of the project.

### 6.5 Recommendations for future work

Our group decided to focus on the pre-existing sewage network and to analyze its possible failures and shortcomings. However, as we found in the earlier weeks, the sewage and sanitation challenges facing the city are numerous and complex. Here are some of our suggestions for further interesting directions of study.

- More in-depth study of the existing network: due to the difficulty of acquiring official data with our limited time frame, successive groups may be able to further our data analysis with more in depth and comprehensive data, or to include new data resources we did not explore which include, but are not limited to:
  - Population, development, and density data post-2010
  - More detailed breakdown of water consumption per resident
  - Investigate the maintenance and repair operations of overflows
- Analysis of the Bajo Grande sewage treatment plant and its plans for amplification
- Study the pollution of the Rio Suquía (extended to those types of pollutants that haven’t been considered in any previous study).
- Sewage and sanitation systems for areas without sewage network access
- Health impacts of river and water contamination
- Geography, hydrology, and ecological characteristics of Córdoba

*Extraneous suggestion:* decide early (pre-departure) which topic is of most interest to the group so that data that must be obtained from official sources and government entities can be accessed by the time the program begins.
Acknowledgements

We would like to express our deepest appreciation to Victoria Bianchi, the General Manager of Global Engineering Programs at Stanford University that organized, assembled our team and worked with Child Family Health International (CFHI) to make this project a reality. We would like to thanks Carlos Giavay, head of IntercambioCulturalCórdoba, for organizing our visits and interviews with the different organizations and providing comfort in our stay in Córdoba. We would further like to express our gratitude to the Municipality of Córdoba for kindly providing information for our analysis and allowing us to visit the Estación De Aguas Residuales (EDAR) treatment plant. Also, to Aguas Cordobesas, Servicio Meteorológico Nacional, and Área de Epidemiología Provincial for providing empirical data for water consumption, rain and temperature, and diseases cases respectively. Additionally, to Centro de Derechos Humanos y Ambiente (CEDHA) and Club de Derecho for giving us valuable insight on the judicial proceedings in the city of Córdoba, Movimiento ADN for taking us to meet with OMAS NGO and taking us to Villa Libertador, and the Colegio de Ingenieros Civiles, Universidad Tecnológica Nacional (Regional Córdoba), Universidad Nacional de Córdoba (Faculty of Exact, Physical, and Natural Sciences) for providing us with a technical & engineering perspective and showing us the facilities. Finally we would like to give a special thanks to Secretaría de Ambiente Natural y Cambio Climático providing us with a macroscopic perspective.
References


BN Americas. (2016, July). Córdoba wastewater treatment plant expansion and drainage pipelines. http://www.bnamericas.com/project-profile/en/colectores-y-ampliaci%C3%B3n-de-plantadepuradora-de-liquidos-cloacales-de-C%C3%B3rdoba-colectores-y-ampliaci%C3%B3n-de-plantadepuradora-de-liquidos-cloacales-de-C%C3%B3rdoba


Appendix

10.1 Photos of the Blockages and Removal Process

Fig. 10.1 - 1 blockages found in the sewage system (Provided by the Municipality of Córdoba)

Fig. 10.1 - 2 blockages found in the sewage system (Provided by the Municipality of Córdoba)
Fig. 10.1 - 3 blockages removal process  (Provided by the Municipality of Córdoba)

Fig. 10.1 - 4 blockages removal process  (Provided by the Municipality of Córdoba)
Fig. 10.1 - 5 blockages removal process  (Provided by the Municipality of Córdoba)

Fig. 10.1 - 6 Sewage system when blockages occur  (Provided by the Municipality of Córdoba)
Fig. 10.1 - 7 Sewage system when blockages occur (Provided by the Municipality of Córdoba)

10.2 Photos of Sewage Overflows in the city

Fig. 10.2 - 1 Overflow (provided by Stanford group members)
Fig. 10.2 - 2 Overflow (provided by Stanford group members)

Fig. 10.2 - 3 Overflow (provided by Stanford group members)
10.3 Photos of Sewage Overflows in Villa Libertador

Fig. 10.3 - 1 River contaminated (provided by Stanford group members)

Fig. 10.3 - 2 Overflow (provided by Stanford group members)
Fig. 10.3 - 3 Houses (provided by Stanford group members)

10.4 Photos of Rio Suquia downstream of EDAR plant in Chacra de la Merced

Fig. 10.4 - 1 Chacra de la Merced (provided by Stanford group members)
Fig. 10.4 - 2 Rio Suquia downstream of EDAR plant (provided by Stanford group members)

Fig. 10.4 - 3 Rio Suquia downstream of EDAR plant (provided by Stanford group members)
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Watch the experience