**UNIVERSIDAD CATÓLICA SANTO TORIBIO DE MOGROVEJO**

**FACULTAD DE INGENIERÍA**

**ESCUELA DE INGENIERÍA CIVIL AMBIENTAL**


# Una revisión de la tecnología de osmósis inversa enfocada al tratamiento de agua contaminada por metales pesados y sales, para el consumo humano y aplicación en la costa del Perú

**TRABAJO DE INVESTIGACIÓN PARA OPTAR EL GRADO ACADÉMICO DE BACHILLER EN INGENIERÍA CIVIL AMBIENTAL**

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# ÍNDICE

# A Review of Reverse Osmosis Technology Focused on the Treatment of Water Contaminated by Salts and Heavy Metals for Human Consumption and Application in Coastal Peru

## Una Revisión de la Tecnología de Osmósis Inversa enfocada al tratamiento de Agua contaminada por Metales pesados y Sales, para el Consumo Humano y aplicación en la Costa del Perú


## ABSTRACT

Developing countries still have certain deprivations in their sanitation systems, mainly drinking water, responsible for satisfying the basic needs of man and without which we would not exist. The shortage is due to several factors, one is that water suitable for human consumption is fresh water, whose 99% of this comes from underground sources and this type has a very low percentage with respect to salt water, 3% compared to 97% respectively of the total water on the planet. The population increase and human activities, especially industrial ones, have generated a lot of demand and pollution of this resource. The natural sources supplied by a population may have certain contaminants present as salts; chlorides or sulfates; or heavy metals such as mercury, lead, cadmium, arsenic, chromium, manganese; In large concentrations they are harmful to human health. This global problem causes the need to implement new and simple technologies for purification, as is the case of Reverse Osmosis, in which through a membrane system it manages to desalinate and remove the contaminants in order to be able to use the treated water to supply the population. It seeks to provide an alternative treatment in contaminated underground collection systems on the Peruvian coast, since the region has considerable amounts of salts and heavy metals and is required. This research considered scientific articles, theses and websites ranging from 2010 to 2022, from databases such as Scopus, Proquest, Google scholar, Scielo, Redalyc, Alicia, Sciencedirect.


**Keywords:** Reverse Osmosis, Drinking water, Heavy Metales, Desalination.


## RESUMEN

Los países en desarrollo aún presentan ciertas privaciones en sus sistemas sanitarios, principalmente el Agua Potable, encargado de satisfacer las necesidades básicas del hombre y sin el cual no existiríamos. La escazes se debe a diversos factores, uno es que el agua apta para consumo humano es agua dulce, cuyo 99% de esta proviene de fuentes subterráneas y este tipo presenta un porcentaje muy bajo respecto al agua salada, 3% frente a 97% respectivamente del total de agua en el planeta. El aumento poblacional y las actividades del hombre, especialmente las industriales, han generado mucha demanda y contaminación de este recurso. Las fuentes naturales que abastecen una población pueden tener ciertos contaminantes presentes como sales; cloruros o sulfatos; o metales pesados como el mercurio, plomo, cadmio, arsénico, cromo, manganeso; en grandes concentraciones son perjudiciales para la salud humana. Esta problemática mundial causa la necesidad de implementar tecnologías nuevas y sencillas para potabilización, cómo es el caso de la Ósmosis Inversa, en la cual mediante un sistema de membranas logra desalinizar y remover los contaminantes a fin de poder emplear el agua tratada para abastecer a la población. Se busca brindar una alternativa de tratamiento en sistemas de captación subterráneos contaminados en la costa peruana, dado que esta región presenta considerables cantidades de sales y metales pesados y es requerible. Esta investigación consideró artículos científicos, tesis y webs que van desde los años 2010 hasta el 2022, provenientes de bases de datos como Scopus, Proquest, Google académico, Scielo, Redalyc, Alicia, Sciencedirect.


**Palabras clave:** Osmósis Inversa, Agua Potable, Metales Pesados, Desalinización.

# INTRODUCTION

Water is a very important resource for living beings since we need it to exist, and this is thanks to the consumption we make, which is 20 to 50 liters of water daily (National Institute of Statistics and Informatics (INEI), 2020).

The deficient state of the domestic serviceor (drinking water), not only causes damage to the health of a population, but also indirectly affects other factors within a city and / or country, such as its socioeconomic development, environment, political stability, availability of water, among others (Economic Commis-sion for Latin America and the Caribbean (ECLAC), 2011).

According United Nations Development Programme (UNDP), 2020 ; He informs us: "Water scarcity is disrupting more than 40% of the world's population; This is worrying and will increase as climate change also increases." Approximately 829,000 people in low- and middle-income countries die annually as a result of poor water and poor hygiene.(World Health Organization (WHO), 2019)

The United Nations (UN), considering the 2030 Agenda whose objective is sustainable development, in its objective number 6 contemplates the rights of people to clean drinking water and sanitation, considers access to these services as a fundamental right for people, and an important step for the prompt recovery of living standards throughout the planet (Marenco, 2020).

For this reason, in order to propose a solution to this problem and contribute to the 2030 agenda, which seeks to reduce water scarcity and promote the consumption of safe water, it is neces-sary to seek methodologies that allow water to be used and reused, not only from the point of view of its management and care, but also through the treatment of the resource in its dif-ferent sources of catchment, As in the case of tubular wells or underground catchments that feed population centers and also serve for agriculture, which if they are contaminated can be treated to later return to function and save high costs in the construction of new collection works.

Science, together with technology, through its advances have given way to man can develop techniques that allow him to im-prove in various aspects whether domestic, commercial, or industrial, which has improved the quality of life of people, how-ever, the activities to reach these results generate some demand and environmental impact on the ecosystem. That is why the need arises to implement an efficient technology, which contrib-utes to the ecosystem, reducing these impacts and seeing waste as resources and not as threats, as is the case of reverse osmo-sis, which is bearing fruit in several countries, such as Colombia, Mexico, Brazil, the United States, among others. This technolo-gy is a treatment that is responsible for removing both contami-nants by salts and heavy metals in such a way that it seeks to reuse water of different qualities and characteristics.(Mejía Hernández & Ardila Pinzón, 2014)

Objective of the review and formulation of research questions

This article gives us a systematic review of the Reverse Osmosis Technology which will be focused on the treatment of water contaminated by salts and heavy metals, in such a way that it allows it to be in optimal conditions to be able to supply a popu-lation and with it finally look for a possible application, as is the case of the Peruvian Coast, Region that presents the specific needs that this technology can provide solution, thanks to the advantages of its processes and results, in addition to publicizing some background of the use of this technology, in such a way to guarantee and recommend its use. To obtain the information, reliable references from recognized databases of the last 12 years (2010-2022) will be used. An analysis of the results of these investigations will be made and the information in this article will be summarized.

With this objective, the work seeks to answer the following questions:

l. What are the contaminants present in the water and what amounts are permissible?

ll. What is reverse osmosis technology and what is its method-ology or procedure?

lll. What results does this technology have in its application according to the different authors and articles consulted?

lV. What are the advantages of reverse osmosis technology?

V. What antecedents exist in Peru regarding these methodolo-gies and why is it necessary to implement it on the coast of Peru? In which areas of the coast of Peru could it be applied?

# METHODOLOGY

The article has been executed through a systematic literature review (SRL) focused on the study of reverse osmosis technology in the treatment of water for human consumption. It is important to emphasize that this work is a review prepared at the Santo Toribio de Mogrovejo Catholic University, in Chiclayo, Peru, and was given thanks to the need for the use of technology for the desalination and removal of heavy metals present in the water, either in its different natural sources or supply to the population in the same country and especially in the Coast which is a region where A large number of these contaminants are found. In addition, the simplicity and effectiveness of this, makes it used in any country in the world. Regarding the information base, we decided to perform 5 steps for the review, these include: first, formulate the research questions and choose the database; second, identify keywords by searching for topic accuracy; thirdly and fourthly, to determine the criteria for both inclusion and exclusion, examining their titles and abstracts; Fifth and finally, the relevant full content of the chosen articles will be reviewed.

**Selection of methodology**

To obtain a significant number of articles from academic journals, it was decided to use the databases of Scopus, Proquest, Google Escolar, Redalyc, Alicia and Scielo. And as a result, the necessary studies of articles and theses were found (Tranfield et al., 2003).

**Selection of keywords**

Due to the extensive subject matter covered by this natural resource (water) and the advantages applied by reverse osmosis technology, it is necessary to use keywords, in order to find essential information that is consistent with the topic and objectives of the article. Among these we have:

Reverse Osmosis, drinking water, desalination, heavy metals.

- Technology and water treatment keywords: "Reverse Osmosis" and "Desalination".
- Keywords regarding the resource and its contaminant: "Drinking Water" and "Heavy Metals".

The search was carried out based on the combinations of these endings mentioned above, and the search was limited to the title, and summary.

**Inclusion and exclusion criteria**

We chose to accept journal articles, research reports, websites and specialty theses. While the preference regarding the language of the articles was in Spanish, English and Portuguese, since they were the only languages found in the relevant files and it was no longer necessary to exclude more at this point. Regarding the year of publication that they have, we tried to take all those articles published between 2010 and 2022, in such a way that updated information is used. Some erroneous returns of items that were not related to the central topic were found, so these were discarded. In addition, another point that is the treatment of salty seawater was discarded since only water from direct sources of supply was used.

**Revision of the full text**

With respect to the complete revision of the text, a review protocol was used, which will be taken as will be presented in figure 1, to perform an analysis of total information.

First, the problem of water from its sources of supply was studied, focusing on its contaminants such as salts that are subdivided into components such as chlorides and sulfates and heavy metals such as mercury, lead, cadmium, chromium, arsenic, nickel and manganese.

Secondly, having the content collected, it was possible to define and explain the process of reverse osmosis technology. Continuing, some opinions or discussions regarding the background and the result of the use of this technology in other countries were reviewed.

After that, a brief mention was made of the advantages and disadvantages of this technology, and finally a section was made in which the application that can be given was summarized, in this case on the coast of Peru which is a region that contains much of this problem.

**Summary of results**

This section summarizes the search results, the basis of which was the review strategy guide mentioned above. The methodology for research can be simplified in Fig. 1, it should be noted that in this Fig. 1. The institutional web pages, which were also taken, were not placed. Regarding the database, 273 results were obtained in Scopus, 1163 in Proquest, 10600 in Google Scholar, 27 in Scielo, 1500 in Redalyc and 173 in Alicia.

Limiting the inclusion and exclusion criteria, about 700 results were obtained that will be used for the revision of the text. However, to make a deeper and more practical review, the most important of these were covered, finally obtaining 36 results, included in this synthesis. Fig. 2 will show the final results that have been taken, considering their date of publication. It has been considered to take articles from 2014 to the most recent ones of 2022. It should be borne in mind that, with respect to time, research on this topic has been increasing in countries such as the United States, Brazil, Mexico since around 2010, but there is more notorious research from 2015 onwards.

However, there are many countries in which it is not yet known about this technology, as is the case of Peru and this is due to a lack of interest in research and modern methods that are being implemented and already enjoyed in other countries. Finally, it was

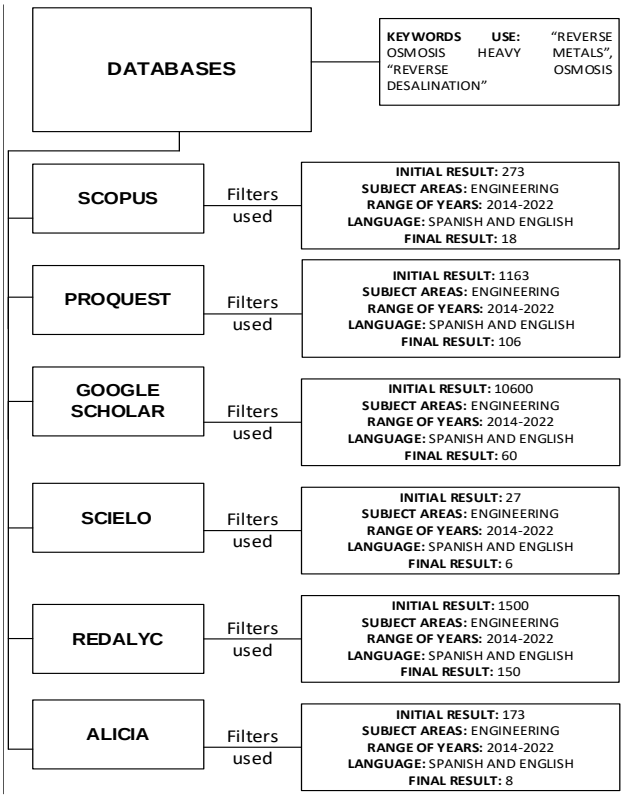


**Fig. 1: Databases and filters used**
**Source: Own**

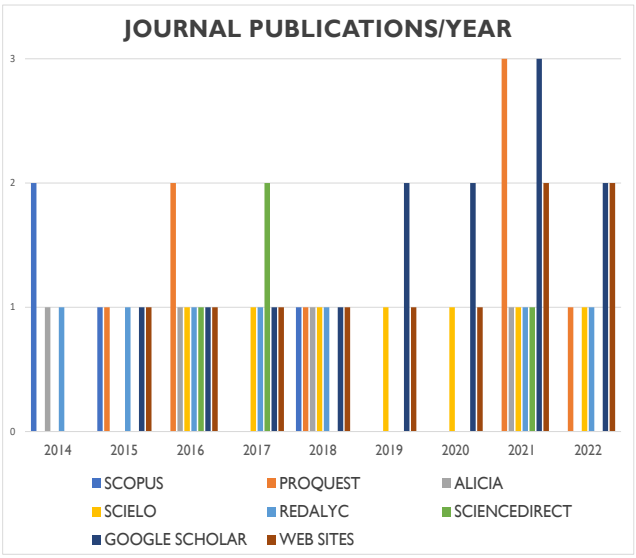


**Fig. 2: Journal Publications/Year**
**Source: Own**

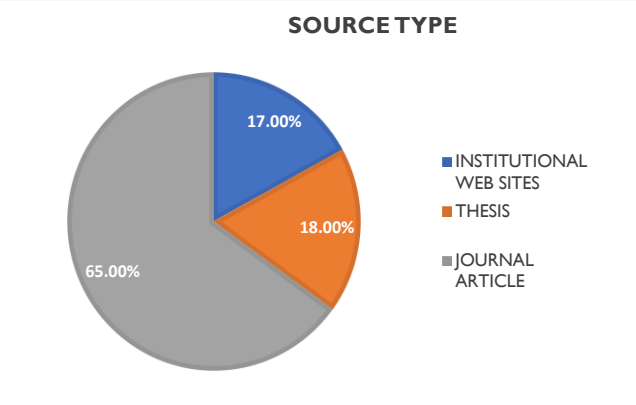


**Fig. 3: Source Type**
**Source : Own**

**Table 1. Final Database Results**

| FINAL DATABASE RESULTS | | |
|---|---|---|
| **DATABASE** | **FINAL EXCLUSION** | **FINAL RESULT** |
| **SCOPUS** | 1. Most of them were excluded because they did not have access to. | ***4*** |
| **PROQUEST** | 1.More relevant.<br>2. Without repeating | ***8*** |
| **GOOGLE SCHOLAR** | 1.More relevant.<br>2. Without repeating | ***13*** |
| **SCIELO** | 1.More relevant.<br>2. Without repeating | ***7*** |
| **REDALYC** | 1.More relevant.<br>2. Without repeating | ***7*** |
| **ALICIA** | 1.More relevant.<br>2. Without repeating | ***4*** |
| **SCIENCEDIRECT** | 1.More relevant.<br>2. Without repeating | ***4*** |
| **WEB PAGES OF STATE INSTITUTIONS** | 2. The most relevant were taken to be practical. | ***10*** |
| **TOTAL** | | ***57*** |

After carrying out the systematic review found and selected, exactly 57 results were taken with which it was possible to perform an analysis and description of the topics to be solved, according to the research questions posed, which will be presented in the following sections.

## RESULTS AND DISCUSSIONS

### Contaminants in water - Sources of heavy metals

Heavy metals such as mercury, lead, cadmium, arsenic, chromium, manganese, are the most common, and are exposed to the aquatic ecosystem, as well as to the soil, from the various activities of man, which is a major threat to living beings, since this is persistent, bioaccumulates and certain non-biodegradable areas are generated in addition to the toxicity that depends on the concentration either low or high (Pabón et al., 2021).

In addition, as he mentions, it is worrying to find them present in the various ecosystems, given that our development depends on the optimal balance of this, especially the sources of supply to homes that allow the

consumption of water for our basic needs (see table 3 and 4 ). Each metal has a different source or is caused by a different activity:(Pabón et al., 2020)

Chromium for example is a compound that is generally used in industries themselves, in areas where plastic coating, electroplating of corrosion-resistant metals, as well as leather finishes, and wood preservatives are used. (Mohan et al., 2006)

Cadmium, whose heavy metal is carcinogenic, is mainly generated by the manufacture of batteries that are made of nickel-cadmium, in addition to corrosive agents and pigments. (to Hamouz et al., 2017)

Mercury according to what could be reviewed 80% of articles mention that theyare found in six sources of pollution, such as erosion, human discharges, agricultural materials, atmospheric deposition, mining, combustion, and industrial discharges; occurring in natural and surface groundwater a content below 0.5 µg / L, however, in mineral deposits and other industrial places there is a much higher amount.(Wu et al., 2016)

Lead as(Mohammad et al., 2017) gives us the most prominent source in which it indicates that it is released into the environment thanks to the mining and burning of fossil fuels, in addition it is intended for the manufacture of batteries, ammunition, metal products and devices for protection against X-rays.

Arsenic is one of the biggest causes of poisoning and this is emitted into the environment thanks to industrial processes such as the smelting of zinc, copper, and lead, or for the manufacture of chemicals and lenses.(Microbiology laboratory ACONSA, 2020)

An important fact is that mercury and manganese are among the most common contaminants in groundwater, this is known since most cases the limits imposed by legislation for water for human consumption are exceeded. This generates aesthetic problems in the water and also directly affects human health.(Guillen Rivas et al., 2021)

According to the review, what stands out 90% is that these sources are caused by man's industrial activities, in which these wastewater is discharged that contaminates those that are in good condition, so we must be aware of this and comply with the permissible limits (see table 2) that gives us the current legislation RD 140/03 (Microbiology laboratory ACONSA, 2020) and the legislation of the regulation of quality of water for human consumption of DS N°031(Ministry of Health, 2010).

### Contaminants in water - Sources of salts

Briefly, according to the research it was obtained that, within the sources of contaminants by salts, stand out: Chlorides and sulfates, which also in large quantities can seriously affect health, when consuming water mixed with these inorganic chemicals, there are certain permissible limits in this case the limits from the Regulation of the Quality of Water for Human Consumption (see table 5 and 6) (Ministry of Health, 2010) .

**Table 2. Sources and Permissible Limits of Heavy Metals in Water RD 140/03 and DS N° 031**

| HEAVY METALS IN WATER | | | |
|---|---|---|---|
| **POLLUTANTS** | **SOURCES OF POLLUTION** | **PERMISSIBLE LIMITS FOR CONSUMPTION (DS N°031 MINISTRY OF HEALTH, PERU)** | **PERMISSIBLE LIMITS FOR CONSUMPTION (RD 140/03 SPAIN)** |
| **Arsenic** | Mining and burning fossil fuels | 10.00 µg/l | 10.00 µg/l |
| **Copper** | Mineral Sulfides | 2.00 µg/l | 2.00 µg/l |
| **Lead** | Mining and burning fossil fuels, and pipeline manufacturing | 10.00 µg/l | 10.00 µg/l |
| **Chromium** | Industrial fur and plastics activities | 50.00 µg/l | 50.00 µg/l |
| **Cadmium** | Industrial fur and plastics activities | 3.00 µg/l | 5.00 µg/l |
| **Mercury** | Mining and burning fossil fuels | 1.00 µg/l | 1.00 µg/l |
| **Nickel** | Industrial activities and landfilling, which can be combined with manganese and iron | 20.00 µg/l | 20.00 µg/l |
| **Manganese** | Industrial activities, and very toxic in high quantities | 40.00 µg/l | 40.00 µg/l |

**Table 3. Heavy Metal Generation Activities in Water**

| HEAVY METAL GENERATION ACTIVITIES IN WATER | |
|---|---|
| **POLLUTANTS** | **ACTIVITIES FOR WHAT THEY ARE USED OR GENERATED** |
| **Arsenic** | Arsenic is one of the heavy metals that cause the most poisoning. It is emitted into the environment as a result of industrial processes such as the smelting of copper, zinc and lead or the manufacture of chemicals and lenses |
| **Lead** | Lead has been widely used in the manufacture of pipes and solder materials, among others, being a very soft material. |
| **Chromium** | It is used in a large number of industries, especially those that use pigments and those that use it as an additive, such as the fur industry and plastics. It reaches the water, therefore, through its discharge into the rivers, as well as through the air by combustion and then by rain. Chromium can cause skin and respiratory problems, as well as damage to the liver and immune system. |
| **Cadmium** | Used in industry for the manufacture of pigments used in textiles, galvanizing metals, paints, graphic arts and paper, nickel-cadmium batteries or plastics such as PVC, and is also a by-product resulting from lead and zinc smelting in the mining industry. |
| **Mercury** | In addition, it can reach water through the burning of solid fuels, such as coal or wood, both industrial (power generation, production of metals or cement, etc.) and domestic. These amounts of mercury that are released into the environment reach the water through rain. Currently, the oceans contain 200% more mercury than is natural, and the atmosphere 500%. |

**Table 4. Heavy Metal Generation Activities in Water**

| HEAVY METALS IN WATER | |
|---|---|
| **POLLUTANTS** | **HEALTH EFFECTS** |
| **Arsenic** | It produces poisoning, its residual discharge of these activities in rivers, affects the marine species we eat, as well as agricultural products that have a special contact with water, such as rice. Arsenic in its inorganic form can cause health effects such as irritation of the digestive system, involvement in the blood and respiratory system, skin problems, as well as damage to the reproductive system, among others. |
| **Lead and Manganese** | It causes problems in the brain and nervous system, fertility problems in men, kidney damage and an increase in blood pressure, among others. Like mercury, pregnant women and children are more vulnerable to lead because it can enter the fetus through the placenta, causing problems in the nervous system and brain. |
| **Chromium** | Chromium can cause skin and respiratory problems, as well as liver and immune system damage |
| **Cadmium** | Cadmium is considered a carcinogen, it mainly attacks the kidneys, where it damages the filtration system and causes essential proteins and sugars to be excreted. This can lead to broken bones, immune and nervous system damage, fertility problems, among others. |
| **Mercury** | The negative health effects of mercury are especially focused on pregnant women and children, since exposure to this metal can occur in the womb. Each year nearly 2 million children are born with mercury levels higher than recommended. |

**Table 5. Sources and Permissible Limits of Salts in Water DS N°031**

| SALTS IN THE WATER | | |
|---|---|---|
| **POLLUTANTS** | **SOURCES OF POLLUTION** | **PERMISSIBLE LIMITS FOR CONSUMPTION** |
| **Sulphates** | Oxidation of sulfite minerals or industrial waste. Some soils and rocks containing sulfate minerals such as groundwater move through rocks causing them to dissolve in the water. | 250 mg Cl/L |
| **Chlorides** | In coastal areas they are caused by infiltrations of sea water. In the arid zone the increase of chlorides in the water is due to the heavy rains that produce the washing of the soils. In the latter case, it may be due to water pollution by wastewater. | 250 mg SO4/L |

**Table 6. Health effects of the presence of salts in wáter**

| SALTS IN THE WATER | |
|---|---|
| **POLLUTANTS** | **HEALTH EFFECTS** |
| **Sulphates** | If drinking water with high levels of sulfate is consumed, dehydration and diarrhea may be experienced. Children are usually more sensitive to sulfate than adults. |
| **Chlorides** | The chloride ion is important for human life, in reduced quantities it allows to maintain good health of the kidneys, nervous system and nutrition. The negative effects are given thanks to the reaction with the sodium ion that can cause diseases that affect the heart or kidneys. |

## Collection of timely information regarding the concept of Reverse osmosis and its process.

Reverse osmosis is a technology that is used in a flow, in its input and output system, and this is characterized by applying crossed systems, which consists of forming interconnected and spiral-shaped systems, where it is possible to remove from 90% to 99% of the contaminants present in the water, through a solution-diffusion mechanism (Zúñiga Martínez et al., 2022).

The mechanism of this system is based on three filters, the first filter consists of a pre-membrane, the second a semipermeable membrane and third a post-membrane (Cardenas Zevallos, 2022).

## Review of articles and results of your research

For the review of articles in a more detailed way, table 7 (7.1, 7.2, 7.3 and 7.4) has been proposed, where it has been chosen only to mention 16 bibliographies of the total so as not to extend the article too much.

**Table 7.1 Review of articles and theses, abstract and results**

| Authors | Name of the article or thesis Fountain | Year | Country | Brief Summary | Research Results |
|---|---|---|---|---|---|
| (Zúñiga Martínez et al., 2022) | Methods of removing metals in water for human consumption: A review. | 2022 | Mexico | This review describes the sources of heavy metal contaminants in water and compiles available information on methods used for water purification and the costs associated with the volume of water processed and/or percentage of contaminants removed. | The physicochemical methods by membranes, adsorbents and electrochemical are the most used to remove heavy metals in the water, being the most economical with a cost of 0.0163 USD / M2 in their operation, while those of reverse osmosis a little more expensive, being 0.3319 USD / m3. It is possible to remove substances such as As, Cr, Cd, Cu, Hg, Pb, Ni, highlighting the As and Pb. In addition, it mentions the applicable legislation. |
| (Cardenas Zevallos, 2022) | Household drinking water filters: A systematic review | 2022 | Peru | Different systems of POU drinking water filters were analyzed, considering as categories of analysis the type of filtration, the filtered element, and the impact of the filter on the user. Regarding the category "type of filtration", it was distinguished that the most used is the activated carbon filter, followed by ceramic filters and reverse osmosis. It recommends researching research focused on the use of UV filters for rural areas of Peru where drinking water does not reach. | The activated carbon filter eliminates both bacterial and viral microbial indicators and to a lesser extent in the elimination of lead. In addition, the ceramic filter is also used in bacterial and viral eradication, and the reverse osmosis filter is usually used in the removal of lead, but also for the treatment of chemical and biological parameters. It should be noted that there are filters with more than one filtration system and / or additional elements, to improve the effectiveness of filtering. |
| (Guillen Rivas et al., 2021) | Study of iron and manganese removal processes in groundwater: a review | 2021 | Ecuador | The article focuses on the process of removing iron and manganese in groundwater, seeking to compare the iron and manganese removal efficiency of these processes, based on research data. | As a result, it was obtained that the progress of the removal methods at present, achieve efficiencies greater than 90%. |
| (Santana Hinostroza, 2021) | "Systematic Review: Groundwater Treatment Methods, 2020 | 2021 | Peru | Sources of groundwater pollution consisting mainly of natural and anthropogenic sources were identified. Among the natural sources were arsenic, fluoride and iron that are part of the mineral numbers found in nature and anthropogenic, the diffuse sources that are given by agricultural activities; urban activities and finally the industries that generate economic activities. | The types of treatment applied in groundwater, such as biological treatment, which perform cleaning in short times such as the method biological degradation by microcosm, resulting in 100% removal of the contaminant, were studied, but these processes are very expensive, since the implementation of energy, equipment and labor is required. In the case of physical and chemical treatments, the toxicity of contaminants is checked more closely, it is not necessary to apply another more implemented treatment, the cost is affordable and helps the environment. |

**Table 7.2 Review of articles and theses, abstract and results**

| Authors | Name of the article or thesis | Year | Country | Brief Summary | Research Results |
|---|---|---|---|---|---|
| | **Fountain** | | | | |
| (Peña Murillo et al., 2022) | Water Purification System in Rural Areas | 2022 | Ecuador | This research begins by contextualizing the problem of the lack of adequate sanitary conditions, drinking water and details about the purification generating water for human and animal consumption without risk of diseases. He mentions that water pollution is mostly caused by man's economic activities. The proposed treatment system is a rain collector and a treatment plant where different processes were made. | The purification system must be simple and cost-effective. Various treatments have been analyzed to eliminate contaminants in water for human consumption, among them are Decantation and flocculation, which separates many types of particles from water and improves the filtration process, requires the use of chemicals, qualified personnel for design and continuous maintenance to ensure efficient treatment. An outstanding technology in purification is biofiltration that can be carried out in porous or granular media. In the Treatment of purification with Coal the efficiency decreases by 5 to 10% |
| (Ortega Ramírez & Sánchez Rodríguez, 2021) | Advanced treatments for wastewater purification | 2021 | Colombia | This review article seeks to identify the most important advances in reference to wastewater purification. For this reason, a detailed explanation is made on the importance of water and its current diagnosis considering the harmful pollutants for the aquatic ecosystem. | By implementing advanced wastewater treatments, a technological development is generated with a focus on water management, which leads to a greater degree of removal of contaminants in the water. In addition, it is evident that exchange techniques and membrane technologies are functional to perform effective and efficient removal processes. |
| (Calvo et al., 2021) | Past, Present and Future of Membrane Technology in Spain | 2021 | Spain | The contribution of Spanish researchers to the membrane systems was evaluated, with a historical compilation of the main milestones. Its database is Scopus (1960-2020) with 8707 documents covering the different disciplines and thematic areas in which membranes intervene. Update information was provided. | For membrane development is necessary high-level research conducted in scientific laboratories and large-scale application, it is noted that most active membrane research groups are listed in the directory of Supporting Information in European consortia or other internationally funded projects. |
| (Saavedra et al., 2021) | Comparative Analysis of Conventional and Emerging Technologies for Seawater Desalination: Northern Chile as A Case Study | 2021 | Chile | Different desalination technologies were studied as alternatives to conventional reverse osmosis (RO) through a systematic literature review. A panel of experts evaluated thermal and membrane processes considering their possible application at pilot plant scale (100 m3/d of purified water) starting from seawater at 20 ◦C with an average salinity of 34,000 ppm. | Currently, membrane desalination processes using energy recuperators have an SEC 50% lower than thermal desalination processes. NM technology presents the technical characteristics and the best economic indices to consolidate in the desalination market. In addition, NM represents a competitive alternative to the conventional OI process. |

**Table 7.3 Review of articles and theses, abstract and results**

| Authors | Name of the article or thesis | Year | Country | Brief Summary | Research Results |
|---|---|---|---|---|---|
| | **Fountain** | | | | |
| (Followed Morote, 2018) | Desalination. From a questioned resource to a necessary and strategic resource during drought situations for the water supply in the Segura River Basin | 2018 | Spain | This Spanish review tells us about how in the last 2 decades due to there have been some plans that have allowed to have a less vulnerable land to droughts and make a brief content regarding the desalination that occurred between 2015 and 2018 and its respective desalination in the supply systems. | It is claimed to have achieved a territory less vulnerable to drought and the effects of climate change, thanks to the desalination carried out in those seasons. |
| (Oliveira et al., 2017) | Physical-Chemical Assessment Of The Waters From Desalinization Process Of Salubrious And Salinos Wells In Rural Communities Of The West Potiguar | 2017 | Brazil | The study was based on analyzing the quality of the desalination process of water wells in rural communities of Potiguar Oeste. This research was conducted around 2014. A record was taken of the communities that are supplied in desalinated water collection and treatment centers through a cadastral survey. | Controlled rural communities, reverse osmosis water treatment plants produce desalinated water with low salt concentrations, as 68% of all samples are in classification class C1S1; 25% in class C2S1 and only 7% in class C3S1. Regarding rejection brine, 93% of wastewater samples were classified as C3 or C4 during the four collection periods, i.e. with a high or extremely high risk of salinization. |
| (Guillen Rivas et al., 2021) | Water purification technology in rural areas as a measure of adaptation to climate change in the Callejón de Huaylas, Ancash - Peru | 2021 | Peru | This article shows us how climate change alters water sources, especially for the supply of rural areas, for which some springs were analyzed in which the physical, chemical and bacteriological characteristics were identified. | he results showed the increase or modification of the concentration of the main chemical components of the water, altering its quality, such was the case of hardness, chlorides, sulfates and residual chlorine; as well as a variation of the characteristics of turbidity, suspended solids and total coliforms. The problem found was reason to propose technology with system for the improvement of the physical, chemical and biological parameters of water from the use of zeolite and activated carbon (Anthracite) or silica sand. |
| (Herrera et al., 2016) | Implementation of Direct Osmosis and Magnetic Nanoadditives for Water Desalination | 2016 | Colombia | Desalination by direct osmosis of synthetic seawater was analyzed on a laboratory scale. This system used a commercial osmotic agent and an osmotic agent prepared, from sugar/glucose anhydride 50/50% w/w and magnetic nanoparticles, modified with carboxymethyl cellulose. | They evaluated the removal of the magnetic nanoparticles, applying an external electromagnetic field. Despite a decrease in the concentration of nanoparticles present in the effluent, after eight cycles of magnetic separation, they found, by atomic absorption spectrophotometry, a concentration of 227mg Fe/L in desalinated water, which exceeds the maximum acceptable value of iron in drinking water (0.3mg Fe/L), thus reflecting the need to improve the magnetic separation process, in water desalination processes, by direct osmosis. |

**Table 7.4 Review of articles and theses, abstract and results**

| Authors | Name of the article or thesis<br><br>Fountain | Year | Country | Brief Summary | Research Results |
|---|---|---|---|---|---|
| (Condorchem Envitech, 2022) | Reverse osmosis and its different applications | 2022 | Spain | This short article details specific things about the subject of reverse osmosis, starting with what the subject, itself is about, then the characteristics it has, the selectivity of recommended membranes, the problems of obstructions that can be obtained and some general applications | RO consists of generating by means of a water-permeable membrane, an aqueous solution with low salt content from another with a high salt content and that in no case is it a filtration process through the membrane, as would be the case of microfiltration or ultrafiltration, rather, the solvent diffuses through the membrane. Its applications are to desalinate seawater and sanitation, produce ultrapure water and decontaminate wastewater. |
| (Mejía Hernández & Ardila Pinzón, 2014) | Reverse Osmosis, Water Impact Mitigation Alternative | 2014 | Colombia | Sustainable development and cleaner production is essential when using technological advances as an alternative to overcome some of the environmental problems, for this reason reverse osmosis is a cutting-edge technology for ultra-water purification, which can be implemented as a tertiary wastewater treatment. | Ultra-water purification systems such as reverse osmosis have become popular and intensified as a solution to water supply problems in different scenarios in Colombia. The reverse osmosis plant found in the utility lab is a tool used as a clean technology model that facilitates student learning. |
| (Pabón et al., 2020) | Water contamination by heavy metals, analysis methods and removal technologies. A review | 2020 | Colombia | Current industrial production systems employ heavy metals for the extraction of a material or as an element in the refining of a particular product which initially results in relatively low-cost products. But using these metals causes a serious problem at the environmental level due to their high levels of toxicity for the organisms with which they interact when they are discharged. Therefore, various methods have been developed to deal with these metals. | The result of this research was clearly to provide qualitative knowledge to the researcher regarding these types of contaminants in water, and the degree of severity that this has regarding the effects on health and the aquatic environment, in addition to treatment technologies on heavy metals. |
| (Grueso Domínguez et al., 2019) | State of the art: desalination using membrane technologies as an alternative to the problem of freshwater scarcity | 2019 | Colombia | The low availability of fresh water, population growth and water pollution make it necessary to look for alternatives to take advantage of brackish resources and water contained in the oceans. Indesalination processes, the separation by membranes stands out, purifying seawater. | Some future challenges are highlighted including: the use of renewable energy sources in processes, the reduction in the use of chemicals, the use of innovative materials for membranes, the search for more effective and cost-effective pretreatment solutions, and the decrease of the total cost of water for the consumer. |

## Advantages of reverse osmosis technology

The results seen above reflect a series of advantages of this technology, which are summarized in this section. The most outstanding are that this interconnected system can remove up to 99% of dissolved substances, it is also very efficient when treating healthy, surface and groundwater, and can be used in considerable flows to the minimum (WaterStation, 2020).

Another important point is that 70% of the authors emphasize that this system takes care of the environment since they do not act chemical actives, and by providing purified water, it is no longer necessary to buy bottled water. It has also been seen to improve the color and flavor of water. It improves quality and saves money, presents space and energy savings. Finally, its maintenance is not so complex; with all this, this reverse osmosis system could be described as viable to be used as a solution to the problem of water scarcity due to water contamination in its sources of catchment, standing out from other systems that require several implementations and constant maintenance.

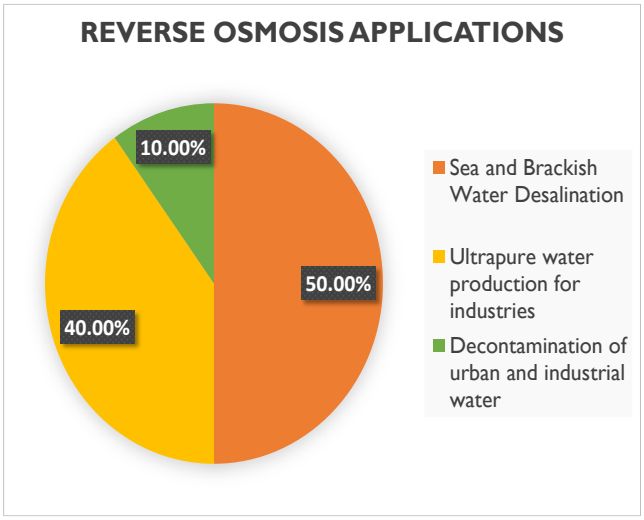


**Fig. 4: Reverse osmosis application trends**
**Source: Own**

**Application of reverse osmosis in Peru and its necessary application on the Peruvian coast (In table 8)**

**Table 8. Applications of Reverse Osmosis Technology in Peru**

| Applications of Reverse Osmosis Technology in Peru | | |
|---|---|---|
| **Author** | **Project** | **Summary** |
| **(Anicama Cubas et al., 2022)** | Reverse osmosis on the beaches of Asia in Lima – Grupo Musiris | The project is located in the Asia area (Km 101 of the Panamericana Sur) and the artificial lagoon was inaugurated last summer (with an area of 55,000 m2 whose implementation was in charge of Crystal Lagoons). The project has its own drinking water treatment plants (Reverse Osmosis) for the houses and apartments and its own irrigation water plant for the condominium. These plants are, the first destined of 113.56 m3 / day and the second of 151.41 m3 / day operated alternately every 24 hours. |
| **(Regional Autonomous Corporations & Corporation for the Sustainable Development of the San Andrés Archipelago, 2019)** | Reverse osmosis at the Decameron Punta Sal hotel | The Decameron Mar Azul Hotel Desalination Plant Project, in the Cocoplum Bay sector, corresponds to the system and infrastructure for the collection and treatment of seawater, for consumption of the hotel, built in its entirety and in operation for several years, since the hotel does not have aqueduct service and all the water supply is by desalination. |
| **(Forú Builds n/a.)** | Reverse osmosis at the port of St. Martin in Paracas Bay and at the Engie Power Plant in Ilo | The system captures water directly from the sea and is located in the port of San Martín in the bay of Paracas that will have a capacity of 120m3 / day. There is another plant that will produce 230 m3/day and will be located at the Engie Power Plant in Ilo. Its place of collection is in the land of maritime beach area, low tide lands and maritime water. It operates 2 reverse osmosis desalination plants with the aim of providing drinking water suitable for human consumption, for domestic purposes in the hotel establishment. |
| **(R. Fernandez, 2021)** | Reverse osmosis in PROVISUR Project South of Lima | Onecomponent of the project is the desalination plant which has a particularity and is that it shares a plot with the WWTP. The plot has an area of about 41,000m2, and is located nine hundred meters from the coastline. The treatment line chosen for this project includes dissolved air flotation (DAF), self-cleaning filters, ultrafiltration, reverse osmosis, CO2 injection and calcite beds. |
| **(District Municipality of Ite, 2021)** | Reverse osmosis in the district of Ite | On August 15, 2021, reverse osmosis plants were 100% operational. The important project provides quality water to the entire population, has five plants designed with high quality technology and distributed in strategic sectors. Of the total 4 will provide up to 46 m3 of pure water daily and 1 will provide up to 56 m3 daily. The sectors directly benefited, in addition to the entire rural sector of the district, are Pampa Baja, Las Vilcas and San Isidro, as well as Pampa Alta and Mirador, the latter two with high population concentration. "Reverse osmosis water is purely for human consumption, for drinking, to prepare food" |

**Application of reverse osmosis on the coast of Peru**

In order to determine a possible application of a reverse osmosis system within a water treatment plant, it is necessary to know what role this fulfills and in which cases we must install it. For this we start with the basic principle of operation of an RO system, which is the removal of 98-99% of salts, minerals, and heavy metals from water. To do this, once we have the results of the tests of our source water, you can decide whether or not to install the system. In the case of Peru in the Selva area, it is not necessary to implement it because the contents of TDS (components dissolved in water) are very low, and do not exceed 20ppm. While in the Sierra del Perú if we have high content of salts, minerals, and metals of the water, then if it is necessary to implement an I.O. system, and in the Costa zone it is also necessary to install Reverse Osmosis since the TDS values exceed in some cases up to 1000 ppm (Investments of Peru, 2022)

# CONCLUSIONS

It was possible to observe the sources of the pollutants present in the water, which are considerably toxic or harmful to both health and the environment according to their concentrations. In order to reuse water of different qualities, it is necessary to implement RO technology, since it will allow the removal of these dissolved particles, such as salts, where we have chlorides and sulfates; and heavy metals such as mercury, lead, cadmium, arsenic, chromium, manganese. Therefore, by improving the quality of water with the OI, it will subsequently be chlorara and then remineralized, to finally obtain drinking water for the population.

The Reverse Osmosis process both for desalination of seawater and / or groundwater and for removal of metals from wells, is one of the processes that have been used in the world and in Peru it is just being taken into account since 2018, however research has not yet transcended, since there are not many implementations of this system in Peru, however it was possible to contribute to the research, collecting the most relevant information on the subject in addition to these applications of the methodology in projects such as the Hotel Decameron in Punta Sal or the Fenix Power plant in Chilca, another is the PROVISUR project used south of Lima, another in the district of Ite in the department of Tacna and another case is in the La Jolla project, of the Musiris group, located in the area of Playa de Asia, which have given great results and can be seen evidenced in the quality of life of the inhabitants present near that area.

As well could be reviewed, in Peru exactly in the Costa y Sierra region, it is necessary to install this reverse osmosis system within a water treatment plant, due to the large amount that can be reached by contaminants that can be TDS values of up to 1000 ppm. Especially in rural areas where there is a lot of water scarcity due to its pollution. Some applications that could be proposed within the review article in the Costa region are, for example, its application in the district of Morrope given that according to (J. Uturunco, 2019) water quality studies in this district there is a presence of arsenic and lead of 30 µg/l that exceed 10 µg/l established in the permissible limits of D.S 031.

Another place of application in the coastal region can be in Tacna, since in this department it presents a large amount of heavy metals, in the evaluation of seawater the levels of heavy metals are low, however, of these copper stands out, which resulted in 12.34 µg / l being greater than the 2 µg / l provided in D.S 031, other data but low in their heavy metals are cadmium 0.53 ug/L, lead 0.72 ug/L, copper 10.66 ug/L and iron 0.36 ug/L (W. I. Fernandez, 2019).

In Tacna for marine sediments, the highest level of manganese was obtained with 164.50 ug/g, and in second place copper with 46.84 ug/g. The average results obtained in marine sediments in the southern zone to the contaminated focus are cadmium 0.16 ug / g, lead 1.44 ug / g, manganese 127.54 ug / g, copper 40.013 ug / g, zinc 12.38 ug / g and iron 1.8 ug / g are normal values in this area (W. I. Fernandez, 2019).

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