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THE UNATTENDED PUBLIC HEALTH CRISIS: ANTIBIOTIC RESISTANT BACTERIA IN PUERTO RICO'S SURFACE WATERS AND ITS POSSIBLE NEGATIVE EFFECTS ON PUBLIC HEALTH

LA CRISIS DE SALUD PÚBLICA DESATENDIDA: BACTERIAS RESISTENTES A ANTIBIÓTICOS EN LAS AGUAS DE PUERTO RICO Y SUS POSIBLES EFECTOS NEGATIVOS EN LA SALUD PÚBLICA

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Abstract
This research evaluates how the incorrect disposal of antibiotics through wastewater and inability to process medications and other bioactive compounds can cause antibiotic-resistant bacteria and its implications for public health in Puerto Rico. This study found that there are multiple sources of contamination with antibiotics such as individual incorrect disposal, animal waste from farms, and pharmaceuticals in humans—the latter being the most prevalent form of contamination. There is a risk of an antibiotic-resistant bacteria outbreak due to its presence in water and multiple sources of contamination which could have potential detrimental effects if left unattended.

Keywords: surface waters, antibiotics, public health, Puerto Rico

Resumen
Esta investigación evalúa como el desecho incorrecto de antibióticos en las aguas negras e inhabilidad de procesar medicamentos y otros compuestos bioactivos pueden causar la proliferación de bacterias resistentes a antibióticos y sus implicaciones a la salud pública de Puerto Rico. Este estudio encontró que hay múltiples fuentes de contaminación con antibióticos como el desecho incorrecto individual, excreta de animal y residuales bioactivos en desechos humanos—el último siendo el más prevalente. Existe un riesgo de un brote de bacterias resistentes a antibióticos debido a su presencia en las aguas filtradas en Puerto Rico lo cual puede tener efectos detrimentales si no es atendido.

Palabras claves: antibióticos, salud pública, aguas potables, Puerto Rico

Introduction

A new era for humanity was marked in 1928 when penicillin, an antibiotic, was discovered. The first antibiotic baffled scientists by revolutionizing surgery, infection treatment, patient life expectancy, and medicine as we know it. Since its discovery a century ago, it has been refined and broadened into different antibiotics for therapeutic purposes (Penicillin, 2021). The evolution and widespread use of antibiotics has led to increased accessibility to this medication and, subsequently, inadequate dosing and disposal of antibiotics, which in turn caused antibiotic-resistant bacteria (ARB) (Mobarki, 2019). These ARBs have been observed since 1977 (Phillpot-Howard et al., 1982), and no active policy to prevent or treat ARBs has been specifically identified.

In recent years, a surge of cases concerning ARB have been observed to have a higher mortality rate and are harder to treat even with early intervention (Kang, 2005). Antibiotics in oral and topical treatments enter the water system through human urine or feces in wastewater. Nevertheless, these medications can be disposed of incorrectly by flushing them in sinks and toilets. However, water filtration plants are not designed to remove antibiotic residues or metabolites present in wastewater (Zhang, 2009). Consequently, the ecosystem and, more specifically, the water carrying these biological active residues can harm agricultural practices, animals, and humans. The U.S. Food and Drug Administration (FDA) and U.S. Environmental Protection Agency (EPA) have different guidelines to address these issues. FDA focuses on the safe disposal of unwanted, unused, or expired prescriptions (FDA, 2022), while EPA's guidelines prioritize environmental impact (EPA, 2022). Both agencies do not recommend flushing medication and advise using authorized collection programs or in-home disposal methods that render the medication unusable. The lack of united vision by these major agencies contributes to the poor governmental strategies to educate the public on adequate usage and disposal of antibiotics.

In Puerto Rico, the possibility to purchase antibiotics can be made without a doctor's prescription, leading to incorrect treatment and disposal of antibiotics via sinks and toilets to the water system. Moreover, there are currently no active campaigns on the island to inform the population of the adverse risks of the generalized use of antibiotics and the improper disposal of unused remnants. Therefore, the proposed hypotheses are the following:

(1) The generalized use of antibiotics locally can lead to environmental human exposure to antibiotic-resistant bacteria in Puerto Rico.

(2) Improper disposal of antibiotic medications through the house toilets can promote human environmental exposure to antibiotic-resistant bacteria in Puerto Rico.

The gathered information will be used to properly assess the actual risk of ARB in our water bodies and its possible effects on Puerto Rico's public health. These inquiries will allow us to form a relationship between these different sources to accept or reject the proposed hypotheses. The first step will be to gather evidence of ARB already present or not in surface water bodies on the island. Then, to identify the bacteria found as normal strains versus resistant to antibiotics due to their presence in recreational waters. The proposed research will also assess the improper disposal practices of antibiotics in various areas and identify high-risk surface water bodies. Finally, Puerto Rico's water provider, the AAA, will be contacted to share the research results.

The gap of knowledge for this study is that not all water bodies on the island have been tested for the presence of antibiotic medications and ARB. This fact can be hiding a possible public health problem whose consequences are complicated to predict now due to the lack of information.

Methodology

The information evaluated and analyzed for this research will consist of quantitative and qualitative data. Statistical data will be used to analyze and interpret percentages, significant values, and any correlations of antibiotic resistance bacteria presence and illness rates as well as ARB population concentrations in surface waters. We will use qualitative information describing characteristics of human environmental exposure to pathological bacteria in surface waters, the general practices of antibiotic use by the local population, and the disposal through home toilets of the unused remnants of prescribed antibiotics. Utilizing both data types will bring a more comprehensive analysis to test how antibiotic prescription, generalized use, and incorrect disposal of antibiotics through home toilets can promote antibiotic resistance bacteria in Puerto Rico's surface waters.

Published peer-reviewed journal studies and articles concerning antibiotic resistance bacteria in environmental presence, human exposure, and possible consequences in Puerto Rico or elsewhere will be the main sources of information. Furthermore, medical research concerning antibiotic usage in patient care and clinical cases will

be taken into consideration. The island's drinking water and wastewater treatment provider, Puerto Rico's Aqueduct and Sewers Authority (PRASA), will be contacted for a more specific look at the current situation regarding Puerto Rico's incorrect antibiotic disposal. Multiple sources of scientific evidence, both in the qualitative and quantitative analysis, will be used in the proposed research to determine if the generalized prescription and use of antibiotics by the local population and the incorrect disposal of the unused remnants of antibiotics can promote the development of antibiotic-resistant bacteria in Puerto Rico's surface waters that can cause a future public health problem.

Results

Medications, like antibiotics, end up in surface water bodies when they are discharged from a treatment plant into a receptor surface water body. The residues or metabolites in the surface water body create a selective environmental pressure that favors the reproduction of antibiotic-resistant bacteria. Therefore, multiple types of bacteria, including harmful ones, create resistance. Antibiotic-resistant bacteria, with antibiotic resistance genes (ARGs), can transfer genes to otherwise non-harmful bacteria and have been identified in surface water bodies (Vazquez-Piñero, 2019). Since the water that passes through treatment plants returns to the environment, it reaches the ecosystem's soil and surface waters, exposing humans and animals in the area and beyond.

Scientists regard antibiotic-resistant bacteria as the new challenge in health due to their unresponsive nature to antibiotics. An infection with such bacteria, even with proper intervention, is much deadlier than a wild strain (Kang et al., 2005). A minimum presence of ARB and ARGs in the environment's surface waters can lead to multiple strains of bacteria developing antibiotic resistance, which threatens public health and safety. This phenomenon leads to increased bacterial transformations, increasing the probability of contamination from direct or indirect contact with ARB-infected foods or water (Waste World, 2019). Therefore, the generalized use of antibiotics by the local population and the incorrect disposal through home toilets of unused antibiotic remnants can lead to the development of various antibiotic-resistant bacteria and antibiotic-resistance genes in the surface waters environment. The inability of treatment plants to eliminate such metabolites increases the likelihood of human exposure to ARB in recreational surface waters. Therefore, this is a serious public health problem in Puerto Rico. The previous rationale means that both hypotheses were not rejected.

Discussion

Medication accessibility has paved the way for lower mortality rates and better healthcare in the modern world. Nevertheless, the disposal of these medications has raised questions about ethical and sustainable practices. Antibiotics, one of the revolutionizing drugs of the past century, have redefined medicine with their treatment properties to control pathogenic bacterial infections. These drugs can be ingested orally, injected, or used in a topical cream to treat immediately infections and wounds in most households. Antibiotics pass through the body, and some residues and metabolites are eliminated via fecal and urine pathways, ending in the wastewater system. People tend to flush in the toilets any expired drugs that they do not use anymore, which make their way through the wastewater system, and finally, they are discharged into a surface water body (Water Science School, 2018). Therefore, the improper disposal and human biowaste of an antibiotic medication puts selective pressure on surface water bodies for the development of ARB. This can cause bacterial infections, which are very difficult to control, in people exposed to those polluted waters.

Puerto Rico has a growing geriatric population due to many issues concerning the economy, security, and quality of life on the island (Fajardo, 2019). This now ever-growing sector of the population counts for the highest consumption of medication when compared to adults and children (Kirzinger, 2019). Therefore, given this skewed distribution of more senior citizens on the island, there will be a higher usage and disposal of antibiotic medication on the island in the following years. There is a lack of governmental campaigns, public awareness, and laws to control incorrect individual disposal of antibiotics that perpetuates improper disposal. In many countries, water filtration plants can not eliminate improperly disposed waste like antibiotics (Liu, 2017), which stimulates the development of antibiotic-resistant bacteria and antibiotic-resistant genes.

Farms and pharmaceuticals are also involved in the mass disposal of antibiotic medication. The USDA allows farm stock to be given medication in minimum intervals (Sneeringer, 2015) to prevent or treat diseases—meaning that even if an animal is healthy, it will still be ingesting antibiotics. This practice has been linked to causing food sensitivity in people that ingest these meats and growing concern about antibiotic-resistant bacteria (Paulas, 2014). Cross-contamination of antibiotic-resistant bacteria is a serious threat, considering that many raw meat product processing plants involve direct human contact, potentially spreading ARB to the general population if mishandled (Sneering, 2015). Washing carcasses that contain antibiotic-resistant bacteria and antibiotics to the water drainage system or remain in a nearby environment. The FDA in the United States imposes rigorous quality control checks in pharmaceutical disposal and management. However, as seen with the COVID-19 pandemic, an outbreak worldwide could spread globally in just a few

months. Chinese and Indian pharmaceuticals improperly discarded medications in large bodies of water and landfill. Therefore, these countries have been harboring and stimulating the global rise of antibiotic-resistant bacteria (Ahmad, 2017). In Puerto Rico's case, the restrictions imposed on pharmaceuticals differ from those of other countries and farms; nevertheless, it is imperative to reevaluate practices on the island.

Contaminated water contains organic and inorganic matter such as foods, biological waste, and chemicals, including antibiotic medications. Before water filtration, plants remove sediment, physical contaminants, and other impurities; medications like antibiotics are in contact with bacteria which can thrive in a rich environment and can interact with genes of resistance and evolve to better adapt to this new environment (Water Science School, 2018).

The company responsible for water quality, distribution, and filtration in Puerto Rico is a governmental-owned institution. Since the island declared bankruptcy in 2015, all governmental agencies, including the Agencia de Acueductos y Alcantarillados (AAA), have suffered from improper funding for sophisticated machinery that could better filter out impurities (Williams-Walsh, 2017). After the 2017 category 5 Hurricane Maria, bodies of water connected to the water filtration plant were found to contain an increased number of antibiotic-resistant genes that impacted river samples, the study even showed that the ARGs found "[...] were consistent with regional concerns like *K. pneumoniae*" (Davis, 2020). The storm's conditions, which left the island without electricity, led people to use bodies of water for hygiene purposes and contaminated the water streams. Moreover, these watersheds of filtered water were left without monitoring or care and remained more stagnant than normal, possibly increasing the probability of antibiotic and bacterial contact. This study not only indicates how Hurricane Maria possibly accelerated the increase of ARB and ARGs present in Puerto Rico's watersheds but can also correlate health incidences that were more common in exposed or near filtered water plants.

The flourishing of ARB and ARGs will cause a hostile medical environment if ignored, not only at a local level in Puerto Rico but potentially globally. Currently, there are no specific medications that target harmful antibiotic-resistant bacteria. Therefore, medical professionals' only solution is increasing the dosage of antibiotics (Anwar, 2020), which in turn creates a cyclic pattern of how antibiotics get into the environment and will increasingly start to favor stronger ARGs and consequently ARBs. An antibiotic-resistant bacteria infection has a higher death rate than wild-strain harmful bacteria, even with early intervention of a patient (Kang, 2005). Other illnesses caused as an indirect effect of antibiotics in water streams are food allergies, cancer, and other chronic illnesses that may be more prevalent in the

following years (Serwecińska, 2020). Even more concerning is the fact that ARB prevailing in society will cause medically advanced treatments to be at risk of becoming obsolete because antibiotics will not work on immunocompromised patients—like cancer (Serwecińska, 2020).

The proliferation of ARB and ARGs in Puerto Rico's water can have detrimental health concerns for vulnerable populations and those living near a surface water body receiving a discharge from a treatment plant. Thus, the growing geriatric population, the multiple types of contamination, and the lack of awareness on the island and at a federal level all contribute to the contamination of water with antibiotics. It is imperative to understand the nature of the problem and the Government's responsibility to take care of the environment for a better future. This study applies relevant findings concerning antibiotic-resistant bacteria to the case of Puerto Rico. Given the information, improper disposal can cause a public health problem of antibiotic-resistant bacteria; thus, the hypotheses are not rejected.

Limitations

A limitation of this study was finding information specifically concerning Puerto Rico's case. We did not find local user awareness studies on properly disposing of and handling antibiotic medications. More studies are needed on watersheds all over the island and the level of contamination caused by local farms and residents. The island's provider of clean water was tried to be contacted and questioned about how they handle such contamination in their system and other questions, but they did not respond. The following studies should focus precisely on the limitations previously stated, as well as an economic-related study concerning *Acueductos y Alcantarillados* and how their lack of governmental funding impacts the water management issues on the island with both the production of drinking water (through filtering plants) and the wastewater treatment plants.

Conclusion

The use of antibiotics has led to mass disposal of the medication that ends up in the environment and surface water bodies. Antibiotics in contaminated water create an environmental pressure that favors the formation of antibiotic-resistant bacteria. In Puerto Rico, antibiotic-resistant bacteria and antibiotic-resistant genes have been identified in filtered water (Vazquez-Piñeiro, 2019. This means the water-filtering plants cannot properly eliminate antibiotics, ARB, ARGs, and many other

medications. Moreover, in areas where antibiotic-resistant genes were found, there was a correlation between antibiotic-resistant bacterial strains and local health concerns (Davis, 2020). The incorrect disposal of antibiotics, such as people disposing of expired or unused medication through the house toilets system, increases the exposure of antibiotics to bacteria in water. Other improper disposals include farms and pharmaceuticals, which are responsible for many antibiotics that end up in water filtration plants.

The multiple sources of water contamination with antibiotics, lack of governmental intervention, little user awareness of disposing of medication, and an inefficient water filtering system all contribute to an increased incidence of ARB and ARGs in Puerto Rico's water. This is alarming, given that antibiotic-resistant bacteria have a higher death rate than regular bacterial strains due to their ability to resist medication (Kang et al., 2005). In the island's future, antibiotics will be increased, setting a precedent for more antibiotic-resistant bacteria in the water systems. As a direct consequence, public health in Puerto Rico is increasingly at risk of an antibiotic bacterial outbreak infection due to the exposure these multiple sources of contamination are causing. It is imperative to use medication as prescribed, promote responsible medication usage, and invest in the evaluation and close monitoring of multiple sources of recently filtered water as well as wastewater.

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