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The works must be unpublished and refer to topics of Experimental design, commerce, options, rural-flora and fauna, agronomy, natural and other topics related to Biology and Chemistry.

Presentation of the Content

As a first chapter we present, *Prevalence of partial edentulism according to the Kennedy classification in patients of the faculty of dentistry at the Universidad Autónoma de Campeche 2022*, by ZAPATA-MAY, Rafael, ROSADO-VILA, Graciella, OROZCO-RODRIGUEZ, Rubén and VIDAL-PAREDES, Jorge, with adscription in Universidad Autónoma de Campeche, as a second article we present, *Clarification of the effluent of an anaerobic digestion process: comparative study of single-stage and double-phase processes, with addition of coagulant and without addition of chemical coagulant*, by RODRIGUEZ-MORALES, José Alberto, RAMOS-LOPEZ, Miguel Ángel, CAMPOS-GUILLEN, Juan and LEDESMA-GARCIA, Janet, as the third chapter we present, *Comparative study of the physicochemical and microbiological parameters of two artesian wells in the community of San Pedro, Frontera, Centla, Tabasco*, by VAZQUEZ-AGUILAR, Clotilde, SUAREZ-GARCÍA, Sandra Manuela, PÉREZ-DURAN, Marco Antonio and REYES-HERNÁNDEZ, Guadalupe, with affiliation at Instituto Tecnológico Superior de Centla, as fourth article we present, *Cyanobacterial bloom in the Chen Ha karst landscape*, by VIZCAINO-RODRIGUEZ, Luz Adriana, RAVELERO-VAZQUEZ, Víctor, CARO-BECERRA, Juan Luis and CANUL-GARRIDO, Divino Miguel, with ascription in the Universidad Politécnica de la Zona Metropolitana de Guadalajara, Universidad Tecnológica del Poniente and Instituto Tecnológico de Tlajomulco.

Content

Article **ECORFAN Journal-Ecuador**
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Prevalence of partial edentulism according to the Kennedy classification in patients of the faculty of dentistry at the Universidad Autónoma de Campeche 2022

Prevalencia de edentulismo parcial según la clasificación de Kennedy en pacientes de la facultad de odontología de la Universidad Autónoma de Campeche 2022

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Abstract

Poor oral hygiene in adult patients, reported and analyzed in different studies that have been done worldwide, has generated a high rate of dental loss. Partial edentulism is defined as a state of oral health that is the cause of an adverse effect of the state of oral health that corresponds to the absence of a certain number of teeth in the mouth. Most of the population has an incomplete but functional dentition, there is another large population group that does not have prosthetic restorations, which are very necessary. The causes of partial edentulism can be congenital or acquired. Total congenital edentulism manifests as a very serious congenital syndrome, which, generally, are not compatible with the patient's life. On the other hand, acquired edentulism refers to dental loss during one's life and can be of secondary causes such as caries or dental loss as mentioned, such is determining the prevalence of partial edentulism in patients of the Faculty of Dentistry at the Universidad Autónoma de Campeche with the Kennedy classification. The loss of dental pieces results in the alteration of the stomatognathic system, resulting in the alteration of the masticatory function, affecting the nutritional state, general health and quality of life. Several studies have affirmed that edentulism, in addition to being related to the patient's nutritional state, is also associated with the following factors: quality of life, age, gender of the patient. An observational, descriptive cross-sectional study was carried out at the Universidad Autónoma de Campeche, in the clinics of the Faculty of Dentistry. The population for this study was 100 subjects. The total number of subjects studied was 100 subjects (n=100), 51% were male and 49% female, the mean age was 59 years with a standard deviation of 11 and a range of 53. Regarding the variable, educational stage, the majority only studied middle school followed by primary school. The distribution of the prevalence of partial edentulism with respect to sex, Kennedy class II reported prevalence in males with 21%. It is followed by class I in males with 10%, class III in third place but in females with 18% and finally class IV where females also prevail with 12%. This study shows that the most prevalent of evaluated patients was found to be Kennedy class II in the male sex, since it was the most representative of the population with 21%, while, on the part of the female patients, it was 18% in class III.

Dental prosthesis, Oral health, Aesthetics

Resumen

La mala higiene bucal en pacientes adultos, reportada y analizada en diferentes estudios que se han realizado a nivel mundial, ha generado un alto índice de pérdida dental. El edentulismo parcial se define como un estado de salud oral que es la causa de un efecto adverso del estado de salud oral que corresponde a la ausencia de un cierto número de dientes en la boca. La mayoría de la población tiene una dentición incompleta pero funcional, hay otro gran grupo de población que no tiene restauraciones protésicas, que son muy necesarias. Las causas del edentulismo parcial pueden ser congénitas o adquiridas. El edentulismo congénito total se manifiesta como un síndrome congénito muy grave, que, generalmente, no son compatibles con la vida del paciente. Por otro lado, el edentulismo adquirido se refiere a la pérdida dental durante la vida y puede ser de causas secundarias como caries o pérdida dental como se mencionó, tal es determinar la prevalencia de edentulismo parcial en pacientes de la Facultad de Odontología de la Universidad Autónoma de Campeche con la clasificación de Kennedy.La pérdida de piezas dentarias trae como consecuencia la alteración del sistema estomatognático, resultando en la alteración de la función masticatoria, afectando el estado nutricional, la salud general y la calidad de vida. Diversos estudios han afirmado que el edentulismo, además de estar relacionado con el estado nutricional del paciente, también está asociado a los siguientes factores: calidad de vida, edad, sexo del paciente. Se realizó un estudio observacional, descriptivo de corte transversal en la Universidad Autónoma de Campeche, en los consultorios de la Facultad de Odontología. La población para este estudio fue de 100 sujetos. El total de sujetos estudiados fue de 100 sujetos (n=100), 51% fueron hombres y 49% mujeres, la edad promedio fue de 59 años con una desviación estándar de 11 y un rango de 53. En cuanto a la variable etapa educativa, la mayoría sólo cursó la enseñanza media seguida de la primaria. La distribución de la prevalencia de edentulismo parcial con respecto al sexo, la clase II de Kennedy reportó prevalencia en varones con 21%. Le sigue la clase I en varones con un 10%, la clase III en tercer lugar pero en mujeres con un 18% y por último la clase IV donde también prevalecen las mujeres con un 12%. Este estudio muestra que el más prevalente de los pacientes evaluados resultó ser Kennedy clase II en el sexo masculino, ya que fue el más representativo de la población con un 21%, mientras que, por parte de los pacientes femeninos, fue de 18% en la clase III.

Prótesis dental, Salud oral, Estética

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† Researcher contributing as first author.

Introduction

The deficient oral hygiene in "adult" patients reported and analysed in different studies that have been carried out worldwide has been generating a high rate of dental loss. The present research work refers to the prevalence of partial edentulism, since partial edentulism is defined as a state of oral health that is the cause of an adverse effect of the state of oral health that corresponds to the absence of a certain number of teeth in the mouth. According to the World Health Organisation (WHO), caries and periodontal diseases are the main causes of tooth loss. Worldwide, 60-90% of school children and almost 100% of adults have tooth decay. Severe periodontal diseases, which can lead to tooth loss, affect 15-20% of middle-aged adults (35-44 years). The majority of the population has an incomplete but functional dentition, there is another large population group that does not have a prosthetic restoration and it is often very necessary. The causes of partial edentulism can be congenital or acquired.

Total congenital edentulism manifests as a very severe congenital syndrome, which are generally not compatible with the patient's life. Acquired edentulism, on the other hand, refers to the fact of tooth loss during our lifetime and can be secondary to the aforementioned caries or tooth loss. The loss of teeth results in the alteration of the stomatognathic system, resulting in altered masticatory function, which affects nutritional status, general health and quality of life. Several studies have affirmed that edentulism, besides being related to nutritional status, is also associated with the following factors: quality of life, age and gender of the patient. A very important point is the socio-economic level of the patient, as it is important for access to conservative or preventive treatment and this leads to an increase in the prevalence rate of edentulism. The Kennedy classification shows us the type of edentulous gap with the highest prevalence, as well as the proposal for conservative and comprehensive treatment. Due to the little information that exists on the subject in our environment, we present this study with the aim of describing the prevalence of partial edentulism according to Kennedy's classification and to study how it is presented in patients according to age, gender and location of the maxilla.

The study will be carried out in the Faculty of Dentistry of the Autonomous University of Campeche in the period 2020 ll, this will allow us to collect important data that will be added to the research on the prevalence of edentulism collected from the data collection forms. The prevalence of partial edentulism will also allow us to focus on prevention techniques before the disease occurs, early diagnosis of the disease and the necessary oral rehabilitation therapy for the partially edentulous. The present work is for the consideration of the students of the career of Dentistry, graduates and public in general so that it can be used as a means of information, investigation and support for other subsequent investigations.

Problem statement

In spite of the existence of preventive measures for all ages, edentulism continues to be one of the problems that a patient can present, due to different causes. Dentistry is considered a very important science within the biopsychosocial wellbeing, impacting both the emotional and psychological aspects of the individual, presenting non-aesthetic factors that have a greater impact on an individual than the masticatory function itself. The Kennedy classification shows us the type of edentulous gap with the highest prevalence, as well as the proposal for conservative and comprehensive treatment. Due to the little information that exists on the subject in our environment, we present this study with the aim of describing the prevalence of partial edentulism according to Kennedy's classification and to study how it is presented in patients according to age, gender and location of the maxilla. The study will be carried out in the Faculty of Dentistry of the Autonomous University of Campeche in the period 2020 ll, this will allow us to collect important data that will be added to the research on the prevalence of edentulism collected from the data collection forms. The prevalence of partial edentulism will also allow us to focus on prevention techniques before the disease occurs, early diagnosis of the disease and the necessary oral rehabilitation therapy for the partially edentulous. The present work is for the consideration of the students of the career of Dentistry, graduates and public in general so that it can be used as a means of information, investigation and support for other subsequent investigations.

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Theoretical framework

Oral diseases become a major health problem due to their high prevalence, public demand and strong impact on individuals and society, and are considered an integral part of the craniofacial complex involved in vital functions such as nutrition, communication and affection; therefore, oral health is related to wellbeing and quality of life from functional, psychosocial and economic points of view. They also affect a limited area of the human body but their consequences and impact affect the body as a whole. The World Health Organisation WHO defines oral health as the absence of oral or facial pain, oral or throat cancer, infections or ulcers, periodontal disease, dental caries, tooth decay, tooth loss, as well as other diseases and disorders that limit an individual's ability to bite, chew, laugh, laugh, speak or compromise psychosocial well-being. Oral disease is the result of specific health conditions, responses to exposure to certain bacterial agents, diet rich or lacking in carbohydrates, fluorides, poor oral hygiene habits, access to dental care, acquisition of knowledge about oral problems, individual responsibility for one's own health, consistent attendance at services and others. Oral health is not only related to the presence of teeth naturally or artificially, it is also related to the condition of the teeth, as well as the condition of the soft tissues of the oral cavity that do not disturb the functional capacity of the specific oral cavity and the general health of the individual. The preservation of oral health is of paramount importance for proper nutrition and relationships with others. Among the main diseases that affect the oral cavity are dental caries, which is defined as an infectious disease of multifactorial origin characterised by the softening of the hard tissue of the tooth that evolves to form a cavity, or the loss of teeth if it continues its natural evolution without treatment.

A large part of the population suffers from it unnecessarily, mainly due to lifestyle, diet and inadequate oral hygiene, as well as restricted access to dental health services, lack of oral care culture and the high costs of dental care, among others. According to several authors, the main causes of tooth loss are dental caries and periodontal disease, which are public health problems due to their prevalence and incidence; periodontal disease is the main cause among adults. According to tooth type, molars are mainly extracted for caries and anterior teeth for periodontal disease.

According to the report "Global Burden of Oral Conditions in 1990-2010" derived from The Global Burden of Disease GBD 2010 Study, oral diseases and disorders remain highly prevalent, collectively affecting around 3.9 billion people worldwide. The most common problem, of all the conditions assessed in the study, and with the greatest global burden of disease was untreated dental caries in the permanent dentition, while severe periodontitis and untreated caries in primary teeth were the sixth and tenth most prevalent conditions, affecting 11% and 9% of the world's population, respectively. Similarly, severe tooth loss was the 36th most prevalent condition, with a global estimate of 2%. For a long time, people considered tooth loss to be a natural occurrence and a characteristic of advancing age. With the development of society and the increase in educational level, populations became more aware of the need to maintain their teeth and even keep them healthy, but this philosophy has not reached everyone equally, as it has become a challenge for stomatology to extend and achieve it.

Tooth loss alters the functions of the stomatognathic system, such as mastication, phonetics and aesthetics. In the case of the masticatory function, it can lead to a change in the person's diet, forcing new dietary practices determined by a greater consumption of soft and easy to chew foods, causing dietary restrictions and compromising the person's nutritional status. Tooth loss is a complex outcome that reflects an individual's history of dental disease mainly dental caries and periodontal disease and their treatment by dental services throughout life.

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However, it shows not only dental disease, but also the attitudes of patients and dentists, the dentist-patient relationship, the availability and accessibility of dental services, and the prevailing philosophies of dental care. People suffering from edentulism see their quality of life diminished, as they cannot consume certain types of food, the masticatory process is deficient and therefore the digestive process and adsorption of nutrients extracted from food, phonation is severely affected and therefore the communicative process and facial aesthetics, self-esteem is impaired, the assessment and perception of edentulism is defined as the total or partial absence of dental pieces, which will not be replaced later in a natural way.

In order to simplify the description, compression and design of partial dentures in edentulous jaws, several classifications have been created. With the above we can understand that the lack of teeth in a person is an important alteration to consider because it can alter their physical condition in general, as well as their state of mind and general state of health; it is classified as partial or total edentulism; it can be preventable, irreversible and constitutes a mutilation, a loss of physical integrity. It is the result of systemic diseases such as diabetes and prevalent oral diseases.

The causes are diverse, the main ones being dental caries, chronic periodontitis, root fractures, poor oral hygiene and socio-demographic level, or it can be secondary to orthodontic reasons, aesthetics, prosthetic needs, trauma, generated by socio-economic, cultural factors, private policies that favour inequalities, inequities in health. Tooth loss alters the functions of the stomatognathic system, such as mastication, phonetics and aesthetics. In the case of the masticatory function, it can lead to a change in the person's diet, forcing new dietary practices determined by a greater consumption of soft and easy to chew foods, causing dietary restrictions and compromising the person's nutritional status. It should be emphasised that all the components of the stomatognathic system suffer alterations in position, size and contour, including the bony modification that will result in the new edentulous ridge.

The partial edentulous person is able to re-establish the function of chewing, phonation and swallowing, through the preparation of the removable partial prosthesis by the specialist in oral rehabilitation. Due to the great variety of cases of partial edentulism, it was necessary to establish a classification system, which was elaborated by Edward Kennedy in 1925. This system allowed the dental professional to design the prosthetic appliance in the most effective way and to know the state of conservation of the dental pieces in the mouth. Kennedy is credited with the initiative to present a way of classifying the partially edentulous. Most of the studies that include a way of classifying partially edentulous arches use Kennedy's classification.

In Venezuela, as well as studies carried out abroad, it is observed that the lower Kennedy Class I is the most frequent type of partially edentulous arch. This is related to the general pattern of tooth loss, which shows that molars are lost first, followed by premolars and finally lower anterior teeth. The method proposed by Edward Kennedy in 1925 attempts to group partially edentulous arches so that principles can be established to facilitate the design of each situation. Kennedy's classification sets out the different options that can be observed in a partially edentulous patient and allows a very practical and quick recognition and identification of their condition, as well as the approach to the most favourable design to solve the case being analysed.

Class l Partially edentulous arch with bilateral edentulous areas distal to the remaining natural teeth. Class ll Partially edentulous arch with a unilateral edentulous area distal to the remaining teeth. Class lll Partially edentulous arch with a unilateral edentulous area with natural teeth remaining anterior and posterior. Class IV Partially edentulous arch with an edentulous area anterior to the remaining natural teeth and crossing the midline. Applegate provides eight rules to facilitate the application of Kennedy's method.

Rule 1: All grading should be done after the indicated tooth extractions have been performed. Rule 2: If a third molar is missing and therefore not replaced, it should not be considered for classification. Rule 3: If a third molar is present and is to be used as an abutment, it should be considered for classification.

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Rule 4: If a second molar is absent and is not to be replaced due to lack of antagonist, it is not to be considered for classification. Rule 5: The posterior edentulous area(s) shall be determined by the classification. Rule 6: Edentulous areas other than those determining classification are called modification areas and shall be designated by a number. Rule 7: Only the number of edentulous areas and not their extent shall be considered. Rule 8: In Class IV there shall be no modification zones. Any subsequent edentulous areas will result in a change of class.

Dental caries is a multifactorial, transmissible pathology of infectious origin that affects the dental pieces, producing the progressive destruction of hard tissues and in which modulating etiological factors are involved, such as general health, socioeconomic level and level of education, among others. Caries usually starts hidden from view in the fissures of the tooth or in the interdental spaces. In its initial stage it can be stopped and even reversed, but in its advanced stage a cavity is formed. At this point, treatment is necessary to restore the function of the tooth, including removal of the decayed tissue and a filling or crown. If left untreated, caries can lead to extensive destruction of the tooth, with pain and infection.

The latter can lead to abscess formation or even septicaemia. Endodontic treatment or extraction of the tooth is necessary at this stage. The reduction of acid attack of the tooth enamel can be achieved by reducing the total intake and frequency of sugar consumption. Protection of the tooth surface can be achieved by ensuring adequate exposure to fluorides. Actions can also be taken to reduce the effect of biofilm through good oral hygiene. Studies reported worldwide on its prevalence, such as the World Health Organization in 2004, showed 60-90% in school children and almost 100% in adults, and the Dental Federation International in 2010, found 44%, affecting almost half of the population. Dental caries is a disease of high prevalence and severity in the populations of many countries. In industrialised countries it affects more than half of the population, and because it is a cumulative process, the severity of the damage increases with increasing age. From the perspective of causality, caries is a complex disease as it is caused by the interaction of different mechanisms.

For its analysis, the action of several genes, environmental, cultural, social and local factors must be considered. Several authors mention that dental caries is a public health problem due to its high prevalence. Dental caries is a process that can evolve and lead to tooth loss if not treated in a timely manner. In Mexico, it has been documented that the prevalence of dental caries is between 70 and 85% in the secondary dentition at the age of years.

The onset of the carious process cannot be attributed to a single cause, since its development requires a confluence of factors that determine the carious lesion, i.e., that the aggression of the dental enamel is of great magnitude, that the resistance of the enamel to acid dissolution is insufficient, and that the mechanisms of remineralisation of the enamel do not take place. When dental caries reaches the deep dental tissues, it becomes an emergency in stomatological services, but only if we know how this condition starts and spreads can we cure and prevent it. It is in this direction that the greatest efforts to control this most frequent disease should be directed. It is for these reasons that we were motivated to carry out this work. Dentists fill teeth by removing decayed tooth material with the use of a dental drill and replacing it with a material such as silver alloys, gold, porcelain or composite resin. The latter two materials most closely resemble the natural appearance of the tooth and may be preferred for front teeth. Many dentists consider silver and gold alloy amalgams to be stronger and tend to use them for the back teeth, although there is a tendency to use the highly resistant composite resin for the back teeth as well.

Periodontal disease: Certainly in the last decade there has been increasing evidence that periodontal disease is a global public health problem that health systems need to address and that periodontal disease is the leading cause among adults. According to tooth type, twenty-one molars are extracted mainly due to caries and anterior teeth due to periodontal disease. Tooth decay and periodontal disease in advanced stages cause pain and the individual, when he or she does not have sufficient resources, prefers to remove it by tooth extraction, and is reluctant to face long and expensive conservative treatment, which is often not available in public health services. Specific bacteria are the essential cause of periodontal diseases.

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Other important risk factors are smoking, unhealthy diet, genetic factors, stress or excessive alcohol consumption. Periodontal diseases are also associated with certain systemic diseases such as diabetes, cardiovascular diseases, respiratory diseases and some complications during pregnancy. Periodontal disease is a bacterial disease that causes low-intensity infection, with important metabolic consequences and local inflammatory reactions that destroy supporting and protective tissues of the tooth. Gingivitis Periodontal disease begins with gingivitis, a chronic inflammation of the gums, which is very common and reversible for most patients. It can progress to periodontitis, a more serious situation in which there is destruction of the supporting bone.

In 15% of the population the disease can progress to severe periodontitis which can lead to tooth loss. The most difficult part is to identify the sites that are already progressing from gingivitis to periodontitis. We can find sites with a depth of 4 mm but still no radiographic evidence of bone loss and this is mainly due to the low sensitivity of radiography and probing error. It has been calculated that the probing error is approximately 1 mm and added to the degree of inflammation, we can easily go from 3 mm to 4 mm. This must be carefully analysed by interpreting all periodontal clinical parameters. The extent of gingivitis can be classified as localised ≤30% of affected sites and generalised >30% of affected sites. It can also be marginal, papillary and diffuse. Periodontitis is the most common chronic inflammatory disease seen in humans. It is a major public health problem, causing tooth loss, disability, masticatory dysfunction and nutritional status. Poor nutritional status. The manifestations of periodontitis also include bleeding, halitosis, gingival recession and tooth loss, which can have an impact beyond the individual sufferer. Periodontitis also compromises speech, reduces quality of life and is an increasing burden on the economy. Chronic periodontitis Unlike gingivitis, periodontitis is inflammation of the gingiva and supporting periodontium, significantly affecting gingival connective tissue, periodontal ligament, cementum, bone. Pathognomonic findings include inflammation, bleeding on probing, periodontal pocket formation, attachment loss and radiographic bone loss.

Aggressive periodontitis Aggressive periodontitis usually occurs in individuals under 35 years of age, but it is suggested that it can occur at any age. The rate of periodontal destruction is rapid and since it begins early in life, the destruction is seen in younger subjects. But the analysis should not be based on age alone but on clinical findings, radiographic findings, family and personal history, laboratory aids. In the early stages of periodontal disease, most of the treatment consists of scaling and root planing, which means removing plaque and tartar in the pockets around the teeth and smoothing the root surfaces. In most cases of early periodontal disease the above treatment and daily home care is all that is required for a satisfactory result. More advanced cases may require surgical treatment. Early diagnosis of periodontal diseases is one of the main motivations for today's dental practice. With prevalence data being so contumacious, the prevention of gingivitis and periodontitis is one of the basic commitments of a dentist to the society in which he or she develops as a health professional.

Background and terminology

Luna Gabriel in his thesis, incidence of partial edentulism according to the Kennedy classification in the social rehabilitation centre of the city of Loja in the period June - November 2011, carried out an observational, descriptive and cross-sectional study, where he obtained the following results: Kennedy class III is the most frequent in both jaws with a total of 55.72% and modification III-1 in both jaws with 26.91%. According to age, in the ranges: under 20 years, 20 to 39 and 40 to 59 years, Kennedy class III is the most frequent, with the exception of the range over 60 years, in which class I is the predominant one. According to sex, in both men and women and in both jaws, Kennedy class III was the most frequent.1 Vega L. in Trujillo, Peru carried out a study to determine the prevalence of partial edentulism according to the Kennedy classification in adult patients attended at the second specialisation unit in stomatology of the national university of Trujillo during the years 2011-2016.

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A descriptive, retrospective and cross-sectional study was carried out. A total of 399 clinical histories of adult patients between 25 and 70 years of age who met the selection criteria were evaluated in this study. Class III was found to be the most prevalent 50.59%, followed by Class II 16.81%, Class I 14.9% and Class IV 1.62%. In the upper jaw class III was the most prevalent 66.9%, followed by class II 18.2%, class I 11% and IV 3.9%, while in the lower jaw class III was the most prevalent 53.8%, followed by class I 24.3%, class II 21.92%, with no record of class IV. According to modifications, the most prevalent in the upper jaw was class III with modification 2 26.7% and modification 1 24.2%; and in the lower jaw, class III modification 1 27.1%. According to age group, class I prevailed in the 56-70 age group 24.4%, class II 22.2% in the 56-70 age group, class III 77.9% between 25-40 years and class IV 3.1% between 56-70 years. Regarding gender, class III is the most frequent in males 63.3% and in females 58.3%. It is concluded that there was a higher prevalence of Kennedy class III in both jaws, genders and age groups. Loja Carlos from the University of Cuenca in Ecuador. He carried out a study to determine the prevalence of partial edentulism according to Kennedy class in patients who attended the clinic of the Faculty of Dentistry of the University of Cuenca during the periods 2012-2016. The results showed a higher prevalence of class III with 57.8%, followed by class II with 13.1%, class I with 8.3% and class IV with 0.5%, with no association between sex and the type of arch affected by edentulism. 3 Fernández Miguel. The objective was to determine the prevalence and distribution of edentulism, as well as the associated socio-demographic and socio-economic variables in individuals aged 35 years and over. A cross-sectional study was conducted in 656 randomly selected subjects. Men and women aged 35 years and older were included in the study. The mean age was 49.06 ± 10.33. The individuals were mainly female 63.3%. The overall prevalence of edentulism was 15.7% CI 95%: 12.9-18.5; among females it was 17.6% and in males 12.5% $p = 0.081$. The prevalence of edentulism was higher among older subjects $p < 0.001$. It was observed that the higher the schooling $p < 0.001$, the higher the socioeconomic level $p < 0.001$ and in those who had a car at home $p < 0.05$, the prevalence of edentulism was lower. Patiño Suárez María Magdalena et al. in their article edentulism, functional dentition in older adults in Tuxtla Gutiérrez, Chiapas 2019.

The objective was to evaluate the prevalence of edentulism and functional dentition, as well as its association with some sociodemographic factors in the older adult population who attended dental care at the Faculty of Dental Sciences and Public Health of the University of Sciences and Arts of Chiapas. Cross-sectional study of 441 MA between 60 and 89 years of age. Data were collected through a questionnaire and oral examination, the average age was 68.9 ±7.13 years, the majority were women 69.4%. The prevalence of edentulism was 25.6%, with a higher p 0.05 being found between the groups. In all groups, patients had mild or moderate TMD. Results of this clinical study showed that the presence of TMD in removable partial denture wearers could not be correlated with Kennedy's classification, once the presence of TMD in patient Lopez Judith In her thesis: Prevalence of partial edentulism according to the Kennedy Classification in the Oral Rehabilitation Service of the "Cirujano Mayor Santiago Távara" Naval Medical Centre in Lima, Peru 2009, she studied patients between 20 and 90 years of age of both sexes in the Oral Rehabilitation Service of the "Cirujano Mayor Santiago Távara" Naval Medical Centre, for which 161 patients were sampled, 145 men and 16 women. As a result, Class I was the Kennedy Class that presented the highest percentage with 38.43%, followed by Class II with 37.68%, Class III with 23.3% and finally Class IV with 1.1%. Strict mandibular Class I without modification proved to be the most frequent in relation to the other classifications taking into account modifications with 20.4%. No cases of Class IV were found in the lower jaw or in the female sex.7 According to Charieva et al, the most frequent type of partial edentulism in this sample of patients from the European Union in 2012 was Kennedy type III, both in the upper (50.0%) and lower jaw (41.1). Kennedy class IV was the most frequent (7.1% in the maxilla, 5.6% in the mandible) in at least the majority of cases treated with removable partial dentures in both arches.8 Cordova, Heydi conducted a research study whose general objective was to determine the prevalence of partial edentulism according to the Kennedy classification in patients aged 30 to 59 years from the centre Imágenes Estomatológicas EIRL, Lima 2017. The sample consisted of 150 panoramic radiographs of partially edentulous patients.

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The results showed that 32% of the population had a prevalence of Kennedy Class I partial edentulism, 26.7% Kennedy Class II, 39.3% Kennedy Class III and 2% Kennedy Class IV. Also, of the total population with partial edentulism in the upper jaw, 23.9% had a Kennedy Class I, 32.6% a Kennedy Class II, 36.9% a Kennedy Class III and 6.6% a Kennedy Class IV. In the lower jaw, 35.6% had a Kennedy Class I, 24% a Kennedy Class II, 40.4% a Kennedy Class III and 0% a Kennedy Class IV. On the other hand, it was also found that, of the total male population, 30% had a Kennedy Class I, 24.3% a Kennedy Class II and 45.7% a Kennedy Class III, while of the total female population, 33.75% had a Kennedy Class I, 28.75% a Kennedy Class II, 33.75% a Kennedy Class III and 3.75% a Kennedy Class IV. The prevalence of partial edentulism according to Kennedy Class I presented modification I with 47.9%, Class II modification III with 50% and Class III modification I with 47.9%, Class II modification III with 50% and Class III modification I with 47.5%. It was concluded that the most frequent Kennedy class was Class III in both the upper and lower jaw, also being more frequent in the male and female genders.2 Zambrano, Christel In her 2016 graduation work she carried out a descriptive analytical study of cross-sectional observational type with a universe of 156 patients, of these a sample of 116 male and female patients was obtained who presented partial edentulism in an age range from 22 to 50 years or more who attended the dental office of the Jacobo and Maria Elena Ratinoff Day Hospital. The results of the study showed that out of a universe of 154 patients obtained attending the dental consultation at the Jacobo & Maria Elena Ratinoff Day Hospital, 75% 116 patients were partially edentulous and 25% were non-partially edentulous. 72% of the sample of 116 partially edentulous patients were female patients and 38% were male. Within the female gender 76% were partially edentulous females and within the male gender 73% were partially edentulous males. Class III modification 1 prevailed in both jaws, there was a higher prevalence of partial edentulism in the lower jaw, however, in the upper jaw there was a higher prevalence of tooth loss, and the older age range 50 and over presented a higher percentage of partial edentulism. Padilla, Maria et al. in Mexico In their article "Dentition status and its impact on quality of life in older adults" (2017) conducted a descriptive cross-sectional study in AM students at the University of the Third Age in Mexico City.

The sample size was calculated based on descriptive studies with a population size of 250 people. An identification form was used to obtain personal data and comorbidities, in addition to a clinical evaluation of the oral cavity by means of the CPOD register, and the evaluation of edentulism and prosthetic load. In relation to the state of the dentition, the mean CPOD index was 1.04 ± 1.47 CI95% 0.75-1.33 for decayed teeth, 7.9 ± 7.3 CI95% 6.43-9.37 for missing teeth, 4.9 ± 4.2 CI95% 4.13-5.81 for filled teeth. The mean of the total CPOD index was 0.497. For edentulism a percentage of 87% of partial edentulism was obtained, 12% of total edentulism.10 Gonzalez, Cristina In her research "prevalence of partial edentulism according to the kennedy classification. ucsg dental clinic. 2015" her objective was to determine the prevalence of the type of partial edentulism according to the Kennedy classification in the UCSG dental clinic. A descriptive type of research was carried out, where the medical records of the patients were examined to determine what type of edentulism according to Kennedy the patients had in 2015. Of the 205 records reviewed, it was observed that in the upper jaw, class III was the most prevalent with 38%, followed by class II with 32%, and in the lower jaw, class II was most prevalent with 33% followed by class I with 30%.11. 4

Methodology

The study design was observational, descriptive and cross-sectional, and was carried out at the Universidad Autónoma de Campeche, in the clinics of the Faculty of Dentistry. The sample was obtained using the finite sample size formula with a total of 100 subjects.

Results

Of the study population of subjects n=100, 51% were male and 49% were female. The mean age was 59 years with a standard deviation of 11 and a range of 53. With respect to the variable school grade level, the majority only studied secondary school 50% followed by primary school 30%, high school 15%, university 5%. The distribution of the prevalence of partial edentulism with respect to sex, where Kennedy class II prevails in males with 21%. This was followed by class I in males with 10%, class III in females with 18% and finally class IV, also prevalent in females with 12%.

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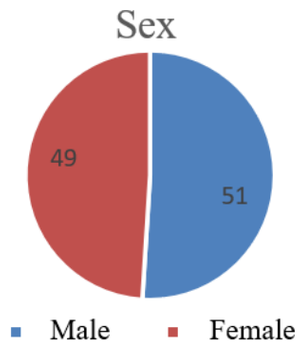
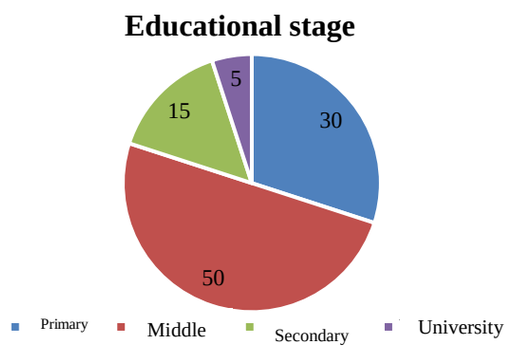


Graphic 1

Partial Edentulism	Male	Female
Class I	10 %	7 %
Class II	21 %	12 %
Class III	12 %	18 %
Class IV	8 %	12 %
Total	51 %	49 %

Table 1



Graphic 2

Conclusion

This study shows that the patients attending the Faculty of Dentistry demonstrated that Kennedy Class II is the one that obtained the best results in the male sex, while in Kennedy Class III the female sex stood out as the majority in the population studied. It is worth mentioning that these patients are studied with different age ranges, as well as schooling.

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Clarification of the effluent of an anaerobic digestion process: comparative study of single-stage and double-phase processes, with addition of coagulant and without addition of chemical coagulant

Clarificación del efluente de un proceso de digestión anaerobia: estudio comparativo de procesos de una y dos fases, con adición de coagulante y sin adición de coagulante químico

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Abstract

A study of the phenomenon of sedimentation of sludge from the anaerobic digestion of codigestion phases and monostage was performed, compared with addition and without addition of coagulant, the dose and concentration required was determined in the laboratory by jar test, the concentration of $FeCl_3$ resulted in 15000 mg / l. The results of the sedimentation curves of the interface below codigestion phases fit the equation $y = 0.0861\ x^2 - 14.198\ x + 970.63$, the interphase curves below co-digestion phases with addition of $FeCl_3$ fits an equation $y = 0.0714\ x^2 - 12.512\ x + 1008.4$, the interface above single-stage codigestion fits an equation $y = 0.0423\ x^2 - 6.3681\ x + 917.91$, the interface below single-stage codigestion fits an equation $y = 0.0953\ x^2 - 15.714\ x + 975.1$, the interface above single-stage codigestion with addition of $FeCl_3$ fits an equation $y = 0.0393\ x^2 - 5.196\ x + 977.79$, the interphase below single-stage codigestion with addition of FeCl3 fits into an equation $y = 0.838\ x^2 - 13.824\ x + 981.43$.

Codigestion phases, Codigestion monostage, Anaerobic digestion, Coagulant, Sedimentation

Resumen

Se realizo un estudio del fenómeno de sedimentación del lodo proveniente de la digestión anaerobia de la codigestión fases y monoetapa, se comparó con adición y sin adición de coagulante, la dosis y concentración requerida se determinó en laboratorio mediante prueba de jarras, la concentración de $FeCl_3$ resulto de 15000 mg/l. Los resultados de las curvas de sedimentación de la interfase por debajo de codigestión fases se ajusta a la ecuación $y = 0.0861\ x^2 - 14.198\ x + 970.63$, la de interfase por debajo de codigestión fases con adición de $FeCl_3$ se ajusta a una ecuación $y = 0.0714\ x^2 - 12.512\ x + 1008.4$, la de interfase por arriba de codigestión monoetapa se ajusta a una ecuación $y = 0.0423\ x^2 - 6.3681\ x + 917.91$, la de interfase por debajo de codigestión monoetapa se ajusta a una ecuación $y = 0.0953\ x^2 - 15.714\ x + 975.1$, la de interfase por arriba de codigestión monoetapa con adición de $FeCl_3$ se ajusta a una ecuación $y = 0.0393\ x^2 - 5.196\ x + 977.79$, la de interfase por debajo de codigestión monoetapa con adición de $FeCl_3$ se ajusta a una ecuación $y = 0.838\ x^2 - 13.824\ x + 981.43$.

Codigestión fases, Codigestión monoetapa, Digestion anaerobia, Coagulante, Sedimentación

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Introduction

Chemical precipitation, discovered in 1762, was a method of wastewater treatment widely used in England as early as 1870. Lime was used in many cases as a precipitating agent, sometimes alone, but very often in conjunction with calcium chloride, magnesium chloride, alumina sulfate, ferrous sulfate, charcoal, and many other substances. Chemical treatment was also widely used in the United States in the late 1890s and early 1900s; but with the development of biological treatment the use of chemicals was abandoned. In the early 1930s some attempts were made to develop new methods of chemical treatment and a few chemical treatment plants were installed.

At present it is an effective treatment process for the removal of many contaminants. Coagulation with alumina, ferric sulfate, or ferrous sulfate and softening with lime both involve chemical precipitation. The removal of substances from water by precipitation depends mainly on the solubility of various compounds formed in water. For example, heavy metals are found as cations in water and many will form solid hydroxides and carbonates. These solids have low solubility limits in water. Thus, as a result of the formation of insoluble hydroxides and carbonates, the metals will precipitate out of solution.

With this we can say that it is one of the most commonly used processes in water treatment. In fact, experience with this process has produced a wide range of treatment efficiencies.

Sludge sedimentation

In many locations, the discharge of industrial effluents to sewers has resulted in wastewater that is not treatable by biological means. In such situations, physicochemical treatment is an alternative solution. The main drawback of this treatment method, which has limited its widespread use, is the handling and disposal of large volumes of sludge resulting from the addition of chemicals.

On the other hand, it is worth mentioning that sludge from treatment plants often has very variable compositions. In some cases, it is often able to flocculate by simple agitation or by the addition of a flocculant or flocculation aid (polyelectrolytes); in other cases, it is necessary to use a coagulant to accelerate the formation of flocs that can be precipitated (chemical precipitation as an aid to flocculation).

Features

In order for the treatment and disposal of the sludge produced in wastewater treatment plants to be carried out in the most effective way, it is important to know the characteristics of the solids and sludge to be processed. The characteristics are variable, depending on the origin of the solids and sludge, the time elapsed since their production and the type of process to which they have been subjected.

Amount of sludge

The handling and disposal of sludge resulting from chemical precipitation was in the past, and still is today, one of the major difficulties encountered in this treatment method. Sludge is produced in large volume in most chemical precipitation operations, often amounting to 0.5% of the volume of treated wastewater.

Chemical conditioning

The use of chemicals to condition the sludge for dewatering is economical because of the higher yields and flexibility of the results obtained. Chemical conditioning results in coagulation of solids and release of absorbed water. Conditioning is used prior to vacuum filtration and centrifugation. The chemicals used are ferric chloride, lime, alumina sulfate and organic polymers. It is recommended that chemicals be dosed and measured in liquid form to facilitate mixing with the digested sludge.

Dosage

The chemical dosage required for any given type of sludge is determined in the laboratory by means of jar type tests, which allow the chemical dosages to be determined. The types of sludge, listed in approximate order of increasing chemical requirement for conditioning, are as follows:

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1. Mixture of untreated (raw) primary sludge.

2. Mixture of raw primary sludge and trickling filter sludge.

3. Mixture of raw primary sludge and excess activated sludge.

4. Aerobically digested sludge.

5. Mixture of anaerobically digested primary and excess activated sludge.

6. Aerobically digested sludge (normally dewatered on drying beds without the use of conditioning chemicals).

The general objective of the present investigation is to deepen the phenomenon of sedimentation of sludge from anaerobic digestion of two processes such as Single and Double Phase, making a comparison with the addition of coagulant and without the addition of chemical coagulant in the sludge of the substrate of CODIGESTIÓN FASES and CODIGESTIÓN MONOETAPA. It is expected to follow a flocculated particle behavior as proposed by the tests carried out by Talmadge and Fitch (1955).

Justification

As the waste products of the process will be inorganic solids, liquids and gases. The gases should be extracted from the digester and processed to obtain energy, or simply burned and evacuated without use. The solid inorganic matter, due to its inert nature, should not present any problems for disposal. The objective pursued with the clarification of digester effluent is twofold. On the one hand, the concentration of the settled sludge should be as high as possible in order to minimize the volume of sludge to be transported to subsequent processes (e.g., dewatering, thickening, etc.) and, on the other hand, the supernatant liquids should be recirculated to the wastewater treatment process, so it is important that they have the lowest possible concentration of solids or organic matter.

Methodology

In this experiment, the phenomenon of sedimentation of the substrates CODIGESTION FASES and CODIGESTION MONOETAPA was studied by making a comparison with the addition of coagulant and without the addition of chemical coagulant as mentioned above.

Initially, the experimental plant consisted of three digesters with a capacity of 100 liters, to which an acid phase system was added as shown in Figure 1, which at first the three digesters were inoculated with digested sludge. The operating regime of the three digesters was in mesophilic monostage. The digesters were fed in the following way:

For this stage of the experiment, we worked only with the substrate mixture of FANGO plus FORSU, i.e. in CODIGESTION. Two different technologies were operated in a comparative manner as follows:

The CODIGESTION SINGLE-STEP DRYER

The digester CODIGESTION PHASES (1 Acidic Phase + 2 Methanogenic Phase). As shown in figure 1.

Sampling parameters

In addition, the following parameters are analyzed in each digester influent: pH, Temperature, Total Solids, Total Volatile Solids, Total Filtrable Solids, Biochemical Oxygen Demand, Organic Matter, Moisture and Ash.

The effluent: pH, Temperature, Total Solids, Total Volatile Solids, Total Filtrable Solids, Biochemical Oxygen Demand, Alkalinity, Volatile Fatty Acids and of the biogas produced: pressure, flow, $\%CH_4$, $\%CO_2$.

The analyses were carried out following the analytical methodology established by the "Standard Methods for the Examination of Water and Wastewater", APHA-AWWA-WPCF, and analogous to the Environmental Protection Agency (EPA).

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Figure 1 Phased co-digestion and single-stage co-digestion digesters

Sampling methodology

After having verified the satisfactory parameters of the effluent of the digesters, the sampling of the sludge from each of the digesters was carried out in a clean jar with a handle, graduated with a capacity of 2 liters, which was immediately taken to the laboratory, The measurement of these two parameters was carried out for 10 minutes and with constant agitation to avoid flotation or resuspension of the sludge until the reading remained stable. The point for the extraction of the samples were the outlets corresponding to the reactors of the sludge of the different substrates corresponding to MONOETAPE CODIGESTION and PHASE CODIGESTION respectively.

The rest of the sludge was deposited in a 1 L beaker, it was shaken manually for approximately 5 to 10 minutes, this was done to release the possible gases that had been trapped in the sample, then it was poured into a graduated cylinder of 1 L and the sedimentation or flotation time of the sludge was timed over time, The notes of the experiment were made in the record sheet, in this table it makes reference to the notes corresponding to the sampling date, the sample in question, the test number, as well as the start and end time of the experiment, the minutes at which the start interface was presented and its interfaces both above and below.

Determination of the optimum coagulant

To determine the optimum dosage of the different types of coagulants, we started with the lowest dosage and increased the dosage until we observed a significant change in sludge sedimentation.

As previously mentioned, the extraction and disposal of the sludge was limited, so the maximum amount of sludge available was 3 liters.

For the determination of the optimum coagulant, the "jar test" was carried out in 100 ml test tubes in which 50 ml of sludge were deposited.

Determination of the optimal coagulant dosage

For the determination of the optimum coagulant dosage, the "jar test" was also carried out in test tubes of 100 ml capacity in which 50 ml of sludge were deposited.

Figure 2 Tests of the optimum coagulant, as well as its optimum coagulant dosage

Chemical sedimentation

Once the above steps were completed, the sedimentation tests were carried out without the addition of coagulant and with the addition of coagulant, as follows:

1. One liter of sludge sample was placed in a graduated cylinder without the addition of coagulant.

2. Immediately afterwards, the same sample of sludge is placed in another graduated cylinder of one liter, but with the addition of the previously obtained dose of coagulant.

3. The sedimentation or flotation time of the sludge was timed over time, and the experiment was recorded on the log sheet.

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4. With the data recorded, we proceed to plot a graph for each of the tests, this is done with the milliliters vs. minutes over the time in which the experiments were carried out, at the end of these we proceed to make the comparison between the tests and proceed to record the observations.

Sample treatment

In the second stage of the experiment at the 90th minute of the CODIGESTION FASES and CODIGESTION MONOETAPA chemical sedimentation tests, the aliquots (without coagulant and with coagulant) of the last 5 tests were extracted, this was carried out by introducing a 10 ml pipette up to the interface free of sludge (supernatant), It is important that when introducing it, this is done with the end opposite to the tip covered with the index finger, this is done with the purpose of not introducing the sludge in the pipette, which can be found in the interface from above, and this can bring as consequence interferences in the analysis as in the results.

A small aliquot is obtained, which is discarded because it is the first one. The previous procedure is repeated as many times as necessary, until the volume necessary for COD and turbidity determination is obtained.

Determination of supernatant quality

After obtaining the aliquots of the supernatant of the substrates of PHASE CODIGESTION and MONOETAPE CODIGESTION respectively, as shown in Figure 3, the determination of the parameters corresponding to COD and Turbidity is carried out.

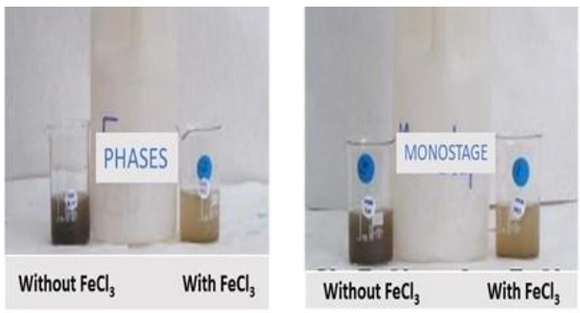

Figure 3 Obtaining the volume for the determination of COD and Turbidity parameters

Results

The main results obtained are summarized below:

Agitation variable

One of the main variables that directly influences the process of sludge sedimentation of the different substrates is the agitation.

For this purpose, the sludge was poured into a 1 L beaker and stirred manually for approximately 5 to 10 minutes. To immediately perform the sedimentation test.

The total of 56 sedimentation tests performed are shown in Table 1.

Substrate	Number of trials	1 Resuspension		2 Resuspension	
		Number of resuspensions	%	Number of resuspensions	%
Phase co-digestion without FeCl3	14	1	7	0	0
Phase Co-digestion with FeCl3	14	0	0	0	0
Codigestión de Monoetapa sin $FeCl_3$	14	1	7	0	0
Codigestion of Monostage with FeCl3	14	1	7	0	0

Sedimentation time variable

Another variable that influences the phenomenon of sedimentation in the mud of the different substrates. It is the time necessary for the sedimentation curve to stabilize and tend to an asymptotic value, not presenting the resuspension phenomenon.

For the 56 sedimentation tests that were carried out, we proceeded to obtain the necessary time. Until the value of the curve tends to horizontal, the type of substrate to which it corresponds, and the averages were as follows: The substrate CODIGESTION FASES in its two modes (with addition of FeCl3 and without addition of FeCl3) the average time was 101.4 minutes for each and finally the substrate CODIGESTION MONOETAPE in its two modes (with addition of FeCl3 and without addition of FeCl3) the average time was 100.4 minutes for each.

Therefore, the time required for the sedimentation curve to tend to a horizontal value is as follows:

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Substrate CODIGESTION MONOETAPA in its two modalities (with addition of FeCl3 and without addition of $FeCl_3$).

CODIGESTION FASES substrate in its two modes (with addition of FeCl3 and without addition of $FeCl_3$).

Variable gas production.

For the 56 trials that were carried out, the number of resuspensions was counted as well as the time in minutes that these occurred, which were as follows:

The CODIGESTION FASES substrate without addition of FeCl3 showed 1 trial that showed resuspension and this occurred at minute 58.

CODIGESTION FASES substrate without FeCl3 addition did not show any resuspension.
The substrate CODIGESTION MONOETAPE without addition of FeCl3 showed 1 trial with resuspension occurring at minute 21.

The substrate CODIGESTION MONOETAPE with the addition of FeCl3 showed 1 trial that presented a resuspension and this occurred at minute 33.

Variable type of substrate

Another variable that influences the sedimentation phenomenon is the comparison of substrates. The behavior was different in the two cases in general, in terms of: sedimentation velocity, resuspension, gas generation, compaction of the bottom interface, flotation of the top interface, etc.

To evaluate the effect of the addition of a chemical coagulant on the sedimentation properties, the following are mentioned:

Substrate Codigestion Phases without addition of $FeCl_3$

Of the 14 sedimentation assays performed with the CODIGESTION FASES substrate, 12 assays presented double interphase (85.7%). Two trials presented a single interphase (14.3%), and one trial presented a resuspension (7.14%).

Regarding the sedimentation of the substrate CODIGESTION PHASES it should be noted that here the interface above was very low, so the results were discarded as being of little relevance to our research.

On the other hand, the sedimentation curve of the interface below the substrate CODIGESTION PHASES fits a second degree polynomial form as shown in equation 1.

$$y = 0.0861\,x^2 - 14.198\,x + 970.63 \qquad (1)$$

As can be seen in Figure 4, which corresponds to the shape of the type 3 settling sedimentation model, presenting a parabolic shape that descends very smoothly for the first 20 minutes, then slowly smoothes out and finally remains constant at minute 70 with an interface of approximately 400 ml.

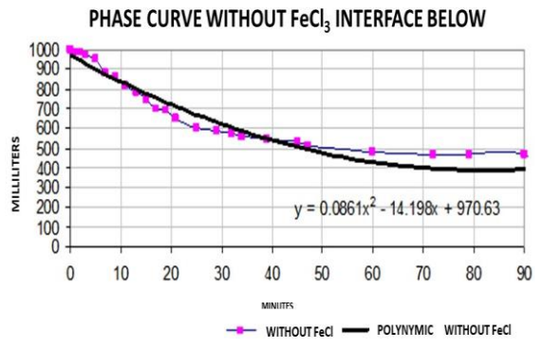

Figure 4 Representative curve of CODIGESTION FASES substrate without addition of coagulant over time

CODIGESTION PHASE substrate with addition of $FeCl_3$

The average $FeCl_3$ in the CODIGESTION FASES substrate in the trials was 1.93 ml in 50 ml of sludge.

The $FeCl_3$ concentration required for sedimentation of the PHASE CODIGESTION substrate was 15000 mg/l.

Of the 14 sedimentation tests performed on the CODIGESTION FASES substrate with FeCl3 addition, 14 tests showed double interphase (100%). 14 trials showed double interphase (100%). None of the tests showed any resuspension. The sedimentation curve of the interface below the substrate CODIGESTION PHASES with FeCl3 addition fits a second degree polynomial form, as shown in equation 2.

$$y = 0.0714\,x^2 - 12.512\,x + 1008.4 \qquad (2)$$

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As can be seen in Figure 5, which corresponds to the shape of the type 3 settling sedimentation model, presenting a parabolic shape that descends very smoothly during the first 30 minutes, then slowly smoothes out and finally remains constant at minute 70 with an interface of approximately 480 ml.

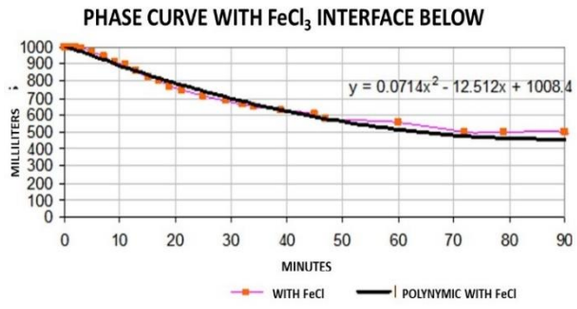

Figure 5 Representative curve of CODIGESTION FASES substrate with coagulant addition over time

Figure 6 shows comparatively the 2 representative curves of the PHASE CO-DIGESTION substrate without FeCl3 addition and with $FeCl_3$ addition.

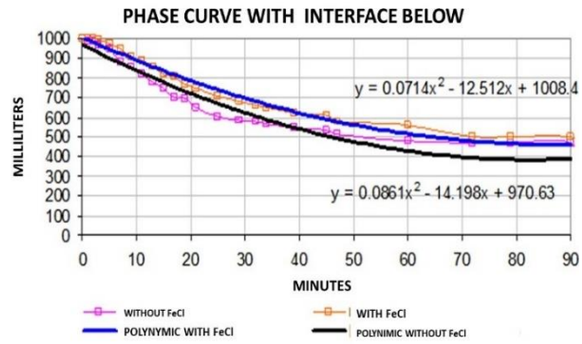

Figure 6 Integration of the representative curves of the substrate CODIGESTION PHASES with and without $FeCl_3$ addition

1. In the substrate CODIGESTION FASES without addition of $FeCl_3$ the resulting sludge-free supernatant is approximately 400 ml. In a time of 90 minutes. While on the other hand with the PHASE CODIGESTION substrate with addition of $FeCl_3$ the sludge free supernatant is approximately 500 ml.

2. The two curves of the substrate PHASE CODIGESTION without addition of FeCl3 and the substrate PHASE CODIGESTION with addition of $FeCl_3$ can be fitted to a second degree polynomial.

3. The two fitted representative curves have a very similar behavior, being displaced by approximately 100 ml from each other.

4. According to the results, the substrate CODIGESTION FASES with the addition of $FeCl_3$.

5. According to the results, the one with the highest compaction is the PHASE CO-DIGESTION substrate without $FeCl_3$ addition.

Substrate CODIGESTION MONOETAPA without addition of FeCl3

Of the 14 trials of the CODIGESTION MONOETAPA substrate, 14 trials showed double interphase (100%), and 1 trial showed resuspension (7.14%).

The sedimentation curve of the interface above the MONOETAPE CODIGESTION substrate conforms to a second degree polynomial form, as shown in equation 3.

$$y = 0.0423x^2 - 6.3681\,x + 917.91 \qquad (3)$$

As can be seen in Figure 7, which has the shape of a parabola that descends rapidly and irregularly in the first 20 minutes, and then descends very smoothly, until it finally remains constant at the 80th minute with an interface of approximately 700 ml.

The sedimentation curve of the interface below the substrate CODIGESTION MONOETAPA fits a second degree polynomial form, as shown in equation 4.

$$y = 0.0953x^2 - 15.714x + 975.1 \qquad (4)$$

As can be seen in Figure 7, which corresponds to the shape of the type 3 settling sedimentation model, presenting a parabolic shape that descends very rapidly in the first 20 minutes, then slowly smoothes out and finally remains constant at the 80th minute with an interface of approximately 320 ml.

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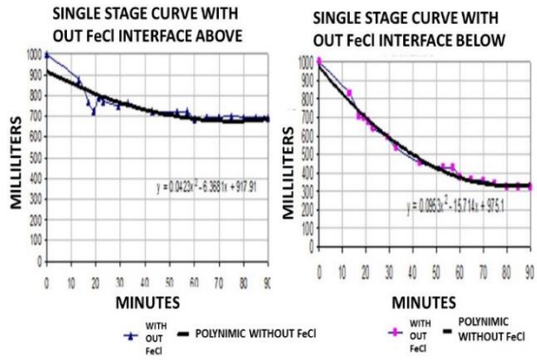

Figure 7 Fitted curves of the sedimentation process of the substrate CODIGESTION MONOETAPE without $FeCl_3$ addition of all the trials of the experiment over time

Substrate CODIGESTION MONOETAPA with addition of $FeCl_3$

The average $FeCl_3$ demand in the CODIGESTION MONOETAPE substrate in the trials was 2.6 ml in 50 ml of sludge.

The $FeCl_3$ concentration required for the sedimentation of the CODIGESTION MONOETAPA substrate was 15000 mg/l.

Of the 14 sedimentation tests performed on the substrate CODIGESTION MONOETAPA with $FeCl_3$ addition, 14 tests showed double interphase (100%) and 1 test showed resuspension. 14 trials presented double interphase (100%), and 1 trial presented a resuspension of the substrate.

The sedimentation curve of the above interface of the MONOETAPE CODIGESTION substrate with FeCl3 addition can be fitted to a second-degree polynomial form, as shown in equation 5.

$$y = 0.0393x^2 - 5.196x + 977.79 \quad (5)$$

As can be seen in Figure 8, which has the shape of a parabola that descends rapidly and irregularly in the first 20 minutes, and then descends very smoothly, until finally remaining constant at the 80th minute with an interface of approximately 835 ml.

The sedimentation curve of the bottom interface of the substrate CODIGESTION MONOETAPE with FeCl3 addition can be fitted to a second-degree polynomial form, as shown in equation 6.

$$y = 0.838x^2 - 13.824x + 981.43 \quad (6)$$

As can be seen in Figure 8, which corresponds to the shape of the type 3 settling sedimentation model, presenting a parabolic shape that descends very rapidly in the first 20 minutes and irregularly, and then slowly smoothes out irregularly and finally remains constant at the 75th minute with an interface of approximately 400 ml.

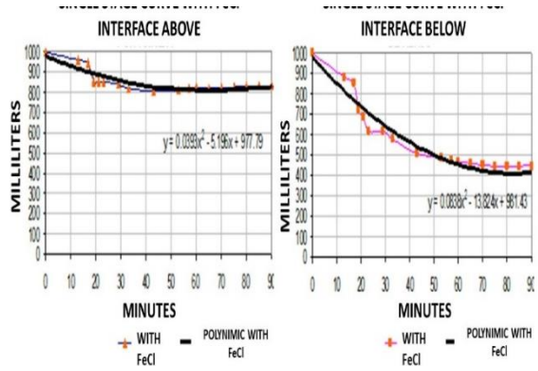

Figure 8 Fitted curves in the substrate sedimentation process CODIGESTION MONOETAPE with addition *of $FeCl_3$ from all tests of the experiment over time*

Figure 9 shows comparatively the 2 representative curves of the MONOETHAPE CODIGESTION substrate without $FeCl_3$ addition and with $FeCl_3$ addition.

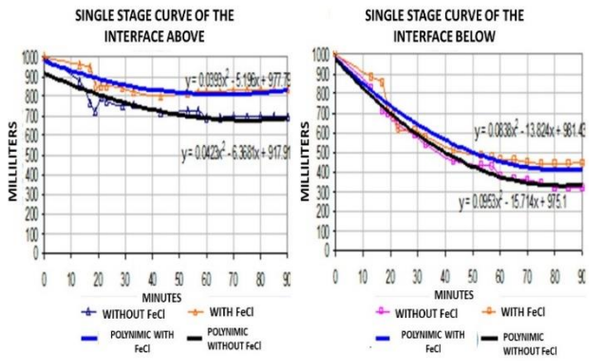

Figure 9 Integration of the representative curves of the substrate of MONOETAPE CODIGESTION with and without $FeCl_3$ addition

The quality of the clarified product with $FeCl_3$ addition is better than that without FeCl3 addition, as shown by the BOD and turbidity values in Table 2 and 3.

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Sample Phases	DQO (mg/l)		Turbidity (NTU)	
Sample prom.	With FeCl	No FeCl	With FeCl	No FeCl
1	4028	5179	413	439
2	1687	2797	301	320
3	1690	4929	221	262
4	4864	11351	75	200
5	3862	6068	172	283

Table 2 COD and Turbidity values of the sample supernatant sample sedimentation process steps

Sample Monoetapa	DQO (mg/l)		Turbidez (NTU)	
Sample prom.	With FeCl	No FeCl	With FeCl	No FeCl
1	9784	12086	360	427
2	3916	6153	275	388
3	1690	5070	160	234
4	8108	18918	263	325
5	4965	6068	224	330

Table 3 COD and Turbidity values of the supernatant of the single-stage sample of the sedimentation process

So, we can make a comparison and comment on similarities and differences.

Regarding the interface from above.

1. The two representative curves behave very similarly, but in parallel, tending to an asymptotic value and an offset of about 100 ml between each one.

2. The representative curves are fitted to a polynomial equation of second degree.

3. The Monostage Codigestion substrate with $FeCl_3$ addition shows higher interphase flotation above than the Monostage Codigestion without $FeCl_3$ addition.

4. According to the results, the one with the highest effluent sludge flotation is the single-stage Codigestion substrate with the addition of $FeCl_3$.

Regarding the interface from below

1. The behavior at the first 50 minutes is practically identical, although from minute 60 onwards the curves slowly separate, the shape of the curve of the substrate Codigestion Monostage with $FeCl_3$ tends to become an asymptotic value of approximately 400 ml, while on the other hand the curve of the substrate Codigestion Monostage sn $FeCl_3$ tends to a value of approximately 300 ml, indicating a better compaction of the sludge.

2. The representative curves are fitted to a polynomial equation of second degree.

3. The substrate of single-stage co-digestion without $FeCl_3$ addition shows a higher compaction of the interface from below than the single-stage co-digestion without $FeCl_3$ addition.

4. According to the results, the one with the highest effluent clarification is the single-stage codigestion substrate with the addition of $FeCl_3$.

5. According to the results, the one with the highest compaction is the Phases Codigestion substrate without addition of $FeCl_3$.

6. With regard to the COD and turbidity results, the one with the best supernatant quality was that of the Phase Co-digestion substrate with the addition of $FeCl_3$.

Conclusions

Substrate CODIGESTION STAGES

Of the 14 sedimentation tests performed on the substrate Codigestion Phases, 12 tests showed double interphase (85.7%). Two trials presented a single interphase (14.3%), and one trial presented a resuspension (7.14%). However, the interface above was very scarce, so we conclude that in this type of substrate the interface presented by the interface above is negligible and easily eliminated.

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On the other hand, at the interface below it occurs in a similar way in the Phases Codigestion substrate without $FeCl_3$ as with $FeCl_3$ addition. Therefore, the addition of the coagulant has no influence.

As regards the clarification of the effluent, it turns out that it is higher with the addition of $FeCl_3$.

Of the 14 sedimentation tests performed on the substrate Codigestion Phases with addition of $FeCl_3$. 14 trials presented double interphase (100%).

Substrate CODIGESTIÓN MONOETAPA

Of the 14 trials that were carried out with the Codigestion Monostage substrate, 14 trials showed double interphase (100%) and 1 trial showed resuspension (7.14%).

With regard to the sedimentation of the substrate Codigestion Monostage, the two interfaces were present here, both from above and below, so that if the two interfaces are considered as a whole, then the following two interfaces are considered.

The sedimentation curve turns out to be better for the curve for the Mono-stage Codigestion substrate without $FeCl_3$.

Of the 14 sedimentation tests performed on the substrate Codigestion Monostage with FeCl3 addition, 14 tests showed double interphase (100%). 14 trials presented double interphase (100%).1 trial presented a resuspension (7.14%).

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Comparative study of the physicochemical and microbiological parameters of two artesian wells in the community of San Pedro, Frontera, Centla, Tabasco

Estudio comparativo de los parámetros fisicoquímicos y microbiológicos de dos pozos artesianos en la comunidad de San Pedro, Frontera, Centla, Tabasco

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Abstract

The scarcity, mismanagement and poor quality of water resources are alarming; Some data shows the lack of the resource, more than two billion people lack access to drinking water services; more than four and a half billion people lack access to sanitation services; Nearly half a million children under the age of five die each year as a result of water-related diseases (Vivot, E. *et al*., 2012). To know the water conditions of the wells of the community of San Pedro, Centla, Tabasco, samples of fecal and total coliform water were taken, as well as physicochemical analysis: hardness, pH, chlorides, turbidity, sedimentable solids, color, nitrogen from nitrates, odor, of which those that exceeded the maximum permissible limits based on the criteria of NOM-127-SSA1-1994 were: chlorides, turbidity and fecal coliforms, the data identified outside the norm were analyzed in the program MINITAB to determine the trend of the data, the dispersion and if there is a relationship between the data, as well as data projections based on the confidence levels of 0.05 and 0.10%. It was observed in the results that the fecal coliforms show uniformity of the data from both wells, in both wells a normality of the data is observed although well 2 has an elevation of the LMP based on the norm, for turbidity a difference was also observed. normality and uniformity of the data from both wells. Concluding that the data have a tendency to increase in general. Containment and prevention strategies are established for the analyzed parameters.

Fecal coliforms, Total coliforms, Chlorides in water, Water quality

Resumen

La escasez, mala gestión y mala calidad del recurso hídrico son alarmantes; Algunos datos muestran la falta del recurso, más de dos mil millones de personas carecen de acceso a servicios de agua potable; más de cuatro mil millones y medio de personas carecen de acceso a servicios de saneamiento; cerca de medio millón de niños y niñas menores de cinco años mueren cada año a consecuencia de enfermedades relacionadas con el agua (Vivot, E. *et al*., 2012). Para conocer las condiciones de las aguas de los pozos de la comunidad de San Pedro, Centla, Tabasco, se tomaron muestras de aguas de coliformes fecales y totales, así como análisis fisicoquímicos: dureza, pH, cloruros, turbidez, solidos sedimentables, color, nitrógeno de nitratos, olor, de los cuales los que rebasaron los límites máximos permisibles en base a los criterios de la NOM-127-SSA1-1994 fueron: cloruros, turbidez y coliformes fecales, los datos identificados fuera de norma se analizaron en el programa MINITAB para determinar la tendencia de los datos, la dispersión y si existe relación entre los datos, asi como proyecciones de datos en base a los niveles de confianza de 0.05 y 0.10 %. Se observó en los resultados que los coliformes fecales muestran uniformidad de los datos de ambos pozos, en ambos pozos se observa una normalidad de los datos, aunque el pozo 2 tiene una elevación de los LMP en base a la norma, para turbidez también se observó una normalidad y uniformidad de los datos de ambos pozos. Concluyendo que los datos tienen una tendencia a incrementar de forma general. Se establecen estrategias de contención y prevención de los parámetros analizados.

Coliformes fecales, Coliformes totales, Cloruros en agua, Calidad del agua

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Introduction

Water is considered to be the universal solvent, given its characteristics and properties that is related to its molecular structure, which allows it to easily dissolve ionic compounds and polar compounds and solubilize others of lipidic character. This distinctive feature gives water a great importance, since it can have diverse applications; without forgetting that it is an essential element for the maintenance of life on the planet, as mentioned by (Pérez-López, 2016, pp. 4-6). Therefore, and for all of the above it is important to know the ideal conditions of the vital liquid for this it is necessary to rely on what establishes the Mexican environmental regulations that based on the use or final disposal of water, the standards to know the maximum permissible limits of the ideal parameters are; NOM-001-SEMARNAT-1996 and NOM-002-SEMARNAT-1996 and we consider of utmost importance the NOM-127-SEMARNAT- 2021, it is necessary to establish guidelines and guidelines that allow us to evaluate with greater certainty and efficiency the quality of water sampled with the firm purpose of having water available for human domestic use.

There are many studies carried out on surface water bodies or groundwater where the water quality of these bodies of water is evaluated, observing high levels of contamination (Lozada, P. *et al*., 2010), contaminated water has a great impact on both health and the environment. According to Morell and Hernández (2000), high concentrations of chlorides, nitrates and heavy metals, as well as physicochemical parameters, high levels of contamination limit the viability of the liquid and increase its toxicity, so the study of contamination, the measurement of its effects and the control of its evolution and are aspects of utmost importance. It is essential to monitor aspects such as potability, the presence of fecal coliforms, free chlorine, alkalinity, the amount of suspended solids, conductivity and hardness, since the aforementioned contaminants come from different human practices that affect its quality and, therefore, all the activities and organisms that depend on the vital liquid.

The objective of this work is to evaluate the quality of water under certain physicochemical parameters identified with greater significance that allow identifying the feasibility and viability of water consumption in two water wells in the community of San Pedro, Frontera, Centla, Tabasco, which are the only water supplies for this community and therefore are of utmost importance to know the water conditions and thus in turn know if the water complies with the corresponding regulations.

Problem statement

La Barra de San Pedro, Frontera, Centla, Tabasco is a community of 517 inhabitants, with a distance of two kilometers from the sea, in this community there is a strong problem of water shortage for human consumption, derived from the water problem the inhabitants of the community made two artesian wells with the purpose of supplying water for consumption, It is worth mentioning that other artesian wells have been drilled without obtaining favorable results because of the proximity to the sea, the wells show a large amount of salts that are found in the water of deep wells, the purpose of knowing the quality of the water of these wells is because the inhabitants use these waters for their basic daily services.

The analyses carried out for this study were chlorides, hardness, turbidity, nitrogen, pH, fecal coliforms and total coliforms, since these parameters allow us to know the condition of the water and the consideration of its use for human activities, using the applicable environmental regulations.

It is worth mentioning that the availability of fresh water is decreasing worldwide; 1.2 billion inhabitants do not have access to a safe drinking water source. Diseases caused by contaminated water kill more than 4 million children per year and 20% of all freshwater aquatic species are extinct or in danger of disappearing (Martínez-Romero et al., 2009).

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Objectives

General objective

To evaluate the water quality of two artesian wells in the community of San Pedro, Frontera Centla, Tabasco under the corresponding regulations.

Specific objectives

- Perform physicochemical analysis (hardness, turbidity and pH) of water from two artesian wells in the community of San Pedro, Frontera, Centla, Tabasco.
- To perform microbiological analysis (fecal coliforms and total coliforms) of water from two artesian wells in the community of San Pedro, Frontera, Centla, Tabasco.
- Statistical analysis of physicochemical and microbiological data to determine the trend in the quality of water for human consumption during 1 year in the town of San Pedro, Centla, Tabasco.

Methodology

a) Description of the sampling site

The community Barra de San Pedro is located in the Municipality Centla of the State of Tabasco Mexico and is located at the GPS coordinates: Longitude (dec): -92.469722 Latitude (dec): 18.643333 at 10 masl (Figure 1).

The total population of Barra de San Pedro is 384 people, of which 200 are male and 184 are female. The citizens are divided into 158 minors and 226 adults, of which 12 are over 60 years old.

In Barra de San Pedro there are a total of 89 households, of these 89 dwellings, 6 have dirt floors and about 23 consist of only one room. 86 of all homes have sanitary facilities, 0 are connected to public utilities, 89 have access to electricity.

Of the population aged 15 years and older, 0 have no schooling, 131 have incomplete schooling, 66 have a basic schooling and 26 have a high schooling. 66 have basic schooling and 26 have post-basic education.

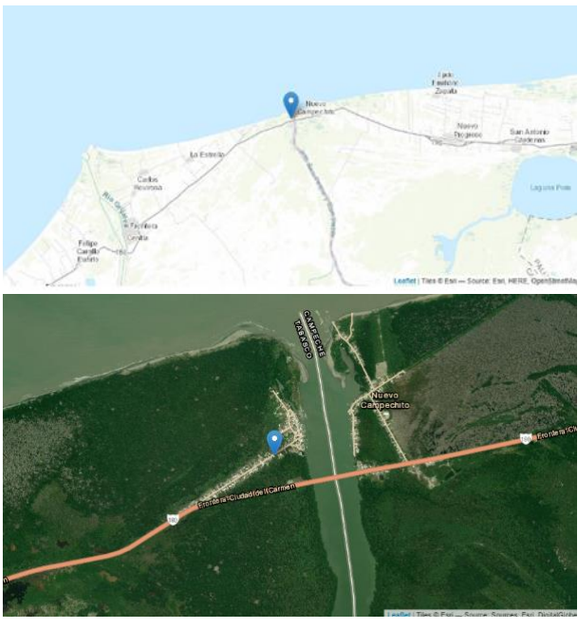

Figure 1 Micro-location of the sampling points

a) Design and implementation of the sampling plan

The methodological design was established with the objective of evaluating the quality of water in relation to its quality, for human consumption, to which the inhabitants of the San Pedro community in Centla, Tabasco, have access, during 1 year (2021). Through field visits, two sampling points were selected to diagnose the quality of the water used by the community for domestic use, these points are artesian wells, one of which is located in a private home and the other is of common use of the community, this one is located at the edge of one of the main streets of the community. This selection was based on the fact that they are the only freshwater options available (Table 1). Samples were taken from the two wells, naming them Well 1 (at the river bank) and Well 2 (located at the entrance of the community). Water sampling of the artesian water supply wells was conducted during the year 2021. At each sampling point, the following field parameters were determined: temperature, pH, electrical conductivity, water color, odor, and transparency in order to determine the characteristics of the groundwater at the time of sampling; the concentration of residual chlorine was also determined to determine if it complied with the Mexican Official Standard NOM 127-SSA1-1994. The laboratory parameters were turbidity, settleable solids, total hardness, calcium hardness, nitrate nitrogen, chlorides, total coliforms, and fecal coliforms (Table 2).

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Sampling point	Geographical location	Description
Well 1	N 18º 38'23.2" WO 92º28'28.7"	River bank well
Well 2	N 18º38'35.8" WO 92º28'08.9"	Well housing

Table 1 Location of sampling points

Water well 1	Location	river bank		
ON-SITE PARAMETER	MEASUREMENT UNITS	ANALYSIS RESULT	DATE OF ANALYSIS	MEXICAN ENVIRONMENTAL STANDARD (ANALYSIS METHOD)
Sampling time	NA	11:05	25/03/2021	NA
Water color	NA	Transparente	25/03/2021	NA
Smell of water	NA	NO	25/03/2021	NA
Transparency	cm	60	25/03/2021	NA
Water bubbles	NA	NO	25/03/2021	NA
Water temperature	°C	29	25/03/2021	NMX-AA-007-SCFI-2013
Environmental temperature	°C	37	25/03/2021	NA
pH	0 a 14 U-pH	7.44	25/03/2021	NMX-AA-008-SCFI-2016
Water film	NA	NO	25/03/2021	NA
Floating matter	NA	NO	25/03/2021	NMX-AA-006-SCFI-2010
Conductivity	µmhos/cm	1067	26/03/2021	NMX-AA-093-SCFI-2000
Dissolved oxygen	mg/L	NA	25/03/2021	NMX-AA-012-SCFI-2001
LABORATORY PARAMETER	MEASUREMENT UNITS	ANALYSIS RESULT	DATE OF ANALYSIS	MEXICAN ENVIRONMENTAL STANDARD (ANALYSIS METHOD)
Water color	U Pt-Co	5	25/03/2021	NMX-AA-045-SCFI-2001
Turbidity	UNT	3.2	25/03/2021	NMX-AA-038-SCFI-2001
Settleable solids	mL/L	0.1	25/03/2021	NMX-AA-004-SCFI-2013
Total hardness	mg/L $CaCO_3$	331.24	26/03/2021	NMX-AA-072-SCFI-2001
Calcium hardness	mg/L $CaCO_3$	291.85	26/03/2021	NMX-AA-072-SCFI-2001
Nitrate nitrogen (NO_3)	mg/L	0.96	26/03/2021	NMX-AA-079-SCFI-2001
Chlorides	mg/L	497.36	26/03/2021	NMX-AA-073-SCFI-2001
Total coliforms	NMP/100 mL	< 2	25/03/2021	NMX-AA-042-SCFI-2015
Fecal coliforms	NMP/100 mL	< 2	25/03/2021	NMX-AA-042-SCFI-2016

Water well 2	Location	Entrance to the town		
ON-SITE PARAMETER	MEASUREMENT UNITS	ANALYSIS RESULT	DATE OF ANALYSIS	MEXICAN ENVIRONMENTAL STANDARD (ANALYSIS METHOD)
Sampling time	NA	11:50	25/03/2021	NA
Water color	NA	Transparente	25/03/2021	NA
Smell of water	NA	NO	25/03/2021	NA
Transparency	cm	60	25/03/2021	NA
Water bubbles	NA	NO	25/03/2021	NA
Water temperature	°C	28	25/03/2021	NMX-AA-007-SCFI-2013
Environmental temperature	°C	42	25/03/2021	NA
pH	0 a 14 U-pH	8.13	25/03/2021	NMX-AA-008-SCFI-2016
Water film	NA	NO	25/03/2021	NA
Floating matter	NA	NO	25/03/2021	NMX-AA-006-SCFI-2010
Conductivity	µmhos/cm	457	26/03/2021	NMX-AA-093-SCFI-2000
Dissolved oxygen	mg/L	5.11	25/03/2021	NMX-AA-012-SCFI-2001
ON-SITE PARAMETER	MEASUREMENT UNITS	ANALYSIS RESULT	DATE OF ANALYSIS	MEXICAN ENVIRONMENTAL STANDARD (ANALYSIS METHOD)
Water color	U Pt-Co	5	25/03/2021	NMX-AA-045-SCFI-2001
Turbidity	UNT	0.82	25/03/2021	NMX-AA-038-SCFI-2001
Settleable solids	mL/L	NA		NMX-AA-004-SCFI-2013
Total hardness	mg/L $CaCO_3$	177.18	26/03/2021	NMX-AA-072-SCFI-2001
Calcium hardness	mg/L $CaCO_3$	155.23	26/03/2021	NMX-AA-072-SCFI-2001
Nitrate nitrogen (NO3) (NO_3)	mg/L	3.55	26/03/2021	NMX-AA-079-SCFI-2001
Chlorides	mg/L	244	26/03/2021	NMX-AA-073-SCFI-2001
Total coliforms	NMP/100 mL	< 2	25/03/2021	NMX-AA-042-SCFI-2015
Fecal coliforms	NMP/100 mL	< 2	25/03/2021	NMX-AA-042-SCFI-2016

Figure 2 Field and laboratory parameters taken at the sampling points

Comparison of maximum permissible limits with respect to NOM-127-SSA1-1994			
Permissible limits of bacteriological characteristics			
Characteristics	Results water well 1	Results water well 2	Permissible limits
Total coliforms	< 2 NMP/100 mL	< 2 NMP/100 mL	2 NMP/100 mL
Fecal coliforms	< 2 NMP/100 mL	< 2 NMP/100 mL	Not detectable NMP/100 ml
Permissible limits of physical and organolectic characteristics			
Water color	5 U Pt-Co	5 U Pt-Co	20 units of true color on the cobalt platinum scale (U Pt-Co)
Olor	No (imperceptible)	No (imperceptible)	Pleasant (Those that are tolerable for the majority of consumers will be accepted, as long as they are not the result of objectionable conditions from a biological or chemical point of view.).
Turbiedad	3.2	0.82	5 nephelometric turbidity units (UTN)
Permissible limits of chemical characteristics			
Chlorides (Cl-)	497.36 mg/L	244 mg/L	250 mg/L
Total hardness (CaCO3)	331.24 mg/L CaCO3	155.23 mg/L CaCO3	500 mg/L CaCO3
Nitrogen from nitrates	0.96 mg/L	3.55 mg/L	10 mg/L
pH (pH units)	7.44	8.13	6.5-8.5

Table 2 Parameters exceeding the maximum permissible limits of NOM 127-SSA1-1994

b) Determination of physical-chemical and microbiological parameters

The methodology for both water sampling and laboratory analysis was that recommended by the Mexican Standard, as shown in Figure 1, in accordance with the requirements of current regulations. Microbiological analysis was performed using the most probable number method in multiple tubes, as proposed by Mexican Standard NMX-AA-042-SCFI-2015.

c) Statistical analysis of the data

Regression analysis, analysis of variance, as well as Durbin-Watson statistics were determined, obtaining the normality of the data with the Anderson-Darling and Kolmogórov-Smirnov tests, which were applied to the parameters that exceeded the permissible limits with respect to NOM 127-SSA1-1994 (Chlorides, turbidity and fecal coliforms). This process was performed using Minitab software version 18.

Results

The results shown are for the parameters that exceeded the maximum permissible limits of NOM 127-SSA1-1994 (Table 2).

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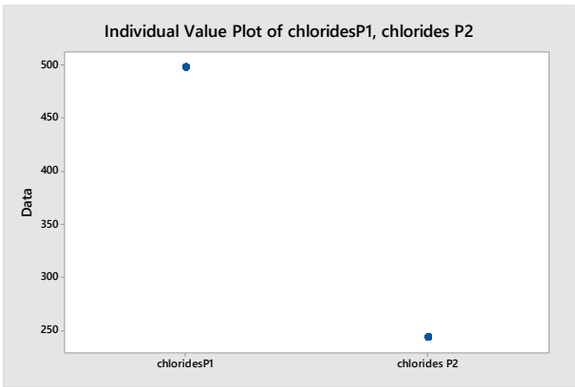
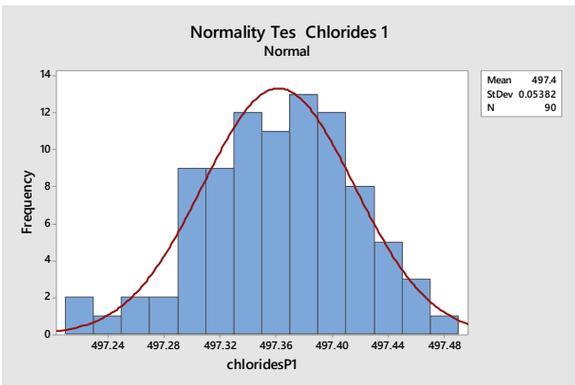
a) Chlorides

As shown in Table 2, chlorides are elevated under NOM-127-SSA and the statistical analysis compares chloride concentrations in water samples from the two wells monitored in 2021, in which it is observed that artesian well 1 located near the river was the one that presented the highest concentration of the pollutant under study; it is worth mentioning this connected to the sea, therefore according to (Pérez-López, 2016, pp. 3-14), the water is assumed to have a high chloride content, since such water (Graphic 1).

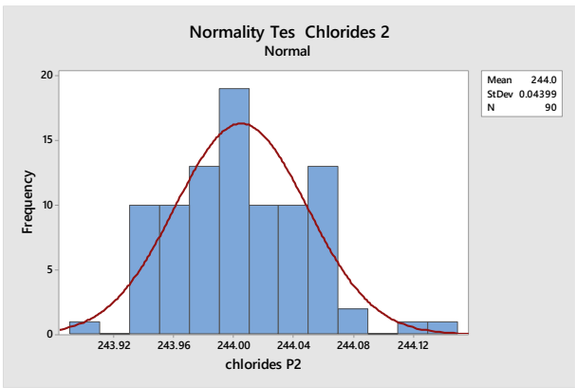


Graphic 1 Comparison of Well 1 and Well 2 data sets for the physicochemical parameter Chlorides



Graphic 2 Normality of chloride data for well 1

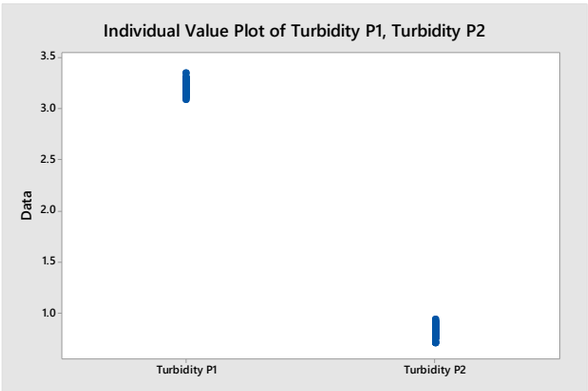
Within the normal range, it is observed that the chloride content is high, which supports the assumption that the proximity of the river mouth to the sea is the factor influencing the high chloride content.



Graphic 3 Normality of chloride data for well 2

Within the normal range, it is observed that the chloride content is low, this supports the assumption that the remoteness of the river mouth from the sea is the factor influencing the low chloride content.

a) Turbidity. Higher turbidity is observed in well 1, due to the fact that the well does not have the optimal conditions to protect the water from the elements, since it is without a cover, allowing the fall of leaves and other materials with organic matter content and the process of decomposition of organic matter generates suspended solids that are directly related to turbidity and color (Graphs 4, 5 and 6).



Graphic 4 Comparison of Well 1 and Well 2 data sets for the physicochemical parameter Turbidity

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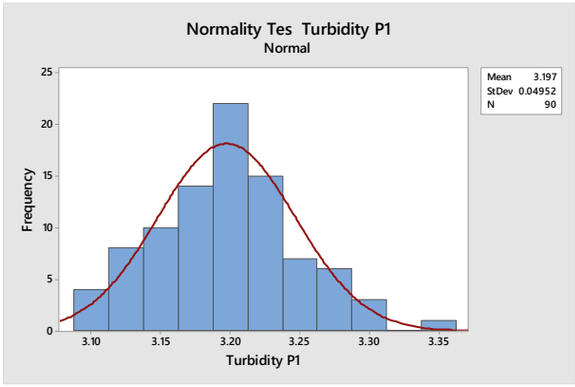
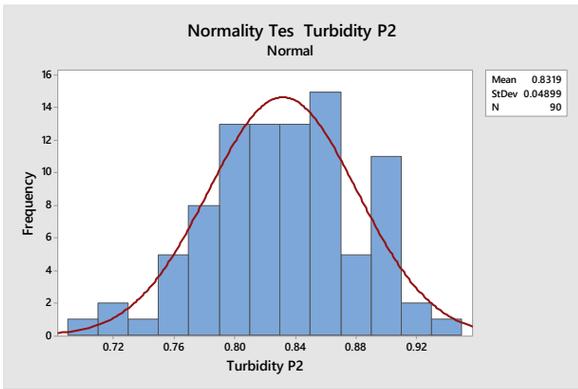


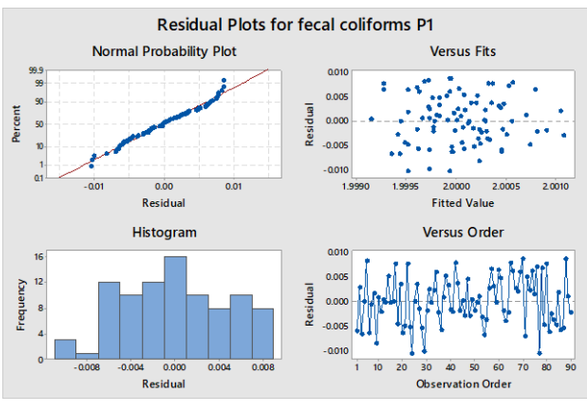
Graphic 5 Normality analysis of turbidity data for well 1



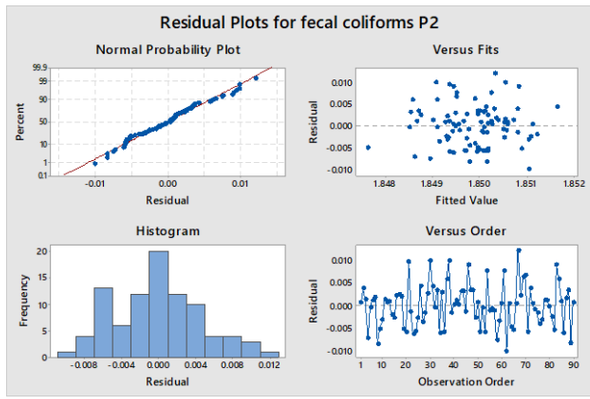
Graphic 6 Normality analysis of well turbidity data. 2

b) Fecal coliforms

Organisms that live in human feces are observed, which are not allowed by the standard, which must be treated with chlorination in both wells to allow the water to be fit for human consumption.



Graphic 7 Statistical analysis of the fecal coliform parameter of the well 1



Graphic 8 Statistical analysis of the fecal coliform parameter of the well 2

Conclusion

Based on the sampling design, which was established as an annual monitoring of the 2 wells, which were focused on the parameters that exceeded Mexican regulations. Therefore, it is concluded that the water used by the community is not suitable for human consumption, with emphasis on NOM-127-SSA1-1994, in addition to the fact that these parameters are negatively altered due to some external factors such as the proximity to a river with connectivity to the sea and the hygienic conditions of the wells.

Recommendations

Based on the data obtained during 1 year of monitoring physicochemical parameters, it is recommended that the community dose the wells with chlorine to eliminate fecal coliforms that are affecting the gastrointestinal health of the population.

If another community well is built in the future, it should be far from the mouth of the well, as this would help mitigate health problems, in addition to complying with Mexican water quality standards**.**

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Cyanobacterial bloom in the Chen Ha karst landscape

Bloom de cianobacterias en el paisaje Kárstico de Chen Ha

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Abstract

The Ejido of Kopomá with an extension of 963,000 hectares, participates in the environmental services program. In this property is located the Cenote Chen Ha. An open-air water body that is often affected by anthropogenic activities that put its conservation at risk. The present study aims to use environmental health indicators to determine the degree of deterioration it presents. Based on this, a conservation and sustainable management plan will be developed. Phytoplankton biodiversity monitoring was carried out in spring and summer. The physicochemical variables determined were pH, temperature, conductivity, dissolved oxygen. In spring greater diversity was observed and the dominant species were diatoms, however, in summer cyanobacteria, *Coelosphaerium, Woronichinia naegeliana and Microcystis predominated*. Alkaline pH in summer: 8.24 and dissolved oxygen: 3.38 ppm. Regarding species richness, the Shannon index was 2.748 for spring and 2.389 for summer. No similarity between populations was observed, the beta similarity index was 0.25. The Chen Ha cenote is highly vulnerable to environmental conditions, our results demonstrated the formation of a cyanobacteria bloom with toxic potential in summer.

Cyanobacteria, diversity index, *Coelosphaerium*

Resumen

El Ejido de Kopomá con una extensión de 963,000 hectáreas, participa en el programa de servicios ambientales. En dicho predio se localiza el Cenote Chen Ha. Un cuerpo de agua a cielo abierto que con frecuencia es afectado por actividades antropogénicas que ponen en riesgo su conservación. El presente estudio tiene por objetivo utilizar indicadores de salud ambiental, para determinar el grado de deterioro que presenta. Con base a ello se va a elaborar un plan de conservación y manejo sustentable. Se realizó un monitoreo de biodiversidad de fitoplancton en primavera y verano. Las variables fisicoquímicas determinadas fueron pH, temperatura, conductividad, oxígeno disuelto. En primavera se observó mayor diversidad y las especies dominantes fueron las diatomeas, sin embargo, en verano predominaron las cianobacterias, *Coelosphaerium, Woronichinia naegeliana y Microcystis*. El pH alcalino en verano: 8.24 y el oxígeno disuelto: 3.38 ppm. Respecto a la riqueza de especies el índice de Shannon fue 2.748 para primavera y 2.389 en verano. No se observó similitud entre poblaciones, el índice de similitud beta fue 0.25. El cenote Chen Ha es altamente vulnerable a las condiciones ambientales, nuestros resultados demostraron la formación de un Bloom de cianobacterias con potencial tóxico en verano.

Cianobacterias, índice de diversidad, *Coelosphaerium*

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Introduction

One of the main characteristics of the hydrology of Yucatan is the karst landscape, which originates from coral reefs and marine sediments that, when exposed to the surface, formed limestone rock. Limestone rocks ($CaCO_3$) react with surface or subway water (which penetrates the fissure of the rocks) in the presence of CO_2 dissolving with the formation of calcium bicarbonate ($Ca(CO_3H)_2$). The insoluble residue composed of clay minerals and iron oxides forms a reddish deposit, known as decalcification clay. The factors that determine the dissolution of the rock are: purity ($CaCO_3$ content greater than 70%), exposure time, thickness of the layers, mineralogical composition, degree of porosity and the fracturing of the rock, in addition to geohydrological and climatic conditions. (Estrada *et al*., 2019). For the particular case of Yucatan the purity of $CaCO_3$ is estimated at 89 and 99 %. Cenotes are bodies of water formed by dissolution and collapse of limestone rock. There are records of approximately 7000 to 8000 cenotes in the State of Yucatan.

The present study was conducted in the Cenote aguada type: Chen Há, which corresponds to a depression of impermeable soils, where surface runoff water accumulates and mixes with salt water due to the porosity of the karst system, which favors the formation of caverns and channels that conduct substantial amounts of water (Valadez, 2012).

Increased nutrients from agriculture or untreated water discharges promote the proliferation of phytoplankton, with a decrease in water quality, see Figure 1.

Figure 1 Cenote Chen Há, summer 2022
Source: Own elaboration

Algae are autotrophic organisms with simple levels of organization and structure; this group includes cyanophyceae or blue-green algae. Phytoplankton fix several thousand tons of carbon per year and constitute the first link in the food chain (Salas, 2009). Cyanobacteria use photosynthesis as their main source of energy. They are among the most primitive organisms on earth, their origin is estimated at 3.5 billion years ago. Their growth is favored with high concentrations of nutrients, however, some researchers report the feasibility of toxic bloom formation in oligotrophic water bodies. It is worth mentioning that it is estimated that more than 50% of these blooms are toxic. Toxins are usually grouped into neurotoxins and hepatotoxins, and their production is directly proportional to the increase in biomass (Roset, J., 2001).

Microalgae reflect the ecological state of surface waters; they are sensitive to physicochemical changes in the environment and are therefore considered biological indicators of water quality, productivity, eutrophication, acidification of the environment and contamination by heavy metals. Most frequently in freshwater bodies (Baylon, 2018).

Cenotes provide benefits in terms of biological diversity of aquatic species, contribution in terms of landscape and environmental protection as well as being outdoor recreational areas (Salas, 2009).

The objective of the present work was to study the changes in biodiversity related to spatio-temporal environmental conditions that describe the vulnerability of Cenote Chen há to environmental factors. The analyses were carried out in the spring and summer of 2022. The Shannon diversity index was determined, based on the richness of species and their components; the value obtained is used as an indicator of the state of contamination of the water body (del Río, 2003).

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Materials and methods

Limnological monitoring. The Chen Ha cenote is located in Chocholá, Yucatán with coordinates 20º 41' 22.3" N and 89 º 52´ 33.8´ W. It is an open-air cenote 85 m in diameter and 27 m deep. Based on the accessibility to the water body, 2 monitoring stations were established and determinations were made in spring and summer 2022. Monitoring of environmental variables: temperature, conductivity, pH, dissolved oxygen, total suspended solids was carried out with a multiparameter probe.

Biodiversity study. Samples were collected by horizontal trawling with phytoplankton net of 40 µm pore size, 30 cm diameter for 60 seconds. Samples were fixed with 1% lugol solution and transferred to the microbiology laboratory of the Universidad Politécnica de la Zona Metropolitana de Guadalajara, based in Cajititlán Jalisco Mexico. For qualitative analysis, the species were recorded and a list of presence (1) and absence (0) was prepared. The analysis and classification was carried out by the traditional method, using a Leica microscope and 30 and 40 X objectives (Vizcaíno et al., 2021). The statistical software EstimateS 9.1.0 for Windows was used to calculate diversity indices. Shannon's alpha diversity index was performed based on incidence data (presence-absence). To determine beta diversity (abundance-based data), multivariate similarity analysis according to Shanon H (Baylon et al., 2018) was employed. Figure 2.

Figure 2 Limnological monitoring of Chen Há cenote (Summer 2022)
Source: Own elaboration

Phylogenetic analysis. It was performed with the sequences deposited in the NCBI database. BLAST (Basic Local Alignment Search Tool) sequence was used Coelosphaerium sp. S3C5 genes for 16rRNA, 16S ribosomal RNA intergenic spacer 23 SrRNA partial and complete sequence. Sequence cleanup was performed visually by removing sequences without conserved or repeated sites. NCBI diagrams were used.

Results

Phytoplankton was represented by 55 taxa belonging to 5 divisions: Bacillariophytes (14), Cyanobacteria (22), Chlorophytes (13), Euglenophytes (3) Dinophytes (3). Unlike those reported by Valadez et al. (2013) in which 63 taxa and six divisions were identified Bacillariophyta (28), Cyanobacteria (22), Dinophytes (six), Chlorophytes (three) Euglenophytes (two), Cryptophytes (two).

Figure 3 shows the morphology of some cyanobacteria and diatoms species identified in the Chen Há Cenote.

Figure 3 *Coelosphaerium*, *Microcystis novacekki*, *Chroococcus turgidus*, *Aulacoseira granulata*, *Diatoma vulgaris*, *Microcystis wesenbergii*, *Mougeotia*, *Pleurotaenium*, *Nägeli*, identified in Cenote Chen Ha, in the monitoring conducted in summer 2022
Source: Own elaboration

Regarding relative abundance, diatoms dominated in spring and cyanophytes in summer, probably favored by environmental variables Our results agree with the researchers regarding the relative abundance of the divisions since cyanophytes were more abundant during summer 143, with respect to 117 in spring. (See graphic 1).

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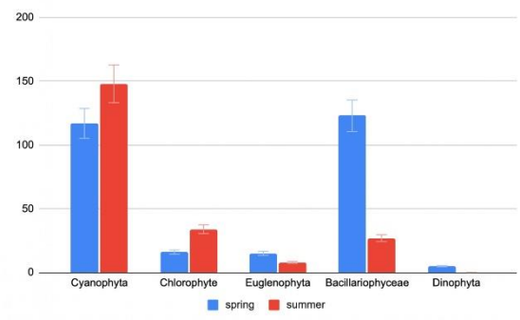

Graphic 1 Phytoplankton diversity in the Chen-Ha cenote, according to monitoring conducted in spring and summer 2022
Source: Own elaboration

Figure 4 shows the diversity of species identified in the limnological monitoring carried out in both spring and summer. The species identified in both climatic seasons correspond to *Coelosphaerium*, *Microcystis aureginosa*, *Botryococcus*, *Pseudanabaena limnetica*, *Oscillatoria* sp., *Merismopedia tenuissima*, *Crucigenia cuadrata*, *Volvox*, *Aulacoseira granulata*, *Aulacoseira italica* and *Navicula*. Greater species diversity was observed in spring, in that season the dominant species was *Navicula* (diatom) and in summer the dominant species was *Coelosphaerium* (cyanophyte).

In summer, *Woronichinia naegeliana*, *Microcystis novacekki*, *Aphanocapsa elachista*, *Nodularia*, *Rhabdoglea yucatanensis*, *Mougeogia viridis*, *Mesotenium macrococcum*, *Colacium vesiculosum*, *Eptitemia argus* and *Nitzschia* were also detected.

In spring the diversity was higher, species such as *Microcystis wesenbergii*, *Microcystis flos-aquae*, *Microcystis incerta*, *Planktothrix agardhii*, *Lyngbya*, *Chroococcus turgidus*, *Planktolingbia limnetica*, *Sinechocystis*, *Gloethece magna* were identified, *Pandorina Charkowiensis*, *Mallomonas*, *Closterium*, *Staurodesmus extensus*, *Tetrastrum*, *Chlorella*, *Selenastrum gracile*, *Kirchneriella*, *Euglena Spirogyra*, *Euglena geitieri*, *Surirella*, *Gomponema angustatum*, *Asterionella*, *Peridium Cinctum*, *Gonyaulax* sp.

Cyanobacteria are known as blue-green algae, they present a cellular organization similar to bacteria due to their great diversity of forms and/or specialized structures, however their metabolism is similar to plants due to their ability to perform photosynthesis (Arana et al., 2019). It should be noted that for the same species there are toxin-producing and non-producing strains.

Toxins are considered to be secondary metabolites obtained as by-products of metabolic pathways associated with photopigment synthesis. They accumulate in the cytoplasm and are released when cell lysis occurs. (Roset, 2001).

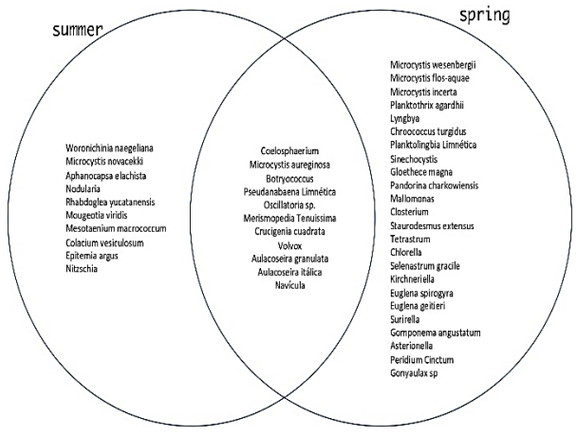

Figure 4 Ben's diagram for phytoplankton biodiversity monitored in Cenote Chen Há in spring and summer 2022
Source: Own elaboration

The relative abundance of cyanobacteria is shown in graph 2. The most abundant species in summer was *Coelosphaerium*, followed by *Woronichinia naegeliana*. The genus *Coelosphaerium* consists of globose colonies, covered with mucilaginous and colorless sheath and spherical or hemispherical cells located at the periphery of the colony, its cell division is in two planes, toxigenic species have been reported as *C. kuetzingianum*, *Nägeli* (Aguilera y Echenique).

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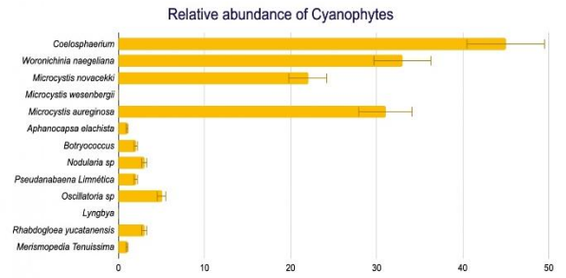

Graphic 2 Relative abundance of cyanobacteria identified in Cenote Chen Ha in October 2022
Source: Own elaboration

Our results coincide with those reported for Lake Shinji, Japan, where in September 2009 the number of *Coelosphaerium* cells was 4.8 x 10 5 cells. L^{-1} and in October it increased to 6.12 x 10 7 cells. L^{-1} and in November the number of cells decreased to 4.64 x107 cells L^{-1}.

According to Godo et al, (2016) *Coelosphaerium* sp. has the ability to produce geosmin (E-1,10-dimethyl-E-9-decane). Said molecule contributes an intense aroma and unpleasant taste to water, with a decrease in its quality. The values of geosmin in this water body are directly proportional to the number of cells. The researchers reported ranges of 12 to 4 ng. L^{-1} in September, 640 to 20 ng. L^{-1} in October and 413 to 17 ng. L^{-1} in November. This molecule is also produced by cyanobacteria, oscillatoriales and nostococales. According to the author, the values of 4 to 10 ng. L^{-1} of geosmin provide taste and odor to the water.

There are reports of *Woronichinia naegeliana* in both eutrophic and oligotrophic lakes, so it is considered to be highly tolerable and characteristic of lentic ecosystems (Nowicka-Krawczyk & Zelazna-Wieczorek, 2017). For the particular case of de Woronichinia naegeliana, its ability to produce microginin FR3 was reported, with LC50 equal to 7.78 µg mL^{-1} with toxic effect to invertebrates, however, the mechanism of action is unknown (Bober & Bialczyk 2017).

Figure 5 shows the dendogram obtained regarding the biodiversity of cyanobacteria, identified in the month of October, in which these species were dominant. Greater similarity was observed between Woronichinia naegeliana and *Coelosphaerium* sp. with respect to *Microcystis* and *Chroococcus* sp.

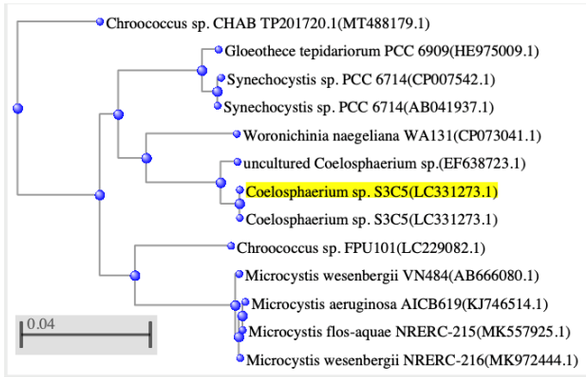

Figure 5 Diversity of cyanobacteria recovered in the Chen Ha cenote in October 2022
Source: Own elaboration

According to Mohan and Thomas, 2022, *Woronichinia naegeliana* has been observed associated with blooms of Microcystis in southern India and its toxic capacity is frequently recognized, and there are reports of its presence in freshwater ecosystems with temperatures close to 29°C and low levels of nitrates and phosphates.

Regarding environmental variables, in spring the average temperature was 32.19 ºC, suspended solids: 1300 ppm and average conductivity 2603 µS/cm, i.e., they reached higher levels than in summer with values of 31.05 ºC for temperature, total suspended solids 1021 mg-L^{-1} and 2372 µS/cm, respectively (see Table 1). Temperate climates (25ºC) frequent in late spring, summer and autumn favor the formation of blooms. The ability of cyanobacteria to adapt to different light intensities is due to their ability to synthesize carotenoids and protective photopigments. (Forjan *et al*., 2007).

Variable	Spring	Summer
pH	7.65	8.24
ppm DO	2.7	3.38
µS/cm	2603	2373
ppm Tds	1300	1021.14
º C	32.19	30.92

Table 1 Average value of the environmental variables monitored in the Chen Ha cenote during the spring and summer of 2022
Source: Own elaboration

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In spring the pH was slightly more acidic 7.65 with respect to the summer which was 8.24. According to Estrada et al. (2019), in karst landscapes, when the pH is in the range of 6 to 10 the predominant carbonate species in the water body is HC03-. The level of dissolved oxygen detected was lower 2.7 ppm with respect to the summer, 3.38 ppm.

In a study conducted in Lago Lagartos, Mexico, the temperature recorded in spring was 26.1 ºC and 27.8ºC in summer, respectively; the pH was 6.9 and 7. Conductivity values ranged from 13 to 18 mS/cm, higher values than those obtained in Chen Ha: 2.6 to 2.37 mS.cm (Valadez et al., 2012). According to Baylón (2018), electrical conductivity influences the distribution, composition, biomass and density of phytoplankton.

One of the characteristics that make cyanobacteria proliferate during summer blooms compared to other species is their tolerance to high temperatures and nutrient concentrations, which decreases vertical mixing in the water body and favors stratification. *Microcystis* is considered a species with adverse effects on aquatic ecosystems and the potential to produce microcystins, which are very stable in nature, producing intoxication in humans and fish mortality. It is worth mentioning that in a study conducted during the formation of a bloom of *Microcystis*, in the month of September, values of 5.5 to 6.5 dissolved oxygen, pH of 9 to 9.8 and temperature of 27.5 to 29º C were recorded (Mohan et al., 2020).

It is worth mentioning that when there is algae bloom production, the use of algaecides is not recommended, since they cause cell rupture and the release of toxins; the use of flocculants and activated carbon filters is recommended (Forján et al., 2008).

The Beta similarity index, calculated from the spring and summer identification, in accordance with the Jacquard model was 0.25. According to the scale, the closer to one the greater the similarity, the value obtained is very low, which indicates that the conditions changed due to the effect of the rainy season, runoff and groundwater mixing. See Figure 6.

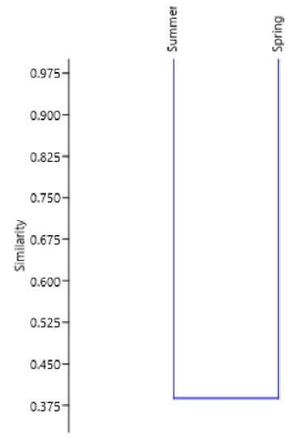

Figure 6 Index of similarity and distance between species identified in Cenote Chen Há, in spring and summer
Source: Own elaboration

Alpha diversity operates within the population at the spatiotemporal scale and beta diversity refers to the variation between populations (Salas, 2009). The scale of values from 0 to 4 bits.ind^{-1} (values greater than 3 bits.ind-1 indicate clean water, values of 1-3 bits.ind-1 indicate moderate pollution and values less than 1 bits.ind^{-1} are characterized as heavily polluted) according to Baylon (2018).

Regarding alpha diversity, the highest species richness was obtained in spring with Shannon index of 2.748 and 2.389 in summer. Similar results 2.77, obtained Baylon et al. (2018) at Station L^{-1} of the high Andean lagoon in the Pasco Region (October 2015). It is worth mentioning that in accordance with the scale of values the contamination is mild, with greater deterioration in summer (See Figure 7).

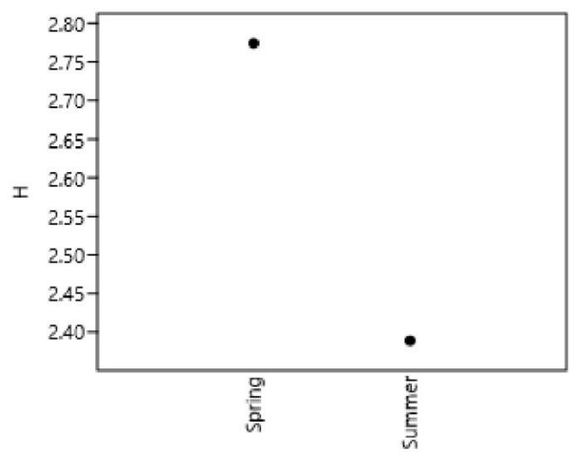

Figure 7 Alpha diversity index (Shannon H) calculated in spring and summer in the Chen Ha cenote, 2022
Source: Own elaboration

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The available concentrations of nitrogen and phosphorus, as well as neutral and alkaline pH favor the growth and proliferation of cyanobacteria, many of which have low palatability due to their large size, the presence of mucilage and their toxic capacity, which favors their accumulation since they suffer less herbivory (de Oliveira *et al*., 2009).

Cyanobacteria are known for their ability to produce a great diversity of secondary metabolites with biological activity. Within which, they include methylisoborneol, geosmin, toxins type: alkaloids, cyclic peptides and oligopeptides, whose biological function is uncertain, as well as protease inhibitors (Bober & Bialcyk, 2017).

Blooms of cyanobacteria producing cyanotoxins in freshwater reservoirs expose the population because they are not removed by conventional treatments and filtration, causing serious public health problems (Lizarralde *et al*., 2020).

In 2012, Valadez reported the formation of blooms in the karst system caused by Microcystis panniformis in November 2007 and Oscillatoria princeps in April 2008. Worldwide, karst zones represent approximately 14.1% of the earth's surface, of which 12.2% is related to limestone. In Mexico, 2.21% of the world total is found, representing 8.93% of the total surface of the country. For the state of Yucatan, 95% of the state is karst landscape (Estrada *et al*., 2019). Karst systems are fragile and are contaminated by untreated discharges from pig farming, poultry farming, the nixtamalization of corn, fertilizers, pesticides, septic tanks, waste from the exploitation of limestone as raw material for construction, which eliminates vegetation and the rocky substrate until reaching the aquifer mantle, which favors the entry of contaminants (Estrada *et al*., 2019).

Our results demonstrate that environmental conditions influenced the biodiversity of the Chen Há cenote and that it is highly vulnerable to contamination. Since the diversity index between spring and summer populations was 0.25 indicating that there is no similarity between populations.

In summer, a bloom of cyanobacteria was observed whose dominant species was *Coelosphaerium*, followed by *Woronichinia naegeliana*, *Microcystis aeruginosa* and *Microcystis novacekki* with toxic potential and capacity to generate environmental impact. It is estimated that the temperature conditions associated with freshwater runoff from the rainy season as well as the probable dragging of fertilizers or agrochemicals as some of the probable sources of contamination favored the proliferation of cyanobacteria.

It is important to monitor the water quality of the cenotes that are used for tourism, since they are often used for recreational activities (diving, swimming, scenery, etc.) to avoid health problems and loss of biodiversity, since these bodies of water are interconnected by subway currents. Studies will continue in winter, in order to know its impact and establish if necessary a bioremediation, conservation and sustainable use plan for Cenote Chen Há.

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Conclusions

The Chen Há cenote experienced the formation of a cyanobacterial bloom in the summer of 2022. The dominant species was Coelosphaerium sp, the alpha diversity index (Shannon H) was 2.83.

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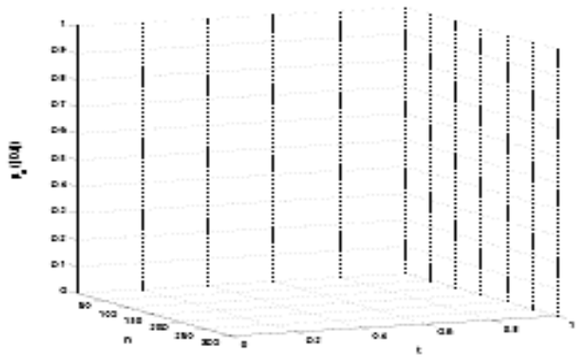

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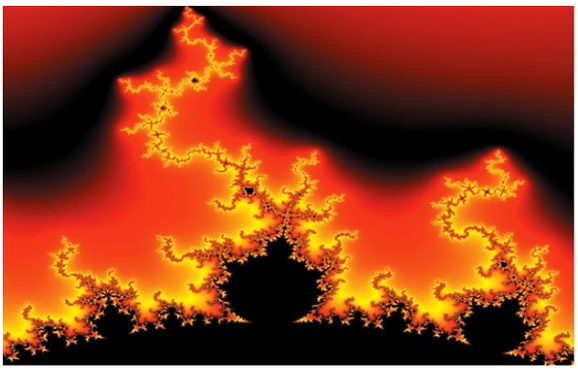

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