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Using the microbial Anammox community to treat wastewater in cities and settlements

Anammox bacteria, discovered in the late 20th century, had a stimulating influence on the development of new wastewater treatment technologies. Processes, involving this type of bacteria, can occur both at urban treatment facilities and industrial enterprises, depending on the degree of contamination of incoming wastewater. In this article, the authors compare various technologies offered on the market for various purposes. The Anammox community of microorganisms is interesting because of its potential ability to purify wastewater saturated with nitrogen compounds, but poor in organic matter. Classical methods of removing biogenic elements cannot effectively treat this type of wastewater. The authors have revealed that in nature Anammox bacteria play a significant role in the nitrogen cycle as well as in the process of thorough biological wastewater treatment and removal of nitrogen compounds. Various patterns of the Anammox process are considered; they differ from one another in oxygen conditions and items of equipment. They are also recommended for the treatment of wastewater featuring different concentrations of contaminants at the inlet to the treatment plant. As a result, potentially effective development areas have been identified. The authors have proven that the quality of wastewater treatment can meet standard requirements if Anammox bacteria are used.

Keywords: *Anammox bacteria, Anammox process, denitrification, nitrification, MVK-Anammox, Sharon-Anammox, Demon, Deamox*

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INTRODUCTION

Today, the task is to intensify processes to ensure their energy efficiency and improve the quality of wastewater treatment at wastewater treatment plants. If we address the treatment of domestic wastewater, the main indicators that determine the quality of wastewater treatment are the biological oxygen demand (BOD), chemical oxygen demand (COD), suspended solids and biogenic elements (nitrogen and phosphorus).

Particular attention is paid to technologies employed to remove biogenic elements, whose excessive content at the outlet from the reservoir causes eutrophication and the death of fish.

Historically, before it was identified that aerobic, anaerobic and anoxic microorganisms, including recently discovered Anammox bacteria, play the most important role in the life cycle of the nitrogen molecule, description of the natural nitrogen cycle had had certain assumptions. A certain role belongs to nitrogen fixers, which are both aerobic and anaerobic. The Anammox community is most important for the nitrogen cycle; it is particularly developed in the oceanic waters, the vital activity of which, along with denitrifying bacteria, saturates the atmosphere air with molecular nitrogen.

First of all, the newly discovered Anammox bacteria can be studied by specialists in applied biotechnology because of the strong potential of a new biological method of wastewater treatment. Before the discovery of Anammox processes, nitrogen-containing substances were removed from effluents using multistage patterns of sequential nitri-denitrification.

It is obvious that currently used biological wastewater treatment solutions cannot be called perfect. Both nitrification (the aerobic oxidation of ammonium nitrogen to nitrite and nitrate) and denitrification (the process of reducing nitrate nitrogen to molecular nitrogen under anaerobic conditions) involve high operating costs. This is due to the high cost of aeration of activated nitrifying sludge, as well as the cost of external sources of organic substrate needed to ensure effective denitrification. Processes, involving nitrification and denitrification, demonstrate a consistently effective treatment quality if the effluent is slightly polluted with nitrogen, but rich in organic matter.

Such methods are optimal for the treatment of domestic wastewater, but it is problematic for the wastewater with a varying ratio of the concentration of total nitrogen and organic pollutants. Experience has shown that the economic effect of traditional denitri-nitrification processes is low [2].

MATERIALS AND METHODS

The ANAMMOX (ANaerobic AMMonium OXidation) process entails the anaerobic oxidation of ammonium by nitrite to form nitrogen. This process is carried out by Anammox bacteria (Fig. 1).

In the anaerobic microbial community, Anammox bacteria are known as planktonomycetes, which use nitrite and ammonium in oxidative processes, resulting in the release of pure nitrogen molecules. Anammox bacterial cells tend to aggregate and create sarcinogenic microcolonial agglomerates.

The cellular structure of bacteria is more or less similar, but insignificant variations have been revealed. The cells are similar in shape to cocci, and they also have incised forms; the diameter rarely exceeds 1 micron. The largest cells are found in Candidatus Anammoxoglobus propionicus [1].

Like all planktonomycetes, Anammox bacteria are divided into several groups, in which particular

Fig. 1. Anammox bacteria

biochemical processes occur. The first one is parifoplasma, which is located between the outer membrane and the first inner one. The second site is located below; it is the riboplasm, which is limited by the second inner membrane. And, finally, there is a unique cellular organelle, or Anammoxoma, surrounded by a double-layer membrane. It occupies about 70 % of the cell volume and is responsible for catabolism [3, 4].

The Anammox process enjoys the increasing attention of scientists from all over the world. The main task of research is to determine the composition of communities of microorganisms, to understand their relationships and to develop the flow chart of the Anammox process.

RESULTS

What is the complexity of research? All Anammox bacteria are characterized by the low growth rate (11 days) and, accordingly, in the future, the operating mode of these bioreactors is slow.

They all function as part of communities. These communities consist of diverse though closely related microorganisms. Their connections are still being investigated by scientists from different countries [5].

The traditional flow chart of the Anammox process is well-known. At the first stage of the process, ammonium is converted to nitrite. Later, molecular nitrogen is formed. The classical flow chart combines two processes: partial nitrification (nitridation) and the AMX process.

The Anammox technology is both economically and environmentally superior to the standard methods:

- lack of demand for organic matter, reduced demand for oxygen, which leads to a 2–3-fold reduction in energy consumption;
- nitrous oxide is not formed during intermediate reactions and, as a result, it has a lower greenhouse effect [6].

More than 100 pilot plants use current Anammox technologies worldwide. They differ in the type of hydraulics, the biomass and the type of loading, if any. Varieties of process charts are shown in Fig. 2 [7].

Let's consider the features of several technologies.

1. The Mosvodokanal Anammox process.

The Anammox-type technology was developed by Mosvodokanal together with the Russian Academy of Sciences for the treatment of return flows, that is, those flows that enter the aeration tank after the sludge treatment stage (for biological treatment purposes). Traditional methods cannot cope with this task due to the lack of organic matter.

The Anammox bioreactor operates as a "carousel" reactor, that is, it is a hydraulically mixed reactor that entails simultaneous mixing and displacement. The temperature in the reactor is maintained in the range of 30–37 °C.

The Mosvodokanal — Anammox technology is distinguished from other types by the presence of.

A reactor, or an additional oxidizer, needed for the removal of organic residues, and the reactor acting as the crusher of activated sludge (Fig. 3) [9–11].

2. The SHARON Anammox.

This process has two stages:

1) SHARON (Single reactor High activity Ammonia Removal Over Nitrite), or a single-stage reactor with highly active ammonia oxidation of nitrites;

2) ANAMMOX, or a reactor for the anaerobic oxidation of ammonium.

Due to the presence of two reactors, the task is to control the growth of solely ammonium-oxidizing bacteria in the Sharon-reactor and to suppress nitrite-oxidizing bacteria.

At the first stage, some ammonium is converted into nitrite in the presence of oxygen. The process does not need any biomass retention. This means that the activated sludge immediately

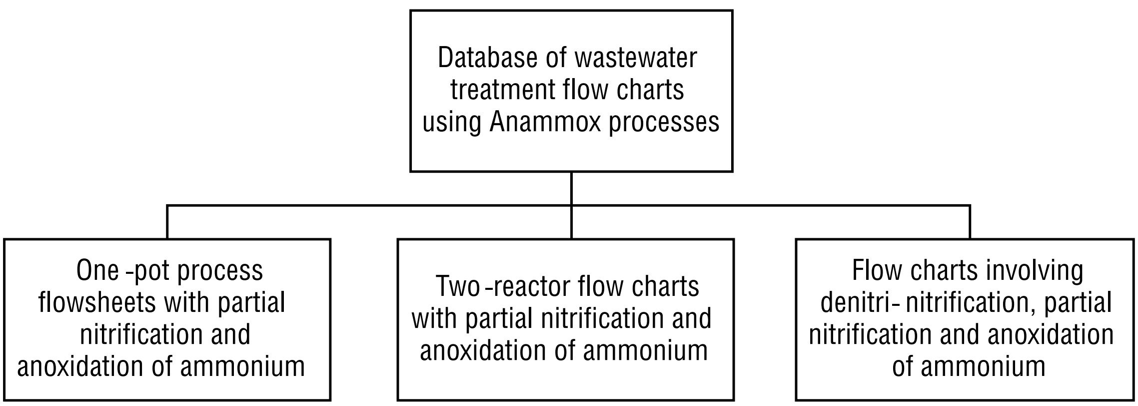

Fig. 2. Wastewater treatment flow charts involving Anammox processes [8]

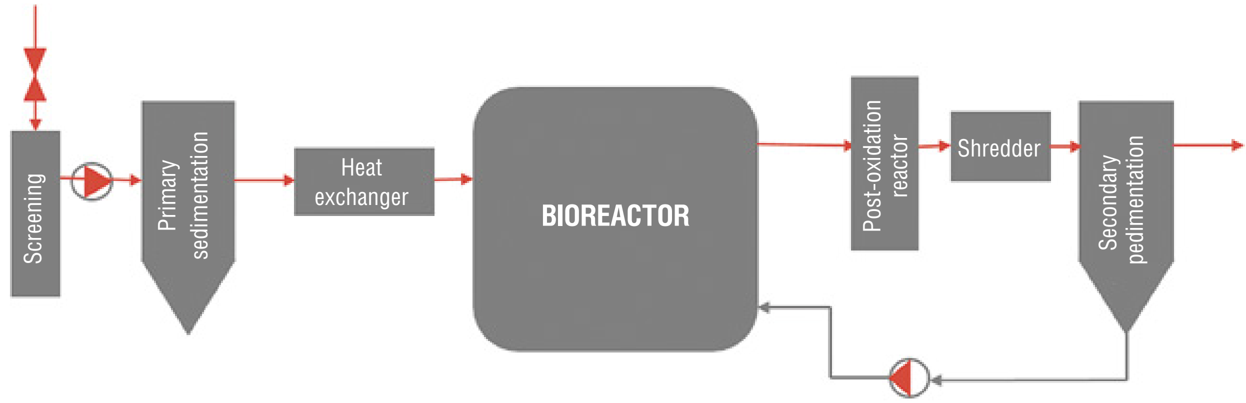

Fig. 3. The Mosvodokanal Anammox – process

contacts nitrogen and flows out of the reactor. In this case, the age of the sludge is about eight days.

At the second stage, the resulting mixture of nitrite and ammonium enters the anaerobic reactor, where it is converted into molecular nitrogen (Fig. 4) [12, 13].

3. The Demon Technology.

The Demon, also known as the Deammonification System, is implemented in the SBR reactor (Fig. 5). Batch processing is carried out by batch feeding of untreated waste water, controlling aeration and agitation, to simultaneously carry out the partial nitration

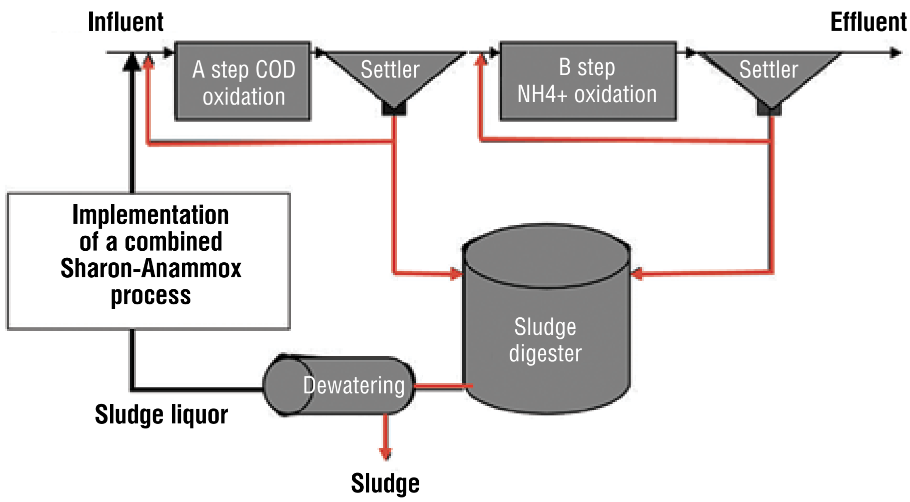

Fig. 4. SHARON-Anammox

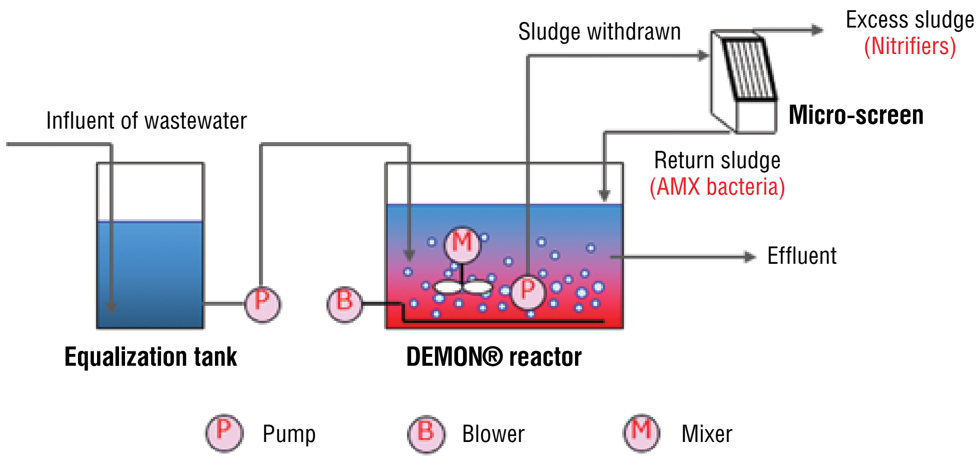

Fig. 5. The Demon Technology

and AMX reaction in the same reactor. The amount of sludge increases when bacteria perform the nitrogen treatment; however, the balance between the metabolism of nitrifying bacteria and AMX bacteria is maintained by selectively removing nitrifying bacteria from the reservoir using a microscreen. Sludge separation is required to retain slow-growing AMX bacteria in the system.

In the long term, this process ensures the process stability [14, 15].

4. The Deamox Technology.

This technology encompasses processes of partial denitrification and Anammox.

The process needs an anaerobic reactor due to the low content of the organic substrate. Further, the flow of wastewater is divided into two streams. The first one enters the nitrifier reactor, the mixing chamber, and the second one enters the mixing chamber.

The combined wastewater stream enters the anaerobic post-treatment reactor having Anammox cultures. The anaerobic reactor consists of SBR-reactors, designed to receive waste water, mix and remove purified water (without aeration).

In conditions of the insufficient amount of an organic substrate and the presence of a significant amount of ammonium nitrogen in the absence of oxygen, the process of partial denitrification leads to the reduction of nitrates to nitrites.

The mode of operation of the SBR-reactors assumes intensive granulation using the initial removal of unstable floccules of activated sludge. The bioreactor is saturated with the Anammox culture after the granulation of heterotrophic denitrifying activated sludge [16–18].

The process of formation of nitrite from nitrate occurs both under autotrophic and heterotrophic conditions, i.e. with the presence of auto-hetero-trophic bacteria, which complicate the process (Fig. 6).

CONCLUSION

The paper considers the influence of Anammox bacteria on the biological removal of biogenic elements, namely nitrogen compounds, as well as its general effect on the nitrogen cycle in nature. The strengths of this process are revealed. As a result, the main directions for the future development of this area have been identified.

1. Increasing the stability of the Anammox process.

Due to the incompleteness of research, not all Anammox bacteria-related factors are taken into account. Hence, the technology operation is unstable. This can disturb the ecological balance in the water bodies. Also, Anammox bacteria are sensitive to some environmental factors, such as temperature, pH, etc., which can also aggravate the instability of operation [18].

2. Treatment at low temperatures.

Currently, much attention is paid to the study of the behaviour of Anammox bacteria at low temperatures, because it is important to track this process in the countries with cold climates, including Russia. Several attempts have been made to design different circuits at low temperatures. These studies are currently being carried out at the Scientific and Educational Center for Water Supply and Sanitation. The system shows more stable performance at a temperature of about 15 °C. The research at lower temperatures continues [19, 20].

3. Purification of low nitrogen concentrations.

4. Treatment in membrane reactors.

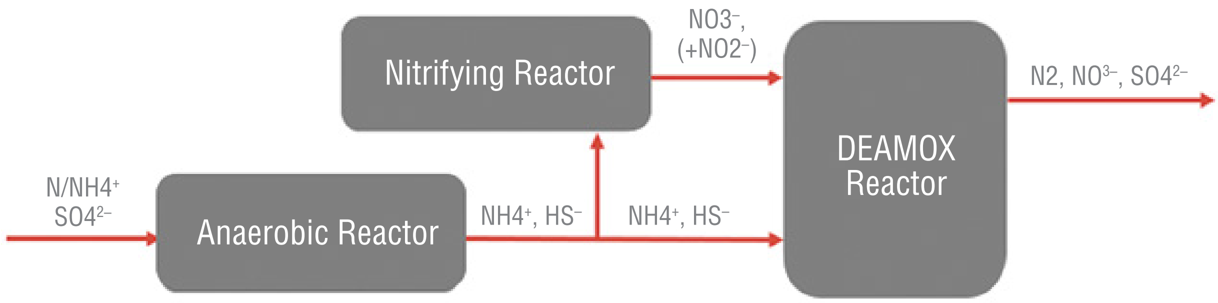

Fig. 6. The Deamox Technology

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Очистка сточных вод городов и населенных пунктов с применением бактериального сообщества Анаммокс

Открытие в конце XX века анаммокс-бактерий вызвало достаточно большой прогресс в разработке новых технологий очистки сточных вод. Процессы с участием данного вида бактерий могут протекать как на очистных сооружениях городов и поселков, так и на промышленных предприятиях в зависимости от степени загрязнения поступающих сточных вод. Данная статья посвящена сравнению различных технологий, которые сегодня предлагаются на рынке для различных целей. Сообщество микроорганизмов Anammox интересно перспективностью очистки сточных вод, насыщенных соединениями азота, но бедных органическими веществами, именно с такими сточными водами не справляются классические методы удаления биогенных элементов. Выявлено, что анаммокс-бактерии играют значительную роль в круговороте азота в природе, а также в процессе глубокой биологической очистки сточных вод от соединений азота. Рассмотрены различные технологические схемы анаммокс-процесса, которые различаются кислородными условиями, набором сооружений, а также рекомендуются для очистки сточных вод с разными концентрациями загрязнений в сточных водах на входе в очистные сооружения. В результате были выявлены перспективные направления развития в этой области. Показано, что качество очистки сточных вод, которое может быть получено использованием изученных бактерий, может соответствовать нормативным показателям.

Ключевые слова: *анаммокс-бактерии, анаммокс-процесс, денитрификация, нитрификация, МВК-Анаммокс, Шарон-Анаммокс, Демон, Деамокс*

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