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Pollution in the lower basin of Jamapa River by the application of antibiotics for veterinary use

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ABSTRACT

Objective: To analyze the level of use of antibiotics in livestock and aquaculture activities developed in the lower basin of Jamapa River, to know the possible impact of these compounds on water quality and the risk to public health.

Methodology: A survey of 60 farmers was conducted using a structured questionnaire with 41 open and closed questions during the year 2020. The use of key informants with experience in the livestock sector and related to the livestock sector in the study area was applied.

Results: Regarding the profile of the producers, it was found that 95% were men, and women only represented 5% (2 women). The 50% of producers have a basic level of schooling; 85% of respondents used antibiotics as a preventive treatment for disease control, 8.3% apply vitamins and 6.7% use dewormers. Among the most frequently used antibiotics is Oxytetracycline.

Study limitations/implications: to assess the toxic risk that exists when using antibiotics in the livestock sector, it is necessary to develop procedures and to plan new regulations for the use of antibiotics in this sector.

Findings/conclusions: a relationship was found with the use of oxytetracycline by the livestock sector. There is great concern about the impact that pharmaceuticals can have on water bodies and outside them. It is necessary to carry out risk assessments based on traditional fish responses, such as changes in growth or survival.

Keywords: veterinary drugs, antibiotics, diseases.

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INTRODUCTION

Antibiotics are the group of pharmaceutical products of extensive use worldwide for their therapeutic purposes in human medicine, veterinary medicine and agriculture (Tang *et al.*, 2017). Extensive administration of antibiotics due to inadequate regulation and poor practices in their use is associated with the increase in antibiotic resistant bacteria and genes (FAO, 2016; Tang *et al.*, 2017; Mestorino *et al.*, 2019; Magnusson *et al.*, 2019;

Image by Jean-Marie at Pixabay

Fernández-Rodríguez *et al.*, 2020). The residuality of these compounds has been detected in livestock derived products such as meat (Aguilar-Gálvez *et al.*, 2018; Rivera-Alegría *et al.*, 2018; Vega-Sánchez *et al.*, 2020), kidney (Guerra and Elera, 2021), and raw milk (Cruz-Mendoza *et al.*, 2017; Jáuregui and Celis-Vielman, 2018). In Mexico, numerous problems related to the inappropriate use of antibiotics used in human and veterinary medicine have been reported (INSP-UNAM. 2010). However, research on the management of these compounds by users and their presence in surface water such as rivers is scarce in Mexico. Main routes of entry of antibiotics into the environment is through human excretion, elimination of unused products, and agricultural use (Gil *et al.*, 2012).

Agricultural and livestock activities such as cattle and pig farming (Cancho-Grande *et al.*, 2000; Echtermann *et al.*, 2019), poultry farming (de Assis *et al.*, 2016; Mestorino *et al.*, 2019), and aquaculture activities such as shrimp farming (Le Truong and Thanh, 2019; Thiang *et al.*, 2021). Together they constitute the main sources of antibiotics for veterinary use (Lara *et al.*, 2019). Antibiotics presence has been reported by various sectors using aquatic ecosystems, along with associated impacts on the organisms that inhabit those ecosystems.

A diversity of antibiotics and types of compounds for veterinary use are applied in the farm animal industry; they are administered primarily through feed and water. Advantages from those compounds include improving feeding and growth efficiency, reducing morbidity for therapeutic, and prophylactic purposes (Kozarova *et al.*, 2004; Grossi-Botelho *et al.*, 2015; Khatun *et al.*, 2018). The impact of antibiotic mixing on the diversity of microbial populations may be associated with their contribution in the ability to adapt and resist antibiotic compounds from wastewater in pig production (Reynoso-Varela *et al.*, 2020). Likewise, their presence is associated with the generation of DNA damage in living organisms (Zirena Vilca *et al.*, 2018).

The adverse effects caused by the use of these compounds have contributed to be included within the group of emerging pollutants, considered as non-persistent but whose solubility in water contributes to their ability to enter all stages of the hydrological cycle, and be detectable in aquatic ecosystems (Gil *et al.*, 2012; Snow *et al.*, 2018). The diversity of antibiotic compounds for veterinary use is incorporated into aquatic systems by the entry of effluents without prior treatment. They can cause effects on the biodiversity and health status of the organisms that inhabit these aquatic ecosystems (Barceló *et al.*, 2007; Jimenez, 2011; Salcedo, 2019).

In the state of Veracruz, most of the rivers that cross through the main population centers receive discharges of municipal wastewater, industrial discharges and various types of pollution from non-point sources (Torres, 2013). In addition, the 14 most important rivers in Veracruz register significant levels of pollution, which implies serious consequences for human health, limits productive activities and deteriorates the environment (CSVA, 2004). Nutrients and pollutants are naturally recycled in aquatic and terrestrial ecosystems. However, the anthropic influence has altered these cycles by increasing the amount of nutrients and pollutants that end up in water bodies, causing problems associated to eutrophication, disruption of natural ecosystems and damage to human health (Torres, 2013). This represents a risk for wild aquatic species such as fish given their potential incorporation into their tissues and generation of adverse effects such as bacterial resistance, among others (Zaragoza *et al.*, 2020). Therefore, the importance of evaluating the use made by users of the different productive activities developed in this basin is highlighted, given the potential impact of antibiotics on public health and the environment. The objective of this research was to determine the level of use of antibiotics in livestock and aquaculture activities developed in the lower basin of Jamapa River, to know the potential impact of these compounds on water quality and the risk to public health.

MATERIALS AND METHODS

Study area

The basin of Jamapa River is part of the Jamapa-Cotaxtla and Medellín river system (Figure 1). It is located between 18° 45' and 19° 13' N, and 95° 56' and 97° 16' W; with an approximate area of 3,912 km^2, it covers 28 municipalities of the state of Veracruz. Within the limits of the basin, two main channels are comprised, the Jamapa and Cotaxtla rivers that originate in the Citlaltepetl or Pico de Orizaba (5700 m) and flow discharged into the Gulf of Mexico (Ortiz-Lozano, 2013).

Sampling techniques and data collection

Data were obtained by applying a structured survey as a sampling instrument (Piña-Guzmán *et al.*, 2019; Costa *et al.*, 2021; Ogwuche *et al.*, 2021). This was applied to cattle ranchers in the municipalities of Jamapa, Cotaxtla and Medellín in Veracruz, Mexico. The study population included antibiotic users located in the municipalities indicated above; which allowed to include a greater representativeness in relation to sex and age of the participants. It also included data on the production unit of the families, the surface of the farm, and the distance from the farm to the lower basin of the Jamapa River.

The questionnaire was the data collection tool on demographics, antibiotic use practices and antibiotic management regulations (Ogwuche *et al.*, 2021). The questionnaire was structured with 41 open or closed questions. A randomly selected representative sample of 60 livestock producers was interviewed individually and in groups. The questionnaire

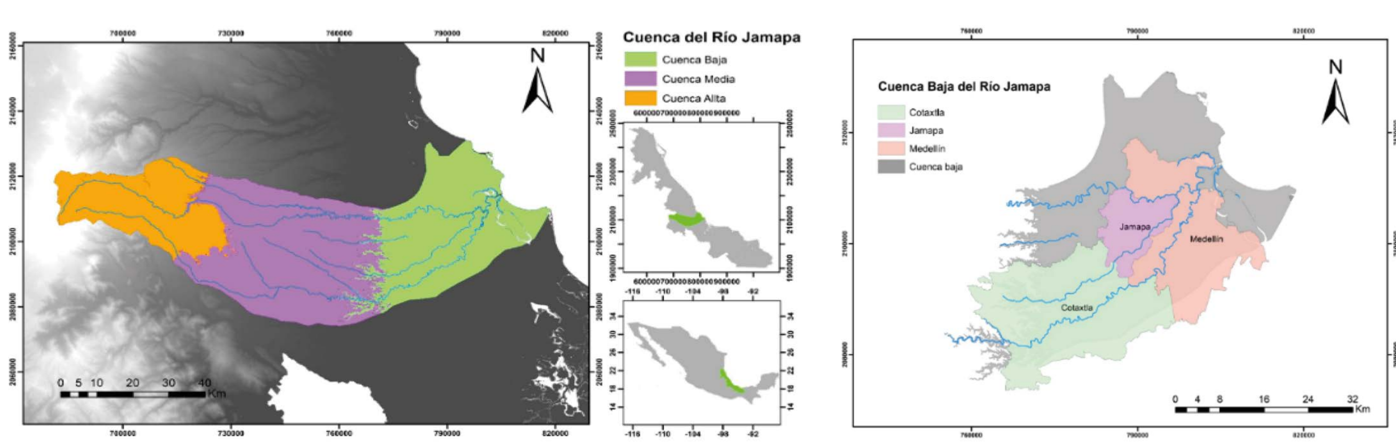

Figure 1. Location of municipalities in the lower basin of Jamapa River, Veracruz.

was previously evaluated as pilot within a group of producers from the study area to verify the quality of the questions and the proper functioning of the instrument designed. The use of key informants with experience in or related to the livestock sector in the study area was included.

Statistical analysis

Descriptive statistics were used with the statistical package TIBCO Statistica 14.0.0.15 (TIBCO Software Inc., Palo Alto, CA, USA) to group all the information collected on the demographic variables of the interviewees. Antibiotic use for the livestock herd, frequency of application of antibiotics and compounds with greater frequency of use; those were the most important data considered in the management of livestock herds.

RESULTS AND DISCUSSION

Socio-economic characteristics of producers and livestock activity

Figure 2 shows the average age of cattle farmers in the municipalities analyzed in this research (50.6±14.6). Orantes-Zebadúa *et al.* (2014) reported the same trend in livestock producers in Chiapas, with an average age of 50 years. Meanwhile, Vilaboa-Arroniz *et al.* (2009b) indicated in three age groups for cattle ranchers in the region of Papaloapan, Veracruz, with average ages of 53±13. 54±15 and 56±12 years old. Also, De los Santos-Lara *et al.* (2015) indicated the same age trend in cattle ranchers in the central region of Chiapas, they reported an average age of 52.4 years, out of which 53% indicated being older than 50 years old. Chalate-Molina *et al.* (2010) reported that dual-purpose livestock producers in the state of Morelos had an average age of 52±12 years.

The average age obtained in those previous studies indicates that there is little generational replacement in livestock activity in the study area; which agrees with Chalate-Molina *et al.* (2010) who indicated that livestock producer groups are characterized by an

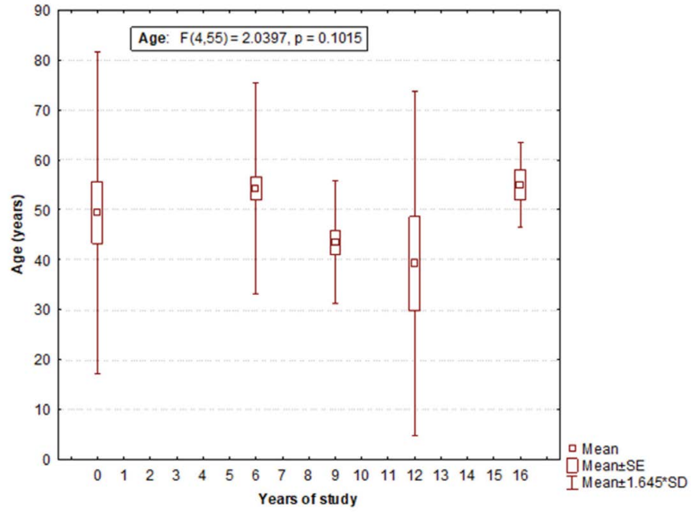

Figure 2. Distribution of age and schooling (years) of cattle ranchers in the municipalities of Medellín, Jamapa and Cotaxtla, in Veracruz, Mexico.

advanced age and low level of education. The latter statement also coincided with this research since it was identified that only 3 interviewees (5%) indicated to have higher level studies such as a bachelor's degree with a 12-year schooling. Chalate-Molina *et al.* (2010) mentioned that INEGI in 2005 recorded that the average schooling of farmers was 6±4 years; this value is lower than the national average of 8.1 years.

Similarly, Orantes-Zebadúa *et al.* (2014) indicated that in farmers there is a basic level of study with a schooling of 6 years (primary completed). On the other hand (Vilaboa-Arroniz *et al.*, 2009b) reported that traditional farmers indicated a schooling at the basic level with 6±6 years, although they also pointed out that 12.1% had a bachelor's level. In contrast, De los Santos-Lara *et al.* (2015) indicated that 90% of their interviewees had a bachelor's degree, with an average schooling of 17 years; 3% had postgraduate studies and 7% basic studies. Vilaboa-Arroniz *et al.* (2009b) identified differences in schooling; reporting that 31% of farmers in transition had a bachelor's degree, whereas 12% of traditional ranchers reported the same.

Regarding gender, 95% of the interviewees were men; indicating that cattle ranching is an activity dominated by the males in the study area, as females only represented 5% (2 women) among the participants (Table 1). In contrast, De los Santos-Lara *et al.* (2015) reported that women with higher education (professionals) had a greater participation in agricultural activities and these represent 10% of the study population analyzed. This may indicate a difference in women's participation in the livestock sector associated with the academic level and the region of the country, because other works do not mention the participation of women in this sector.

In the study area, it was identified that the interviewees had a work experience in livestock of 25.55±50 years. A low correlation was identified with an $r^2=0.5377$ between age and years of experience in the livestock sector as indicated in (Table 1). This coincided with the years of experience in the activity indicated for traditional farmers with 25±13 years, a maximum of 60 and a minimum of 1 year (Vilaboa-Arroniz *et al.*, 2009b). According to Chalate-Molina *et al.* (2010), the experience of the producer in the cattle ranching activity is the main strength that is based on the human resource in dual-purpose livestock (DP); they also highlighted the importance of other attributes such as the availability of family labor, the experience in production and the rusticity of the breeds used. In contrast, De los

Table 1. Characteristics of cattle ranchers in the analyzed municipalities of the central area of Veracruz.

Variable	Average	Minimum	Máximum
Age (years)	50.63	18	85
Escolarity (years)	6.45	0	16
Gender (%)	Male 95%		
	Female 5%		
Cattle experience (years)	25.55	2	60
Available area (ha)	20.5	2	72
Cattle heads number	37	7	150

Own elaboration.

Santos-Lara *et al.* (2015) indicated that Swiss cattle breeders in Chiapas are characterized by experience, education, economic and social potentials to innovate and improve the processes of breeding and selection of livestock.

In this research, 96.66% of interviewees operate extensive livestock farming and only two producers (3.33%) indicated to manage the intensive type. Extensive grazing is the main management system, 98% (Vilaboa and Díaz (2009). And 86.9% of the dual-purpose bovine production system is developed mainly under the extensive grazing management system in the tropical regions of Latin America (Vilaboa-Arroniz *et al.* (2009b). In agreement with the above, Herrera-Calvo and Majadas-Andray (2018) indicated that extensive livestock takes advantage of the resources of the territory, has a behavior of integration and respect with local ecological processes, since it must necessarily adapt to them to maintain the production process.

It should be noted that the information on the area available for livestock activity and the number of herd animals was not provided by the producers. But it should be appointed that this type of information would allow characterizing the scale of livestock production in the study area and the use of antibiotics for this farming activity.

The breeds with the highest predominance in the municipalities analyzed were Dual Purpose Creole with 40% (24 interviewees) and Swiss Cebu (17). In contrast, Vilaboa-Arroniz *et al.*, 2009b) indicated the racial pattern of the cross Swiss × Cebu (79.8%) as the most representative, and it has as fundamental objective the production of milk. Also, Orantes *et al.* (2010) indicated that, in livestock production systems through extensive grazing, Cebu × Swiss breeds have as their genetic source the breeds Cebu × Dutch and Cebu × Simmental, among the main ones. The predominance of Creole cattle in the study area indicates the adequacy of the farmers to obtain livestock according to their economic conditions and the production area.

Livestock producers interviewed in this research reported frequent use of 11 different types of antibiotics. They also indicated that Oxytetracycline with 43.33%, was the antibiotic most frequently used by cattle farmers in the three municipalities analyzed; followed by Penicillin with 15% and Forfenicol with 8.33%. The rest of the antibiotics indicated a less recurrent use such as 3 Sulfas and Tetracicin with 6.66%, Derriengue and Draxxin with 5.0% (Table 2). In this regard, Ogwuche *et al.* (2021) indicated in livestock the use of oxytetracycline (82.6%, 317/384), tylosin (44.5%, 171/384) and gentamicin (43.8%, 168/384), penicillin 39. 3% (151/384) and enrofloxacin 38. 5% (148/384). Herrera-Calvo and Majadas-Andray (2018) highlighted the use of tetracyclines, penicillin, sulfonamides and polymyxins in cattle in Spain; although they highlighted that a figure greater than 50% of antibiotics were destined for pig production.

In Figure 3, the livestock producers in the study area did not indicate to implement any type of clinical analysis for the application of these drugs. Likewise, Ogwuche *et al.* (2021) indicated that 32.0% of respondents did not undergo antimicrobial susceptibility testing (AST) prior to antibiotic treatment.

Recently, the need for adequate administration of antibiotics to preserve the efficacy of existing antibiotics against pathogens has been highlighted (Aslam *et al.*, 2018).

Table 2. Frequently used antibiotics in disease control (diarrhea) reported by cattle ranchers in the municipalities of Medellín, Jamapa and Cotaxtla; Veracruz, Mexico.

Antibiotics for Veterinary Use	Frequency	Percentage	Antibiotic used in diarrhea control	Frequency	Percentage
Penicillin	9	15.00	Penicillin	6	10.00
Oxytetracycline	26	43.33	Oxytetracycline	38	63.33
Florfenicol	5	8.33	Florfenicol	3	5.00
Derriengue	3	5.00	Ampicillin	1	1.66
3 sulfas	4	6.66	Derriengue	2	3.33
Tetracycline	4	6.66	3 sulfas	2	3.33
Flunixin	1	1.66	Tetracycline	2	3.33
Draxxin	3	5.00	11 Via	1	1.66
Shotapen L.A.	1	1.66	Shotapen L.A.	1	1.66
Fluvicin	2	3.33	Oxitetlacycline	3	5.00
7 via	2	3.33	Bactrex	1	1.66

Own elaboration.

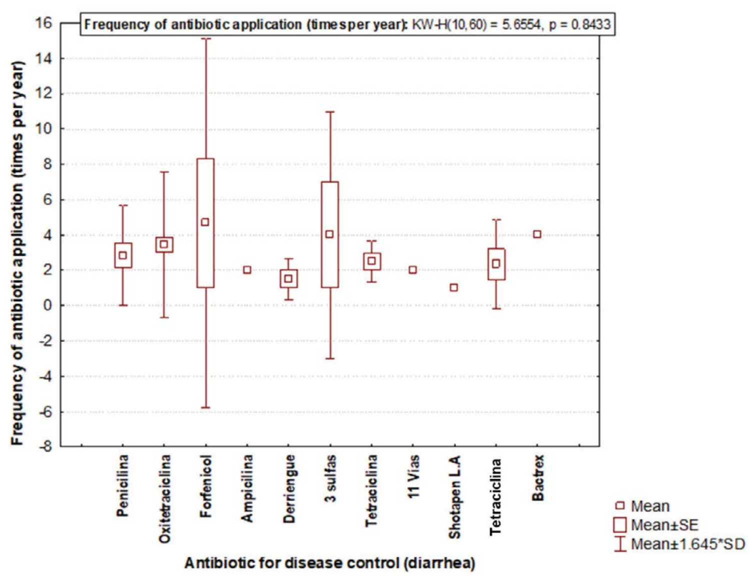

Figure 3. Frequency of antibiotic use reported in the control of diarrheal diseases used by cattle farmers in the study area.

Antibiotics are essential in the therapeutic treatment of bacterial diseases in livestock production, because they affect the health, production and well-being of livestock (Van *et al.*, 2020). Ogwuche *et al.* (2021) reported that 60% of respondents recommended the use of antibiotics for the treatment of non-bacterial pathogens, including viral, helminth and fungal pathogens. This may indicate an abuse of antibiotics for the treatment of pathologies not indicated by these compounds.

The different types of antibiotics indicated by farmers in this research involve a diversity of compounds applied on an extensive production scale. However, Herrera-Calvo and

Majadas-Andray (2018) indicated that regardless of the scale of extensive and industrial production there is an impact on these activities, and the use of antibiotics in extensive livestock farming that must be improved as observed in Figure 3.

The 100% of the interviewees indicated that the route of administration of these antibiotics is through injection. This implies that an elimination period is required for antibiotics and avoid their residuality, reported in milk and meat. Likewise, it was identified in this research that only 20% of the interviewees (12 farmers) indicated having knowledge about the use of antibiotics, they responded that "they kill bacteria". The rest of the interviewees (80%) indicated that they had no knowledge about antibiotics. The latter indicates the importance of the knowledge that producers need to possess about the action of antibiotics for a better decision making on their application to livestock. Regarding access to technical advice, 85% of the interviewees indicated to pay for the advice of a veterinary or zootechnician (MVZ); 15% indicated that they did not have this type of professional advice.

Despite, 100% of those interviewed in this research indicated that they acquire antibiotics supplied to livestock in veterinary clinics. In contrast, Vilaboa-Arróniz *et al.* (2009b) indicated that only 47% of producers receive technical advice from the MVZ related to the Local Livestock Association and 0.25% receive advice from Research Centers, or public and private universities. The latter indicates the importance of technical advice with MVZ professionals, particularly in the management of antibiotics for veterinary use.

Antibiotics are among the best-selling and consumed drugs in Mexico, according to IMSH data (2005) this represents an annual market of 960 million USD and ranks second in annual sales (14.3%) in private pharmacies in the country (Dreser *et al.*, 2008). It should be noted that in Mexico there is no official published information on the volume and management of antibiotics in human and veterinary medicine. This type of information is not required of producers in official statistics such as the National Agricultural Census (INEGI, 2019), this instrument is focused on collecting information on available area, number of livestock heads (cattle, sheep, pigs, poultry), type of feed, among others. In addition, it collects information on the management of compounds such as hormones and anti-tick baths, but the use of antibiotics is not considered in livestock activity.

It was identified that 85.00% of the interviewees in this research used antibiotics as a preventive treatment for disease control, 7.5% applied deworming and vitamins (Table 3). In agreement with the above (Ogwuche *et al.*, 2021) indicated a similar trend, 96.6% reported providing a therapeutic treatment of a disease was the most frequent reason for recommending the use of antibiotics, followed by the prevention and prophylaxis of diseases with 41.7% and for the promotion of growth 4.7%. It should be noted that the preventive treatment with antibiotics reported in the study area should be added to that

Table 3. Preventive treatment for disease control in the cattle herd.

Preventive treatment for disease control	Frequency	Percentage
Antibiotics	50	85. 00
Dewormers	5	7.5
Vitamins	5	7.5

Own elaboration.

implemented for disease control and cases of diarrhea in livestock. This increases three times the consumption of antibiotics given to cattle in this research.

The non-specific use of antibiotics without knowing the causative agent of the disease in animals in the study area is a common practice in agricultural activity worldwide. Likewise, Ogwuche *et al.* (2021) indicated that a high proportion of interviewees in their research corresponding to 81.3%, recommended the use of antibiotics to control non-bacterial pathogens, including viruses, protozoa and even fungi. Although they also reported that 98.7% of the interviewees indicated recommending others to the use of antibiotics for the control of bacterial pathogens.

The 100% of the interviewees indicated that they did not have any type of government support, this may imply that there is no support for the management of cattle and compounds of controlled use such as antibiotics in the study area. Chalate-Molina *et al.* (2010) indicated that there is little dissemination of federal, state and municipal support programs, highlighted the limited contact with people involved in the promotion of farming activity and how this situation makes it difficult to request government support. Cuevas-Reyes *et al.* (2012) reported with information from the Agricultural, Livestock and Forestry Census in Mexico, that the coverage of technical assistance is low, 3% of the national total of production units with agricultural activity have this service, and only 11.7% perceive the lack of technical assistance and training as a problem. In contrast, Vilaboa-Arróniz *et al.* (2009b) indicated that 50.1% of the farmers in the Papaloapan region do not receive technical assistance.

Environmental risk in the mode of application and management of antibiotics

It was previously indicated that oxytetracycline was the most frequent antibiotic for farmers in the study area, because they indicated its easy access to acquisition and affordable economic cost. This coincides with what was reported by León-Aguirre *et al.* (2017) who indicated the detection of oxytetracycline in pig wastewater from small and medium-sized farms in Yucatan. It also demonstrated the persistence and recurrent use of this antibiotic in the water used for livestock activities in Mexico. The antibiotics with the highest detection report in aquatic ecosystems correspond to diverse chemical groups that include tetracyclines (Dang *et al.*, 2007), and aminoglycosides (Shakil *et al.*, 2008).

Pollution by antibiotic residues can reach the consumer through the food chain. It has been identified that antibiotics can cause allergic reactions or alter the intestinal bacterial flora of humans. This contributes to potentiate the risk of generation and proliferation of strains of antibiotic resistant bacteria (ARB) and antibiotic-resistance genes (ARG) (Ventola, 2015; WHO, 2018). As well as, causing marketing problems by affecting product quality and market competitiveness (Guzmán-Carrillo *et al.*, 2012; Grossi-Botelho *et al.*, 2015). The data on the extent of the area used by farmers allow us to know the impact of this activity due to the use of chemical compounds. For example, drugs that include mainly antibiotics and pesticides, or insecticides and herbicides, among others.

In this research it was identified that 93.33% of farmers discard antibiotic residues when throwing bottles in the trash and that only 6.66% of bottles with antibiotic residues are burned.

In agreement with the above, Piña-Guzmán *et al.* (2019) noted that expired veterinary drugs are considered hazardous waste in Mexico, according to NOM-052-SEMARNAT-2005. However, those authors indicated the disorganization in the procedures that include the management and final disposal of antibiotics, since these are eliminated jointly with municipal solid waste or are discharged into the drainage. All of this can expose the general population and the environment to low doses of those antibiotics, which may involve an additional pathway for these compounds.

The main pathways of pharmaceuticals such as antibiotics to the environment are through excretion. A wide range of products are identified in surface, groundwater, and wastewater (Gil *et al.*, 2012). Also, Cheng *et al.* (2018) indicated that approximately 70% are discarded in their original formula through excreta and urine. Meanwhile, Kümmerer (2009) indicated that between 80 to 90% of antibiotics (ATB) are excreted as original compounds in the environment, which means that the compounds have not been metabolized in any animal body. The latter has special relevance since the proximity of water sources, such as the lower basin of the Jamapa River; water was identified at an average distance of 18046. 97±90291.0.6 m, with a minimum distance of 0.0 and a maximum distance of 500 000 m. In addition, the use of antibiotics was identified in the study area, 100% of the farmers indicated to perform anti-tick baths to their livestock herd. The intensive use of antibiotics has generated pollution of environmental matrices such as soil, water, sediments, plants, and their negative effects have been particularly highlighted in biota (Grossi-Botelho *et al.*, 2015). The above agrees with Zirena Vilca *et al.* (2018) who highlighted the need to monitor various environmental matrices to detect and quantify the presence of antibiotics in order to have a better understanding of their long-term effects on living organisms.

The potential ecological risk of antibiotics in the environment should be evaluated to develop management strategies for those substances, with the aim of contributing to the reduction of such compounds in aquatic systems (Grossi-Botelho *et al.*, 2015). Dreser *et al.* (2008) indicated that the sale of antibiotics in Mexico has a higher proportion compared to developed countries and in transition with large pharmaceutical markets. In the case of our country, as previously indicated, there is no official information on the use of veterinary antibiotics, which hinders the establishment of mechanisms to contribute to their rational use in this sector. Ogwuche *et al.* (2021) indicated that there are no guidelines in Nigeria restricting access to veterinary medicines. Grossi-Botelho *et al.* (2015) recommended that public health and regulatory institutions should commit to the prudent use of veterinary antibiotics (VA) due to the risk they pose to human health and the environment.

CONCLUSIONS

The proper management of antibiotics should be a central issue in the field of animal health in the livestock sector in Mexico. Cattle ranchers in the lower basin of Jamapa River use antibiotics in the treatment of diseases, such as diarrheal diseases, without a corroborated bacterial cause. The interviewees reported 11 different antibiotics in the municipalities evaluated in the lower basin of the Jamapa River; that is, the use of a mixture of compounds whose residues can reach the riverbed, given the proximity of the livestock production units to the water source.

A total of 11 antibiotic compounds were found in the three municipalities located in the lower basin of Jamapa River. It is possible that the residues of this mixture of antibiotics could reach the Jamapa riverbed given the proximity of the livestock production units.

The management of antibiotic residues and their final disposal should be addressed as part of good livestock production practices, because producers recurrently use Oxytetracycline for the treatment of diarrhea in livestock. This indicates frequent use of this compound with the risks associated with the presence of these compounds in the environment and public health.

The farmers interviewed have knowledge in the management of livestock production. However, a high percentage do not know the risks of antibiotics. Farmers and all those dedicated to the value chain in the production and fattening of cattle should receive information through government advice and research institutions, to provide them with knowledge about antibiotics and contribute to reduce inappropriate use, and to promote better management practices.

REFERENCES

Aguilar-Gálvez, F.L., Flores-Blacio, M.V, Sánchez-Quinche, Á, R., Zapata-Saavedra M. L. 2018. Determinación de residuos de tetraciclinas en muestras de carne bovina destinadas al consumo humano. *Revista La Técnica*, 20: 67-78.

Aslam, B., Wang W., Arshad, M.I., Khurshid, M., Muzammil, S., Rasool, M. H. 2018. Antibiotic resistance: A rundown of a global crisis'., *Infection and Drug Resistance* 11:1645–1658.

Cancho-Grande, B., García-Falcón, M.S., y Simal-Gándara, J. 2000. El uso de los antibióticos en la alimentación animal: perspectiva actual. *Ciencia y Tecnología Alimentaria*, 3: 39-47.

Chalate-Molina, H., Gallardo-López F., Pérez-Hernández F.P., Lang-Ovalle., Ortega-Jiménez E., y Vilaboa-Arroniz J. 2010. Características del sistema de producción bovinos de doble propósito en el estado de Morelos, México. *Zootecnia Trop, 28*(3): 329-339.

Cheng, D. L., Ngo H. H., Guo W. S., Liu. Y. W., Zhou. J. L, Chang. S. W., Zhang X. B. 2018. Bioprocessing for elimination antibiotics and hormones from swine wastewater. *Science of the Total Environment. Elsevier B.V.* 621:1664–1682.

Costa A, M., Miranda C., Silva V., Silva A., Martins Â., Pereira J. E., Maltez E., Capita R. Calleja-Alonso C., Igrejas G., and Poeta P. 2021. Survey of the Knowledge and Use of Antibiotics among Medical and Veterinary Health Professionals and Students in Portugal. *Int. J. Environ. Res. Public Health*, 18: 2753. https://doi.org/10.3390/ijerph18052753

Cruz-Mendoza, M. L., Hernández-Zepeda J. S., Silva-Gómez S. E., y M.L. Zaragoza-Martínez. 2017. Detección de antibióticos en leche de vaca en San Bernabé Temoxtitla Ocoyucan, Puebla. *Rev. Int. Contam. Ambie*, 34. DOI: 10.20937/2018.34. MANCA

CSVA. (Consejo del Sistema Veracruzano del Agua). 2004. Proyecto de Programa Hidráulico del Estado de Veracruz. Resumen Ejecutivo. Veracruz. 40 pp

Cuevas-Reyes, V., J. Baca del Moral, F. Cervantes-Escoto, y J. Aguilar-Ávila. 2012. Asistencia técnica en el sector agropecuario en México: análisis del VIII censo agropecuario y forestal. *Revista Mexicana de Ciencias Agrícolas*, 3:943-957

Dang H., Zhang X., Song L., Chang Y., Yang G. 2007. Molecular determination of Oxytetracycline resistant bacteria and their resistance genes from mariculture environments of China. *Journal of Applied Microbiology*, 103:2580–2592.

de Assis D.C.S., da Silva G.R, Lanza I.P, Ribeiro A.C.D.S.R, Lana Â.M.Q, Lara L.J.C, et al. 2016. Evaluation of the Presence and Levels of Enrofloxacin, Ciprofloxacin, Sulfaquinoxaline and Oxytetracycline in Broiler Chickens after Drug Administration. *PLoS ONE* 11: e0166402. https://doi.org/10.1371/journal.pone.0166402

De los Santos-Lara, M.C., Orantes-Zebadúa M. A., Osorio-Arce M. M., Córdova-Avalos V., Herrera-Haro J. G., Ruiz-Rojas J. L., Nahed-Toral J., Sánchez-Muñoz B., Manzur-Cruz A., Cruz-López J. L. 2015. Caracterización técnica y socioeconómica de criadores de ganado suizo de registro en el centro de Chiapas, México. *Agro* 249:25-29. DOI: 10.20937/RICA.2019.35.esp02.04

Dreser, A., Wirtz V. J., Corbett K.K., & Echániz G. 2008. Uso de antibióticos en México: revisión de problemas y políticas. *Salud Pública de México*, 50: S480-S487.

Echtermann T., Muentener C., Sidler X., and Kümmerlen D. 2019. Antimicrobial Drug Consumption on Swiss Pig Farms: A Comparison of Swiss and European Defined Daily and Course Doses in the Field. *Front. Vet. Sci*. 6:240. DOI: 10.3389/fvets.2019.00240.

FAO (Food and Agriculture Organization). 2016. The FAO action plan on antimicrobial resistance, Food and Agriculture Organization of the United Nations, Rome. 3-25p. https://www.fao.org/3/i5996e/i5996e.pdf

Fernández-Rodríguez R. E., Bolívar-Anillo H., Hoyos-Turcios C., Carrillo-García L., Serrano- Hernández M., Abdellah E. 2020. Resistencia antibiótica: el papel del hombre, los animales y el medio ambiente. *Salud Uninorte*, 36: 298-32. DOI: http://dx.doi.org/10.14482/sun.36.1.615

Gil M. J., Soto A.M., y Usma J. I. 2012. Contaminantes emergentes en aguas, efectos y posibles tratamientos. *Producción + Limpia*. 7: 52-73.

Grossi-Botelho R., Henrique-Monteiro S., and Luiz-Tornisielo V. 2015. Veterinary Antibiotics in the Environment. Emerging Pollutants in the Environment-Current and Further Implications. http://dx.doi.org/10.5772/60847

Guerra-Delgado M. S., Elera-Ojeda R.N. 2021. Residuos de antimicrobianos en tejido muscular y riñones bovinos comercializados en supermercados de Piura, Perú. *Salud Y Tecnología Veterinaria*, 1: 9-16. https://doi.org/10.20453/stv.v9i1.4008

Guzmán-Carrillo L. E., Espitia-Yanez C., Berthel L.L. 2012. Presencia de Lincomicina como promotor de crecimiento en carne de pollo comercializado en supermercados de Cartagena, Colombia. *Vitae* 19: 328-330.

Herrera-Calvo P.M, y Majadas-Andray J. 2018. La ganadería extensiva, una actividad esencial para nuestra alimentación. Cuaderno Estretando 4. Fundación Entretantos (ed). Valladolid, España. pp:25. doi.org /10.2175/106143018X15289915807254.

INSP-UNAM (Instituto Nacional de Salud Pública-Universidad Nacional Autónoma). 2010. Regulación y promoción para el uso adecuado de antibióticos en México. Propuesta de lineamientos para la acción. Instituto Nacional de Salud Pública (INSP). Facultad de Medicina Veterinaria y Zootecnia UNAM. México. 15 p.

Instituto Nacional de Estadística Geografía, e Informática INEGI. Censo Nacional Agropecuario. 2019. Disponible en línea: www.inegi.org.mx (marzo 15, 2020).

International Marketing System-Health (IMSH). 2005. IMS Retail Drug Monitor - April: International Marketing System-Health, [consultado el 13 de abril de 2008] Disponible en: http://www.imshealth.com.

Jáuregui R., Celis-Vielman E. A. 2018. Prevalencia de antibióticos residuales en leche cruda de bovino en fincas tradicionales en el departamento de Chiquimula, Guatemala. *Actas Iberoamericanas de Conservación Animal*, 12: 25-33.

Khatun, H., Islam S.B., Naila N.N., Islam S.A., Nahar B., Alam NH., y Ahmed T. 2018. Perfil clínico, patron de susceptibilidad a antibióticos de aislados bacterianos y factores asociados con complicaciones en cultivo- pacientes con fiebre tifoidea admidos en un hospital urbano en Bangladesh. *Trop. Med. Int Salud*, 23: 359-366 . https://doi.org/10.1111/tmi.13037

Ko ǻrova I., Máté D., Hussein K., Raschmanová K., Marcinčák S., Jevinová P. 2004. High-performance liquid chromatographic determination of sulfamidine residues in eggs. *Acta veterinaria*, 54:5-6, 427-435.

Kümmerer, K. 2009. Antibiotics in the aquatic environment - A review - Part I. *Chemosphere*, 75:417- 434. doi:10.1016/j.chemosphere.2008.11.

Lara M., Torres M., Baez, S. Albertini. 2019. Aspectos generales del uso de antimicrobianos y su interacción con el medio ambiente: una problemática emergente. *Compend. Cienc. Vet*. 9:24-37. doi: 10.18004/compend.cienc.vet.2019.09.02.24-37

Le Truong, G., and T.L.T. Thien. 2019. Determination of residual quantity of tetracycline antibiotics in shrimp pool water by UPLC-HRMS method. *Vietnam J. Chem*, 57: 758-764. DOI: vjch.2019000126

Magnusson U., Sternberg S, Eklund G, Rozstalnyy A. 2019. Prudent and efficient use of antimicrobials in pigs and poultry. *FAO Animal Production and Health Manual 23*. Rome. FAO.

Mestorino, N., D. Buldain, A. Buchamer, M.L. Marchetti. 2019. Enrofloxacin and ciprofloxacin residues in broiler chicken feathers after enrofloxacin oral administration. *EC Veterinary Science*, 4:180-186.

Norma Oficial Mexicana NOM-052-SEMARNAT.2005, Que establece las características, el procedimiento de identificación, clasificación y los listados de los residuos peligrosos.

Ogwuche, A., Ekiri A. B., Endacott I., Maikai B.V., Idoga E. S, R. Alafiatayo. et al.2021. 'Antibiotic use practices of veterinarians and para-veterinarians and the implications for antibiotic stewardship in Nigeria,' *Journal of the South African Veterinary Association* 92:4-14. https://doi.org/10.4102/jsava.v92i0.2120

Orantes-Zebadúa M. A., A,J. Vilaboa A, Ortega J. E, Córdova A.V.2010. Comportamiento de los comercializadores de Ganado bovino en la región centro del estado de Chiapas. *Revista Quehacer Científico 1*(9): 51-56.

Orantes-Zebadúa, M.A., D. Platas-Rosado., V. Córdova-Avalos., M.C. De los Santos-Lara., A. Córdova-Avalos. 2014. Caracterización de la ganadería de doble propósito en una región de Chiapas, México. *Rev Ecosistemas y Recursos Agropecuarios*. 1:49-58.

Organización Mundial de la Salud (OMS). 2018. Resistencia a los antibióticos

Ortiz-Lozano J.A. 2013. Modificación en la provisión de los servicios ambientales por efecto del cambio en la heterogeneidad ambiental en la Cuenca del Río Jamapa, Veracruz, México. Tesis de Maestría Ecología y Pesquerías, Universidad Veracruzana. Boca del Río, Veracruz. México.137 pp.

Piña-Guzmán, A.B., O. Prado-Rojas, M.G. Ramírez-Sotelo, y F. Robles-Martínez. 2019. Manejo de los medicamentos veterinarios caducos en la zona metropolitana del Valle de México. *Rev. Int. Contam. Ambie*. (Residuos sólidos en México) 35:29-39.

Reynoso-Varela A., R. Alcántara-Hernández, U. Durán-Hinojosa, R. Ulloa-Mercado, D. Serrano-Palacios. 2020. Impacto de los antibióticos de uso veterinario sobre la diversidad microbiana presente en el tratamiento de efluentes porcinos. *Revista Latinoamericana el Ambiente y las Ciencias*, 11:423-426.

Rivera-Alegría F.M., C. Jiménez-Martínez, G. Dávila-Ortiz, D.I. Téllez-Medina, J.M Piña-Gutiérrez, A.J. Chay-Canul. 2018. Remanentes de antibióticos y promotores de crecimiento en carnes de bovino comercializadas en México y su efecto sobre el grosor de las fibras musculares. Pp:789-794. En: Avances de la investigación sobre producción animal y seguridad alimentaria en México. J Herrera-Camacho et al. Eds., 1ª ed., Michoacán, México. 1327 pp.

Shakil S., Khan, R., Zarrilli, R. et al. 2008. Aminoglycosides versus bacteria- a description of the action, resistance mechanism, and nosocomial battleground. *J Biomed Sci*.15:5-14 https://doi.org/10.1007/s11373-007-9194-y

Snow D.D., D.A. Cassada, S. Biswas, M. Shafieifini, Li, X., D'Alessio, M., Carter, L. and Sallach, J.B. 2018, Detection, Occurrence and Fate of Emerging Contaminants in Agricultural Environments. *Water Environment Research*. 90: 1348-1370.

Tang K.L., Caffrey N.P., Nóbrega D. B., Cork S. C., Ronksley P. E., Barkema H.W., Polachek A.J., Ganshorn H., Sharma N., Kellner J.D., Ghali W.A. 2017. Restricting the use of antibiotics in food-producing animals and its associations with antibiotic resistance in food-producing animals and human beings: a systematic review and meta-analysis. *Lancet Planet Health* 1: e316-e327. http://dx.doi.org/10.1016/S2542-5196(17)30141-9

Thiang E. L., C.W. Lee, H. Takada, K. Seki, A.Takei, S. Suzuki, C.W. Bong. 2021. Antibiotic residues from aquaculture farms and their ecological risks in Southeast Asia: a case study from Malaysia. *Ecosystem Health and Sustainability*. 7: 1926337. doi:10.1080/20964129.2021.192633.

Torres-Beristáin B., González-López G., Rustrián-Portilla E., y Houbron E. 2013. Enfoque de cuenca para la identificación de fuentes de contaminación y evaluación de la calidad de un río, Veracruz, México. *Rev. Int. Contam. Ambie*. 29:3, 135-146.

Torres-Beristáin, Beatriz., González-López G., Rustria-Portilla E., y Houbron E. 2013. Enfoque de Cuenca para la identificación

Van Dijk J., Keukens, H. J. 2000. In: Van Ginkel, L.A., Ruiter, A. (Eds.), Residues of Veterinary Drugs in Food: Proceedings of the Euroresidue IV Conference, Veld ºhoven, The Netherlands.

Vega-Sánchez, V., M. Talavera-Rojas, J. Barba-León, A.P. Zepeda-Velázquez, N.E Reyes-Rodríguez. 2020. La resistencia antimicrobiana en *Escherichia coli* aislada de canales y heces bovinas de rastros en el centro de México. *Rev Mex Cienc Pecu*,11:991-1003.

Ventola C. L. 2015. The antibiotic resistance crisis: part 1: causes and threats. *P & T: a peer-reviewed journal for formulary management*, 40:4 277–283.

Vilaboa-Arroniz, J., Díaz-Rivera, P., Ruiz-Rosado, O., Platas-Rosado,D. E., González-Muñoz, S., and Juárez-Lagunes, F. 2009b. Caracterización socioeconómica y tecnológica de los agroecosistemas con bovinos de doble propósito de la región del Papaloapan, Veracruz, México. *Tropical and Subtropical Agroecosystems*, 10:53-62.

Vilaboa-Arroniz, J., Díaz-Rivera. P. 2009a. Caracterización socioeconómica de los sistemas ganaderos en siete municipios del estado de Veracruz, México. *Zootecnia Tropical* 27: 427-436.

Zaragoza-Bastida A., Flores-Aguilar S. C., Aguilar-Castro L. M., Morales-Ubaldo A. L., Valladares-Carranza, B., Rangel-López, L., Olmedo-Juárez, A., Rosenfeld-Miranda, C. E., Rivero-Pérez, N. 2020. Antibacterial and Hemolytic Activity of *Crotalus triseriatus* and *Crotalus ravus* Venom. *Animals* 10 281. https://doi.org/10.3390/ani10020281

Zirena-Vilca, F., W. Gosgot-Angeles, E. Tello-Palma, C. N. Campos-Quiroz, T. Donaires-Flores, y W.A. Zamalloa-Cuba. 2018. Antibiotics and their environmental implications. Journal of High Andean Research, 20: 215-224. DOI: http://dx.doi.org/10.18271/ria.2018.365