

## **EVALUATION OF PHYSICOCHEMICAL CHARACTERISTICS IN GROUNDWATER**

## **EVALUACIÓN DE LAS CARACTERÍSTICAS FÍSICO-QUÍMICAS EN AGUAS SUBTERRÁNEAS**

Alejandro Reyes Torres. [areyes@ismm.edu.cu](mailto:areyes@ismm.edu.cu). Universidad de Moa, Holguín  
Cuba. ORCID: <https://orcid.org/0009-0009-8500-8653>

Yanet Borges Terrero. [yborgest@ismm.edu.cu](mailto:yborgest@ismm.edu.cu). Universidad de Moa, Holguín  
Cuba. ORCID: <https://orcid.org/0000-0003-0920-7801>

Walkis Herrera Blanco. [wherrera@ismm.edu.cu](mailto:wherrera@ismm.edu.cu). Universidad de Moa, Holguín  
Cuba. ORCID: <https://orcid.org/0000-0002-6471-0381>

Suraymi García Cruz. [sgarcia@ismm.edu.cu](mailto:sgarcia@ismm.edu.cu). Universidad de Moa, Holguín  
Cuba. ORCID: <https://orcid.org/0000-0003-4784-3817>

Iroidis Rodríguez Mora. [irodriguez@ismm.edu.cu](mailto:irodriguez@ismm.edu.cu). Universidad de Moa, Holguín  
Cuba. ORCID: <https://orcid.org/0000-0002-0664-2368>

*\*Autor para la correspondencia editorial: [yborgest@ismm.edu.cu](mailto:yborgest@ismm.edu.cu)*

**Received: December 13, 2025**

**Accepted: January 15, 2026**

### **ABSTRACT**

Due to the need to use water from local wells in the La Playa neighborhood, Moa, Holguín, for domestic activities, an evaluation of the physicochemical characteristics and inorganic components of groundwater was conducted to determine its potability. Water samples from five wells were analyzed to measure parameters such as total hardness, pH, alkalinity, total dissolved solids, calcium, magnesium, aluminum, iron, copper, zinc, sulfates, salinity, ammonia, biochemical oxygen demand (BOD<sub>5</sub>), and chemical oxygen demand (COD). The research methodology was developed in four stages. Results show that most parameters fall within acceptable ranges and meet standards; however, the elevated levels of BOD<sub>5</sub> and COD indicate that the water is

not safe for direct human consumption without treatment. This highlights the need to implement corrective measures to ensure water safety in the area.

**KEYWORDS:** water quality; contaminant residues; alkalinity; water security

## **RESUMEN**

Por la necesidad de utilizar las aguas de los pozos criollos en el reparto La Playa, Moa, Holguín para actividades domésticas, se realizó una evaluación de las características físico-químicas y los componentes inorgánicos de las aguas subterráneas para determinar su potabilidad. Se analizaron muestras de agua de cinco pozos para medir parámetros como: dureza total, pH, alcalinidad, sólidos disueltos totales, calcio, magnesio, aluminio, hierro, cobre, zinc, sulfatos, salinidad, amoníaco, demanda bioquímica de oxígeno (DBO<sub>5</sub>) y demanda química de oxígeno (DQO). La metodología de investigación se desarrolló en cuatro etapas de trabajo. Como resultados se obtiene que los parámetros se encuentren dentro de los rangos aceptables, cumplen con los estándares; los elevados niveles de DBO<sub>5</sub> y DQO reflejan que el agua no es segura para consumo humano directo sin tratamiento; esto resalta la necesidad de implementar medidas correctivas para garantizar la seguridad del agua en la zona.

**PALABRAS CLAVES:** calidad del agua; residuos contaminantes; alcalinidad; seguridad hídrica

## **INTRODUCTION**

Water is an essential element in all natural processes on Earth and is vital for the existence of all life forms. Its importance transcends history and has been the primordial axis for the development of society (Oliveros, 2024). Today, freshwater scarcity is a top-priority problem worldwide; 97% of the planet's water (1,400 million km<sup>3</sup>) is saline, and only one-sixth of the remaining 3% (freshwater) is accessible, with 70% of this freshwater found in polar ice caps and glaciers (Crespo, Fernández & Pérez, 2022).

Despite its relevance, water is a limited, vulnerable and increasingly scarce resource. Unfortunately, a global awareness regarding the need to manage this resource reasonably has not been achieved. Consequently, crises related to water use have arisen, causing waterborne diseases, malnutrition, economic stagnation, social instability, conflicts and environmental disasters (Lobaina, 2024).

Conservation of water resources constitutes one of the priority activities of the scientific community in our country and internationally; therefore, the study of environmental problems, contamination and water quality of groundwater and surface water is of vital importance (Rubio, 2017).

Water resources are at risk of contamination; the most important and strategic ones are subjected to a high degree of vulnerability due to negligence, lack of awareness and public ignorance about the obligation to protect them, and the lack of authorities, professionals and technicians responsible for their care and use (Vargas, 2002; cited by Torres, 2019).

Water contamination can occur from various sources: solid, liquid, and gaseous waste, suspended solids, toxic matter, infectious microorganisms, radioactive waste, among others. These substances give water undesirable properties such as corrosivity, toxicity, scale-forming tendency, bad odor, bad taste and poor appearance.

The availability of good quality drinking water is an important factor for preserving public health, and the epidemics caused by water contamination that decimated populations in the past are well known. Currently, these problems are controlled in most urban centers, but the growing development of society continuously increases the quantity and types of sources (Rodríguez, 2019).

For its part, the World Health Organization created the guidelines for drinking water quality, whose purpose is to provide a scientific basis that national authorities can use as a starting point for developing regulations and standards for drinking water appropriate for each country's situation (Márquez & Ortega, 2017).

Guaranteeing water quality plays a fundamental role in the above, referring to «the physical, chemical and microbiological conditions and characteristics that this liquid presents, according to various standards that ensure it is optimal for consumption. Furthermore, it must present acceptable transparency, taste and odor» (Aroca & Toapanta, 2023; cited by Armijos, 2025).

Optimal water quality will determine its suitability for human consumption, as it guarantees that it is free from microorganisms, fungi, bacteria or chemical agents that affect health.

In Moa municipality, mining is one of the most relevant economic activities, but it is also a potential source of water contamination. Mining exploitation generates contaminating waste that deteriorates both surface and groundwater. Significant research has been conducted on the contaminating effects caused by the drainage of acid waters rich in heavy metals from the leaching of spoil heaps and mining waste dams (Crespo, 2023).

Due to the complex electro energetic situation that the country is experiencing, which affects the water supply to the population, prolonging the established days for supplying different areas of Moa, many residents have been forced to use water from existing local wells in their house yards for all domestic activities. Hence, the present research arises, whose purpose is to evaluate the physicochemical parameters and inorganic components of this underground sources, thus determining their suitability for domestic use in «La Playa» neighborhood.

## **MATERIALS AND METHODS**

The research methodology was developed in four work stages:

### *Stage I. Bibliographic review*

During this first stage of the research, a bibliographic information search was conducted through the review of a series of scientific articles, diploma theses, master's theses, doctoral theses and other documents with the aim of obtaining as much information as possible about studies carried out in the area. Furthermore, updated bibliographies used in Cuba and worldwide were consulted.

### *Stage II. Fieldwork*

Recognition marches were conducted for geological description and determination of sampling points. Samples were taken at five points, determined because they are the most used by the population.

For this process, samples were collected in 1L plastic bottles; one bottle per sampling point. The container was initially rinsed to avoid alteration of properties.

As a safety measure, the container was filled completely to prevent oxygen concentration and kept refrigerated. The bottles were labeled to avoid confusion in sample identification.

### *Stage III. Laboratory analysis*

- UPL-PT-A-11 Determination of Ni, Co, Fe, Cu, Zn, Mn, Mg, Al, Cr, Si, V, Pb. Atomic Absorption Spectrophotometry method.
- UPL-PT-G-15 Determination of sulfates with residue ignition. Gravimetric method.

- UPL-PT-V-06 Determination of ammonia in clean water and wastewater. Volumetric method.
- UPL-PT-V-11 Determination of alkalinity. Volumetric method.
- UPL-PT-V-12 Determination of total hardness. Volumetric method.
- UPL-PT-V-13 Determination of Ca and Mg. Volumetric method.
- UPL-PT-E-01 Determination of pH. Electrometric method.
- UPL-PT-E-03 Determination of conductivity. Electrometric method.
- PA-12. Determination of biochemical oxygen demand. 5-day incubation method at 20°C with dissolved oxygen measurement by electrometric method.
- Determination of chemical oxygen demand. Closed reflux method by spectrophotometry.

Expression of results: mg/L, Ms/CM, pH units.

#### *Stage IV. Information processing and analysis*

Based on the results obtained in the laboratory, information was processed using Google Maps, QGIS, and ARGIS; the geographic location map was prepared. For the interpretation of results, Cuban Standard 827 (Cuban Standard 827, 2017) and WHO 2018 Standard were used; results are expressed through graphs.

## **RESULTS AND DISCUSSION**

In the physicochemical evaluation of the waters of La Playa neighborhood, Moa, Holguín, the following characteristics were verified (Table 1), which covers the main population settlement.

Parameter	Unit	Obtained Range	NC 827:2017 Limit	WHO Limit	NC Complies	WHO Limit
<b>Total hardness</b>	mg/L CaCO <sub>3</sub>	94 - 236	400 mg/L	500 mg/L	Yes	Yes
<b>pH</b>	U pH	6.57 - 6.96	6.5 - 8.5	7.0 - 8.0	Yes	Yes *
<b>Total alkalinity</b>	mg/L	80 - 150	N/S	N/S	-	-
<b>TDS</b>	mg/L	156 - 436	1000 mg/L	1000 mg/L	Yes	Yes
<b>Calcium (Ca)</b>	mg/L	20.05 - 43.71	200 mg/L	300 mg/L	Yes	Yes
<b>Magnesium (Mg)</b>	mg/L	17.88 - 41.68	150 mg/L	30 mg/L	Yes	Partial
<b>Aluminum (Al)</b>	mg/L	0.069 - 0.084	0.2 mg/L	0.2 mg/L	Yes	Yes
<b>Iron (Fe)</b>	mg/L	0.018 - 0.102	0.3 mg/L	1.0 mg/L	Yes	Yes
<b>Copper (Cu)</b>	mg/L	0.103 - 0.132	2.0 mg/L	2.0 mg/L	Yes	Yes
<b>Zinc (Zn)</b>	mg/L	0.127 - 0.154	5.0 mg/L	5.0 mg/L	Yes	Yes
<b>Sulfates (SO<sub>4</sub>)</b>	mg/L	20.76 - 70.52	400 mg/L	500 mg/L	Yes	Yes
<b>Salinity</b>	mg/L	0 - 0.2	N/S	N/S	-	-
<b>Ammonia (NH<sub>3</sub>)</b>	mg/L	0	N/P	N/P	Yes	Yes

**Table 1.** Physicochemical Results of Groundwater in La Playa Neighborhood, Moa. N/S: Not specified in the standard. N/P: Not permissible.

### *Total hardness as CaCO<sub>3</sub>*

This is represented by the content of calcium or magnesium salts and is determined by the sum of these ions. The results obtained for the five samples range from 94 mg/L to 236 mg/L, thus corresponding with NC 827:2017; these values are below the maximum admissible limit established in this standard (400 mg/L) and can be classified as potable water.

According to the World Health Organization (WHO 2006), water hardness above 200 mg/L could cause scaling in the distribution system. Soft water with hardness less than approximately 100 mg/L has a low buffering capacity and may be more corrosive to pipes. For human consumption, it established values of 500 mg/L based on taste and domestic use conditions.

### *Hydrogen potential (pH) and Total Alkalinity (TA)*

pH is the value that determines whether a substance is acidic, neutral or basic, calculating the number of hydrogen ions present. pH values vary from 6.57 to 6.96, representing the maximum and minimum values, respectively.

According to Pasojov's classification of waters by pH, all five water samples are classified as neutral. These values fall within those set forth in NC 827:2017, which range from 6.5 to 8.5, while according to the WHO limit of 7 to 8, they are below, although this is not considered a problem because in most groundwater, pH is below 8.3; therefore, they can be declared potable. Meanwhile, alkalinity, which is the water's capacity to neutralize acids, shows values fluctuating between 80 and 150 mg/L.

### *Total Dissolved Solids (TDS)*

According to the WHO, Total Dissolved Solids (TDS) comprise inorganic salts (mainly calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and small amounts of organic matter dissolved in water.

TDS in drinking water come from natural sources, wastewater, urban runoff, and industrial wastewater. High concentrations (exceeding 1200 mg/L) can be unpleasant for consumers. Water with very low concentrations may also be unacceptable due to its lack of taste (Fernández & Guardado, 2021). For the five samples evaluated, their contents vary from 156 mg/L to 436 mg/L; these values do not exceed the maximum admissible limit of the Cuban standard and the WHO.

### *Calcium (Ca)*

Calcium presents values ranging from 20.05 to 43.71 mg/L. All samples are below the maximum admissible limit (200 mg/L) given by NC 827:2017 and the WHO limit (300 mg/L). Calcium is usually the main cation in most natural waters due to its wide dissemination in igneous, sedimentary and metamorphic rocks. This low calcium content is due to the type of lithology existing in the area.

### *Magnesium (Mg)*

The magnesium values obtained range from 17.88 mg/L to 41.68 mg/L, which are below the maximum admissible limit of NC 827:2017 (150 mg/L); however, wells P2, P3, P4, and P5 are above the WHO limit (30 mg/L). Magnesium is an essential element, aiding in energy metabolism, protein synthesis and vascular tone.

### *Aluminum (Al)*

The aluminum values obtained range from 0.069 mg/L to 0.084 mg/L; these are below the WHO limit and the maximum admissible limits of NC 827:2017 (0.2 mg/L). Aluminum concentration in drinking water can affect both water quality and health. Elevated levels can alter water color, turbidity and taste, making it less acceptable to consumers. Although aluminum intake is not considered acutely toxic, it has been associated with concerns about neurological diseases, such as Alzheimer's.

### *Iron (Fe)*

The obtained values reach from 0.018 mg/L to 0.102 mg/L, which are below the maximum admissible limit of the Cuban standard (0.3 mg/L) and the WHO limit (1 mg/L). When this element comes into contact with atmospheric oxygen, it oxidizes, producing a reddish coloration in the water, which appears turbid. High concentrations of iron can affect washing water quality and cause difficulties in distribution systems by allowing the growth of iron bacteria.

### *Copper (Cu)*

According to the WHO (2017), copper is an essential nutrient and, at the same time, a drinking water contaminant; it also states that when copper concentrations are above 1 mg/L, the water stains laundered clothes and sanitary fixtures. At concentrations above 2.5 mg/L, copper imparts an undesirable bitter taste to water; at higher concentrations, it also affects its color. The five samples analyzed reached values ranging from 0.103 mg/L to 0.132 mg/L, which do not exceed the maximum admissible limit of 2.0 mg/L set forth in the Cuban standard and the WHO.

### *Zinc (Zn)*

Zinc gives water an undesirable astringent taste, and its taste threshold (as zinc sulfate) is approximately 4 mg/L. Water with zinc concentrations greater than 3.5 mg/L may have an opalescent color and produce an oily film when boiled. Although drinking water rarely contains concentrations greater than 0.1 mg/L, levels in tap water can be substantially higher due to zinc used in galvanized plumbing materials (WHO 2006). The results obtained for the 5 samples vary from 0.127 mg/L to 0.154 mg/L, which are below the maximum admissible limit (5 mg/L) according to the Cuban standard and the WHO limit. It should be noted that high concentrations (more than 5 mg/L) can cause gastrointestinal irritation, such as diarrhea and nausea, due to its low solubility and poor absorption in the digestive tract.

### *Sulfates (SO<sub>4</sub>)*

The analyzed samples present values ranging from 20.76 mg/L to 70.52 mg/L, below the maximum admissible limit (400 mg/L) stipulated in the Cuban standard, therefore they do not represent any risk to human health.

Sulfates are released into water from industrial waste and through precipitation from the atmosphere; however, the highest concentrations are usually found in groundwater and come from natural sources. Due to the gastrointestinal effects of ingesting drinking water with high sulfate concentrations, it is recommended to notify health authorities of drinking water sources where sulfate concentrations exceed 500 mg/L (de Miguel, 2020).

### *Salinity*

This parameter behaved stably, reaching values ranging from 0 to 0.2 mg/L, having values of 0.2 mg/L in most samples, i.e., in wells 2, 3, 4, 5, with a value of 0 reached in well 1. The water is practically fresh, thus having a very low, almost imperceptible salinity level.

### *Ammonia (NH<sub>3</sub>)*

Ammonia reached zero values, indicating that the water meets quality standards regarding this parameter. This element is an indicator of possible water contamination with bacteria, wastewater or animal waste (WHO, 2018).

### *Biochemical Oxygen Demand (BOD<sub>5</sub>) and Chemical Oxygen Demand (COD)*

BOD<sub>5</sub> represents the amount of oxygen consumed for the biochemical degradation of organic matter through aerobic processes. The determination usually carried out is BOD<sub>5</sub>, i.e., the water sample is placed in the dark at a temperature of 20°C for five days.

Groundwater typically has less than 1 mg/L; if during this time the concentration increases, it means contamination. The results obtained range from 16 mg/L to 18 mg/L, above the limit set by the WHO of 1 mg/L.

COD relates to the oxygen consumed in the oxidation of organic matter contained in a water sample by means of chemical compounds. According to the results obtained, the 5 samples present values of 15 mg/L, above those reflected by the WHO.

The elevated BOD<sub>5</sub> and COD suggest that the water is contaminated with organic substances, such as industrial waste, domestic wastewater, plant contamination and plant leaves. This can cause eutrophication, i.e., excessive algae growth and decreased dissolved oxygen, affecting aquatic ecosystems. For health, this can have a negative impact since these waters may contain pathogenic microorganisms, toxins or harmful chemical compounds. Consuming this type of water can cause gastrointestinal diseases, infections, or poisoning, which requires the implementation of treatment measures and continuous monitoring to guarantee water safety for human consumption.

## **CONCLUSIONS**

The study reveals that the evaluated physicochemical parameters and inorganic components fall within the limits established by Cuban Standard NC 827:2017 and the World Health Organization (WHO) guidelines. The elevated values of Biochemical Oxygen Demand (BOD<sub>5</sub>) and Chemical Oxygen Demand (COD), which exceed permissible limits, suggest the presence of decomposing organic matter, possibly derived from sources such as domestic wastewater or plant leaf waste. The research underscores the importance of addressing contamination sources and improving water management in the area, especially in a context where the population depends on local wells for their supply. The remediation of these waters is essential to protect community health and prevent environmental impacts.

## BIBLIOGRAPHIC REFERENCES

Armijos Luna, M. C. (2025). *Análisis de la calidad del agua potable y su incidencia en la salud de la población de la parroquia Celica, 2024* (Bachelor's thesis, Jipijapa-Unesum).

<https://repositorio.unesum.edu.ec/bitstream/53000/7977/1/ARMIJOS%20LUNA%20MARY%20CARMEN.pdf>

Aroca, S. A. S., & Toapanta, V. H. G. (2023). Calidad Microbiológica del Agua de Consumo Humano: La realidad en el Ecuador: Microbiological Quality of Water for Human Consumption: The reality in Ecuador. *Latam: revista latinoamericana de Ciencias Sociales y Humanidades*, 4(2), 97.

<https://dialnet.unirioja.es/servlet/articulo?codigo=9585943>

Crespo Lambert, M. (2023). *Caracterización de las aguas subterráneas en el poblado Yamanigüey* (Doctoral dissertation, Tesis en opción al título académico de Máster en Geología). <http://ninive.ismm.edu.cu/handle/123456789/4321>

Crespo-Lambert, M., Fernández-Rodríguez, M., & Pérez-García, L. A. (2022). Evaluación de la calidad del agua para consumo humano en el poblado de Yamanigüey según ICA de Montoya. *Minería y Geología*, 38(2), 157-167.

[http://scielo.sld.cu/scielo.php?pid=S1993-80122022000200157&script=sci\\_arttext](http://scielo.sld.cu/scielo.php?pid=S1993-80122022000200157&script=sci_arttext)

Cubana, N. 827: 2017: Agua potable, requisitos sanitarios. *La Habana: Oficina Nacional de Normalización*.

de Miguel Fernández, C. (2020). *Hidrogeología aplicada con aspectos ambientales*. Editorial Universitaria (Cuba).

[https://books.google.com/books?hl=es&lr=&id=331DwAAQBAJ&oi=fnd&pg=PP2&dq=De+Miguel+Fern%C3%A1ndez,+C.+\(2012\).+Hidrogeolog%C3%ADa+aplicada+con+aspectos+ambientales.+Editorial+Digital+Universitaria.&ots=zmC44QKVN4&sig=f9wJEDY3bYgK73t8\\_DAJWnYuVjo](https://books.google.com/books?hl=es&lr=&id=331DwAAQBAJ&oi=fnd&pg=PP2&dq=De+Miguel+Fern%C3%A1ndez,+C.+(2012).+Hidrogeolog%C3%ADa+aplicada+con+aspectos+ambientales.+Editorial+Digital+Universitaria.&ots=zmC44QKVN4&sig=f9wJEDY3bYgK73t8_DAJWnYuVjo)

Fernández-Rodríguez, M., & Guardado-Lacaba, R. M. (2021). Evaluación del índice de calidad del agua (icasup) en el río Cabaña, Moa-Cuba. *Minería y Geología*, 37(1), 105-119. [http://scielo.sld.cu/scielo.php?pid=S1993-80122021000100105&script=sci\\_arttext](http://scielo.sld.cu/scielo.php?pid=S1993-80122021000100105&script=sci_arttext)

Lobaina Lambert A, (2024). Evaluación de las características físico química y los componentes inorgánicos de las aguas de consumo humano en el reparto Costa Azul. (Tesis de pregrado, Universidad de Moa "Dr. Antonio Núñez Jiménez, Departamento de Geología).

Márquez Fernández, O., & Ortega Márquez, M. (2017). Percepción social del servicio de agua potable en el municipio de Xalapa, Veracruz. *Revista mexicana de opinión pública*, (23), 41-59. [https://www.scielo.org.mx/scielo.php?pid=S2448-49112017000200041&script=sci\\_arttext](https://www.scielo.org.mx/scielo.php?pid=S2448-49112017000200041&script=sci_arttext)

Oliveros Verdecia E, (2024) Evaluación de la calidad de las aguas de consumo humano del reparto Costa Azul mediante el índice de calidad de Montoya. (Tesis de pregrado, Universidad de Moa "Dr. Antonio Núñez Jiménez, Departamento de Geología).

Organización Mundial de la Salud (2018). *El agua, el saneamiento y la higiene en los establecimientos de salud: medidas prácticas para lograr el acceso universal a una atención de calidad*. World Health Organization. [https://books.google.com.cu/books?hl=es&lr=&id=2nUOEQAAQBAJ&oi=fnd&pg=PA20&dq=Organización+Mundial+de+la+Salud+\(OMS\).+2017+Guías+para+la+calidad+del+agua+potable.+3ra+edicion,+Ginebra&ots=WCYinF\\_BnW&sig=z7ve7tcdiuNjWnq4bctKBxxriSs&redir\\_esc=y](https://books.google.com.cu/books?hl=es&lr=&id=2nUOEQAAQBAJ&oi=fnd&pg=PA20&dq=Organización+Mundial+de+la+Salud+(OMS).+2017+Guías+para+la+calidad+del+agua+potable.+3ra+edicion,+Ginebra&ots=WCYinF_BnW&sig=z7ve7tcdiuNjWnq4bctKBxxriSs&redir_esc=y)

Rodríguez Fernández M, (2019). Gestión para la reducción de los riesgos hídricos en el municipio Moa. Caso de estudio: Río Cabaña. Tesis en Opción al Título de Doctora en ciencias geológicas, Universidad de Moa "Dr. Antonio Núñez Jiménez, Departamento de Geología.

Rubio Caballero, D. D. L. C. (2017). *Evaluación de la calidad de las aguas en el poblado La Melba* (Doctoral dissertation, Departamento de Geología). <https://ninive.ismm.edu.cu/bitstream/handle/123456789/1211/TesisDanay.pdf?sequence=3>

Torres Rivero, G. (2019). *Calidad de las aguas de consumo humano en los repartos Coloradas nuevas, Caribe, Atlántico y Miraflores del municipio Moa* (Doctoral dissertation, Departamento de Geología). <http://ninive.ismm.edu.cu/bitstream/handle/123456789/3702/TorresRivero2019.pdf?sequence=1>

Vargas, J. R. (Ed.). (2002). *Manejo integrado de aguas subterráneas: un reto para el futuro.* Euned.

<http://books.google.com/books?hl=es&lr=&id=1tHLuRaqBzEC&oi=fnd&pg=PA1&dq=REYNOLDS,+J.,+2002.+Manejo+integrado+de+aguas+subterráneas.Un+reto+para+el+futuro,+San+José,+Costa+Rica.,&ots=gwtsLPcBPs&sig=AFHtwje0JKrEXEiYU0T7G75-etE>