Revista ARACÊ
ISSN: 2358-2472

SANITARY SEWAGE TREATMENT SYSTEM AND WATER REUSE FOR VEGETABLE PRODUCTION IN RURAL AND ISOLATED COMMUNITIES (REAQUA SYSTEM) AS AN ALTERNATIVE FOR IMPROVING RURAL SANITATION CONDITIONS, ADAPTING TO CLIMATE CHANGE AND MAINTAINING FOOD AND NUTRITIONAL SECURITY

https://doi.org/10.56238/arev6n4-415

Submitted on: 11/26/2024 **Publication date:** 12/26/2024

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ABSTRACT

The service to the Brazilian rural population through sewage treatment services is still precarious. Data provided in the National Rural Sanitation Program (PNSR, 2019) show that about 80% of the households present in these areas dispose of their sewage inadequately, in the form of septic tanks or directly in lakes, rivers and the sea. This reality affects about 40 million Brazilians. This situation generates risks to public health and harms environmental quality, especially the quality of surface and underground water bodies, as well as soils. It adds to the situation currently observed to that projected as a result of future scenarios resulting from global climate change. The sixth report of the Intergovernmental Panel on Climate Change (IPCC. 2023) points to an increase in the water deficit for most of the Brazilian territory, and it is necessary, as a strategy to adapt to this scenario, the development of technological assets aimed at improving water quality and making better use of this natural resource. As agriculture is the largest water-consuming economic activity in the country and heavily dependent on fertilizer imports, it is clear that systems that provide the reuse of treated effluents, as well as the nutrients present in them, gain strength and become a priority to deal with the expected risks, increasing the resilience and sustainability of production systems. For this reason, Embrapa, in partnership with IICA,

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developed the Sanitary Sewage Treatment and Water Reuse System for the production of vegetables in rural and isolated communities (ReAqua System), which aims to provide a low-cost alternative, easy installation and operation, low energy and labor dependence, and high efficiency in the removal of organic load and pathogens to serve rural and isolated communities. The ReAqua System consists of two stages, the first consisting of the Sewage Treatment Plant (ETE) and the second the agricultural system for the production of vegetables. The WWTP is assembled using tanks and water tanks, PVC or fiberglass pipes and connections, as well as materials used for civil construction. The sewage treatment system is based on joint Septic Tank – Anaerobic Filter, followed by sequential slow filtration with increasing difficulty and chlorine disinfection. The agricultural system stage of vegetable production is based on the use of gravity irrigation, reuse of nutrients by fertigation, use of soil cover by mulching The quality of the reused water, as well as the agricultural management used, allows the safe production of vegetables with less dependence on mineral fertilizers.

Keywords: Rural sanitation, Decentralized sanitary sewage treatment, Agricultural water reuse, Sustainable development goal 6 (SDG 6), Adaptation to the climate emergency, Environmental, Food and climate justice.

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INTRODUCTION

The sewage treatment rates observed in Brazil are worrying. Data compiled by the Instituto Trata Brasil show that, per day, an amount of sewage equivalent to 5336 Olympic swimming pools is dumped directly into nature (Trata Brasil, 2023a). Detailing the situation, 44.2% of the Brazilian population, about 100 million inhabitants, does not even have access to the collection network and only 51.2% of the sewage is treated at some level. Of the 100 largest Brazilian municipalities, a very small number, 34, have a percentage of the population served by sewage collection services higher than 90%. With regard to sewage treatment, only 18 municipalities of the 100 largest have a percentage of treated sewage above 80%. The North and Northeast regions have the worst numbers for sewage collection (14% and 30.2%, respectively) and sewage treatment (20.6% and 35.5%, respectively), while the Southeast and Midwest regions have the best numbers (81.7% and 61.9% for sewage collection; 58.6% and 60.5% for sewage treatment) (Trata Brasil, 2023b).

Data from the National Rural Sanitation Program (PNSR, 2019) indicate that the numbers referring to the inadequate disposal and treatment of sanitary sewage evolved little between 1991 and 2010 in rural areas. The data available in the PNSR (2019) show that, in 2010, there were 64% of households that disposed of their sanitary sewage in rudimentary tanks, 16% in ditches, lakes and sea, 16% in septic tanks and 4% in the global network. Despite this, there was a large increase in the number of rural households with access to toilets, generating more effluent to be treated. The breakdown of the data also shows that 20.6% of the inhabitants of rural areas have adequate access to sanitary sewage treatment services, 54.1% of the inhabitants have precarious access and 25.3% do not have any type of service. This reality is experienced daily by about 40 million Brazilians (PNSR, 2019). Much of this reality reflects the lower purchasing power and social exclusion that the population living in rural areas in Brazil experiences.

Of these, about 16 million inhabitants live in rural agglomerations (PNSR, 2019). Despite this significant population, most of the technological solutions proposed for the treatment of sewage destined for rural areas have been for individual care at the agricultural property level. It is possible that individual treatment solutions present higher implementation costs given their scale of production/application. Therefore, it is necessary to develop decentralized collective sewage treatment systems as a strategy to improve rural sanitation conditions in Brazil.

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Several systems have been proposed to serve rural areas, such as the use of septic tank sets and anaerobic filters (Vianna et al., 2018), evapotranspiration tanks – TEVAP (Costa et al., 2019; Reis et al., 2023), the SARA System (Mayer et al., 2021) and the Biodigester Septic Tank – FSB (Embrapa, 2001). The treatment efficiencies of these decentralized systems, however, have been shown to be very variable and the concentrations of nutrients and pathogenic microorganisms have been shown, in most cases, to be high in the final effluent when the objective is the reuse for agricultural crops of crops of plant species that are consumed raw, as is the case of some vegetables. Some of these technologies have met the standards proposed by the World Health Organization (WHO, 2006) for unrestricted agricultural reuse. It should be noted that the quality parameters defined by the WHO take into account both the health of the consumer and the worker and, over time, studies conducted in a tropical environment have attested to the safety of the limits established by it. However, there is currently a convergence, especially in developed countries, of the use of water quality parameters that are more restrictive than those proposed by the WHO. Some of these parameters, such as the concentrations of thermotolerant coliforms and/or Escherichia coli, reach the order of magnitude 100 to 1000 times lower.

In Brazil, although there are no national standards for the quality of reused water, in some states they have already been defined, and there are resolutions whose water quality parameters are similar to the more restrictive resolutions previously mentioned, such as COEMA resolution 02/2017, from the state of Ceará. On the other hand, examples of less restrictive resolutions in terms of requiring the quality of reused water, following a line closer to WHO standards (WHO, 2006), are also observed, and those are predominant, as is the case of CERH – MG Resolution number 65 of 2020 (Minas Gerais), Resolution number 419 of 2020 of the Secretariat of Environment and Infrastructure (Rio Grande do Sul) and CONERH Resolution number 75 of 2010 (Bahia).

Some current international resolutions establish the quality limits of reused water based not only on the quality standards obtained by sanitary sewage treatment systems, but also on the basis of the agricultural production system used, considering, mainly, whether or not the plant will be destined for food, the way in which the food will be consumed (raw or after processing) and the existence or not of contact of the reused water with the parts edible plants. Thus, for those crops consumed raw and that have direct contact with reused water, such as those irrigated by sprinkler, higher water quality is required, while for these same crops, when irrigated by drip, there is a lower quality requirement. An example of this type of resolution is the European Parliament's Regulation 741 of 2020. This regulation also defines the sanitary sewage treatment processes necessary for reuse water to be used for unrestricted agricultural reuse, requiring secondary treatment + filtration + disinfection.

It is important, therefore, that new alternatives to serve these communities take into account the need to improve these water quality attributes, especially when considering the importance that currently exists in inserting sanitation devices to the principles of bioeconomy and circular economy, expanding the range of benefits generated. Especially important for socially vulnerable communities is the use of sewage treatment products, by-products and co-products for safe food production as a strategy to reduce food and nutrition insecurity, as well as commonly observed poverty.

There is a clear relationship between low levels of sewage treatment and the occurrence of infectious diseases, especially those transmitted by water, resulting in damage to public health. It is estimated that annually, worldwide, diseases directly linked to low sanitation rates kill 564 thousand people through diarrheal diseases, mainly affecting the most socially vulnerable population (WHO, 2024). This situation can result not only in a higher prevalence of preventable diseases through adequate sanitation systems, but also in an increase in the costs associated with maintaining health systems (Salla et al., 2019). These authors, evaluating the use of potential strategies to improve basic sanitation (water supply, sewage collection and treatment, solid waste management, and drainage water management) in Guinea-Bissau, found that, for every dollar invested in basic sanitation, there is a saving of 4.3 dollars in public health expenditures, making clear the positive economic relationship resulting from investments in this sector. According to Lixil (2016), the global costs of the gaps in sanitation services that still exist reached 222.9 billion dollars in 2015, considering aspects such as mortality, spending on health systems, and losses in economic productivity. In Brazil, sanitation is understood as one of the bases of public health strategies, currently also called single health, comprising the provision of drinking water services and infrastructure, collection and treatment of wastewater, as well as drainage and solid waste management.

Another relevant aspect related to the lack of adequate treatment of sanitary sewage is linked to its potential negative environmental impacts. Diep et al. (2020) consider that the improper disposal of human waste in the environment represents an important ecological concern that affects terrestrial and marine environments, as well as being capable of causing damage to biodiversity in the long term. Pieroni et al. (2015) lists the discharge of untreated effluents among human activities capable of causing greater degradation to water resources. Katz et al. (2010), evaluating the effects of the final disposal of sanitary sewage in septic tanks in a karst area in the state of Florida, United States, found a significant increase in nitrogenous forms in leachate and groundwater, reaching the conclusion that the use of the final disposal of sanitary sewage in about 20 thousand septic tanks results, annually, in the increase of 78 to 240 thousand Kg of N in soils, leachate and groundwater. In addition to other contaminants commonly related to the final disposal of sanitary sewage, such as phosphorus, sulfur and calcium, for example, eutrophication processes of underground and surface water bodies can be favored, leading, as a consequence, to a greater risk to public health and high costs for remediation.

The sixth IPCC report (IPCC, 2023) also points to the increased probability of water deficit in much of the Brazilian territory as a result of climate change such as changes in rainfall regimes, the increase in the occurrence of extreme rainfall events, and the greater frequency and intensity of drought events, in addition to the increase in the frequency and intensity of heat waves and the higher average air temperature. It is worth mentioning that the National Water Resources Policy (PNRH) (Law 9433/1997) defines as activities of priority use of water resources the human supply and the watering of animals, leaving agriculture, in case of occurrence of water crises, unguarded. Therefore, it is important to search for alternative sources of water, such as those for reuse, as a strategy for adapting to climate change. Aware of this reality, the federal government, in the recently enacted Law 14935/2024, which institutes the National Policy on Urban and Peri-urban Agriculture, in its Article 2, item VII, includes the dissemination of recycling and the use of organic waste, wastewater and rainwater as one of its objectives. Also, given the scenario of environmental degradation and the need to reduce the carbon footprint of production systems, it is desirable to seek the reuse of waste as a way to reduce the need to use external inputs, such as mineral fertilizers. The use of reused water from the ReAqua System has good potential for fertigation with concentrations of nitrogen, phosphorus, calcium, sulfur, magnesium and heavy metals, as well as the values of pH, electrical conductivity and pathogenic microorganisms suitable for agricultural production. It should also be noted that Brazilian agriculture is highly dependent on fertilizer imports. In 2023, about 86% of the total traded were imported (ANDA, 2024). Water reuse also provides nutrients and can be part of

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a set of strategies that aim to reduce external dependence on these products, increasing the resilience and sustainability of production systems.

The objective of this publication is to present the ReAqua System, its main characteristics and its potential use to serve rural and isolated communities and for unrestricted agricultural reuse for irrigation.

DESCRIPTION OF THE PROPOSED SYSTEM

The ReAqua System consists of two stages, the first being the sewage treatment process (ETE) (Figures 1 and 2) and the second the agricultural vegetable production system (Figure 2) that uses the final effluent of the system (reuse water) for agricultural irrigation. The slope maintained between each reservoir used for the assembly of the WWTP shall be a maximum of 0.5%. The steps of the system are described below.

Figure 1 – Representative scheme of the sewage treatment stage of the ReAqua System.

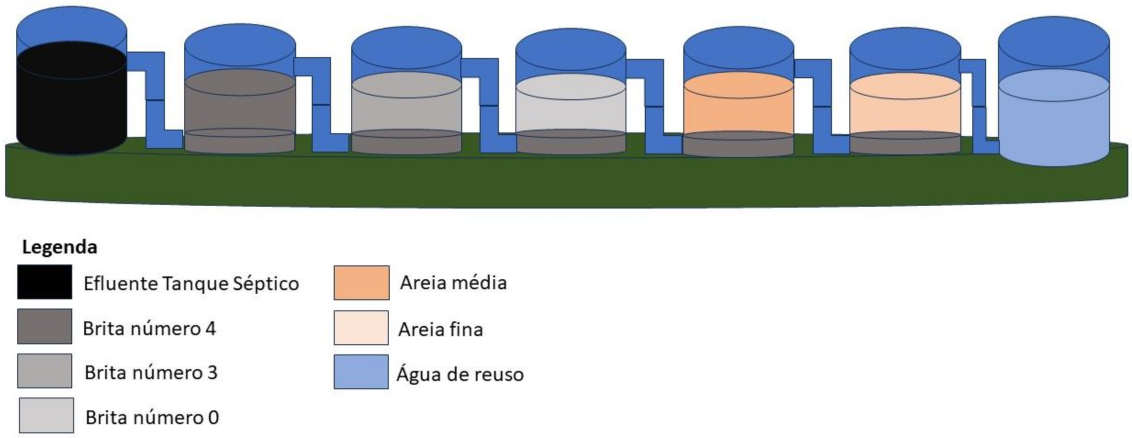

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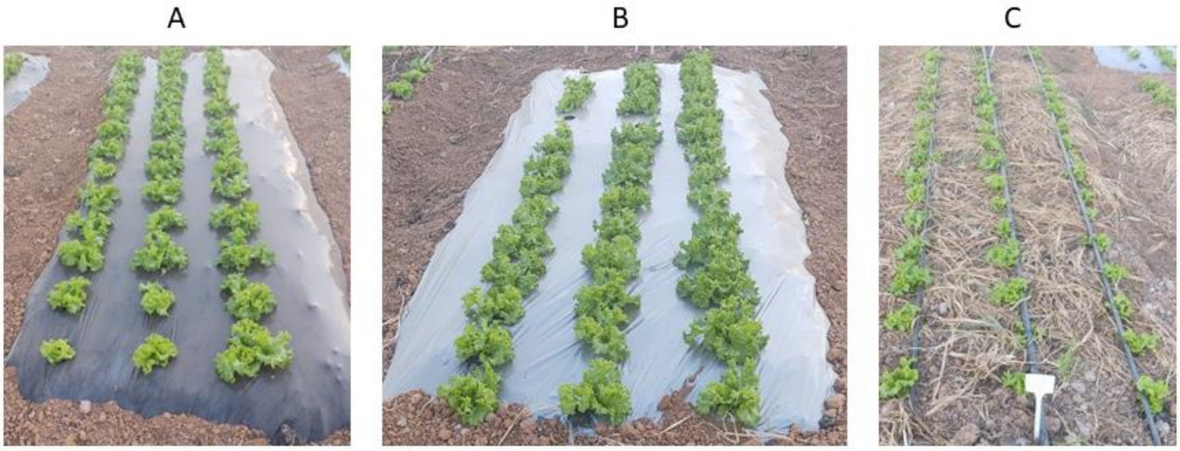
Figure 2 – Prototype of the ReAqua System to serve about 300 people operating under operational conditions (TRL/MRL 6) at Embrapa Hortaliças, Brasília – DF (Sewage treatment stage).

Figure 3 – Prototype of the ReAqua System to serve about 300 people operating under operational conditions (TRL/MRL 6) at Embrapa Hortaliças, Brasília – DF (Agricultural reuse stage).



STAGE 1 - REAQUA SYSTEM WTP, COMPOSED OF THE FOLLOWING PHASES:

Phase 1 – Preliminary treatment consisting of grease trap, grating and desander.

Phase 2 - Secondary treatment consisting of Septic Tank + Anaerobic Filter set with volumes sized according to NBR 7229 and NBR 13969 standards, recently updated by NBR 17076/2024. This set is assembled in a sequence of Polyethylene or Fiberglass Tank and Water Tank for water storage, available in the civil construction market. It is important that such reservoirs have protection against UV radiation in order to increase their useful life. The hydraulic flow used is always upward, with the inflow of the influent at each stage

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at the base of the tank or box and the effluent outlet at the top of the reservoirs. Corrugated conduits (conduits), 3/4 in diameter, are also added to the tank, duly cut in order to obtain units with about 4 cm to 5 cm in length. The addition of the conduits has the function of acting as a support medium for the growth of microbial biomass, increasing the specific area available for degradation of the organic load. At the top of the box, six PVC pipe bars with a diameter of 25 mm and a length of 50 cm are added to serve as a "sigh" for the elimination of gases produced during the anaerobic degradation of the organic matter present in the sanitary sewage. Such gases can also be used for energy purposes, such as the generation of gas used for cooking food. The upper openings of these "sighs" are closed with mosquito nets and shade screens to prevent the entry of flies and mosquitoes, reducing the chance of spreading diseases such as dengue. At the bottom of the tank, as well as all water tanks, 50 mm or 100 mm diameter registers are installed to facilitate the removal of the sludge, as well as the cleaning of the filters. The support medium used in anaerobic filters is crushed stone number 4, distributed internally over the entire diameter and height between 0.80 m and 1.20 m, making up a maximum of 2/3 of the volume of the water tank used to serve as such a unitary process. The reservoir that functions as a septic tank must receive, at the beginning of the operation, inoculation through the addition of sludge from septic tanks in operation and, after ten days, about 1% in relation to the volume of the reservoir of efficient microorganisms (EM) or bioinputs that contain them, such as, for example, the one called Hortbio (Fontenelle et al., 2018).

Phase 3 – Stage that was called multiple filtration with increasing difficulty, composed of the following sequence: gravel filter 3 + gravel filter 0 + medium sand filter + fine sand filter. The filling of the polyethylene water tanks that will be used as filters is as follows, in the direction of the base to the top: crushed stone layer number 4 with 40 cm thickness, two layers of Bidim-type geotextile blanket and 0.80 cm to 1.20 m from the filter bed used for that stage of the treatment process (gravel 3, gravel 0, medium sand or fine sand, respectively). The maximum surface application rate used is 12 m-3.m-2.d-1. The filter bed, including the crushed stone bottom number 4, should not occupy more than 2/3 of the total volume of the reservoir. The cleaning of the filters is always done in the opposite direction of the effluent flow, that is, downward. To this end, after opening the water tank in which the filtering medium was installed, a high-pressure washer covering the entire upper surface area or the hydrojetting process is used. The effluent resulting from the cleaning process must be sent to sinks or drying beds.

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Phase 4 – This stage consists of chlorine disinfection. Chlorinators commonly used to disinfect water for supply extracted from artesian wells installed in the water flow line (in the pipe) after the sand filter can be used for this purpose. Another possibility of simple application is the use of floating chlorinators normally used for disinfection of swimming pools, installed in the reuse water reservoir. It is recommended to use the following active ingredients, already tested, having shown good performance both for disinfection and for agricultural reuse for irrigation of vegetables: Trichloro-s-triazine-trione (usual name – Trichloroisocyanuric acid) and sodium dichloro-s-triazinatriona (usual name – Sodium dichloroisocyanurate), both recommended by the ABNT NBR 15784/2017 standard for use in water treatment for human consumption. The tablet should be changed whenever it shows significant wear or when the results of microbiological analyses indicate so. However, *on-site evaluation is recommended* in order to maintain a minimum free chlorine content in the reuse water of at least 1 mg/L.

STEP 2 - AGRICULTURAL REUSE FOR VEGETABLE PRODUCTION

The agricultural reuse of the final effluent from the treatment should, preferably, be conducted following a set of good agricultural practices. This set aims to allow the reuse of the final effluent from the ReAqua System to be carried out safely, maintaining microbiological contamination rates within legal limits, as well as providing good productivity. It is worth mentioning that the model plant used to determine such sets of good agricultural practices was lettuce (Lactuca sativa L.) in three production cycles, the first conducted with curly lettuce, the second with smooth lettuce and the third with purple curly lettuce. Additionally, the recommendations were also based on the results obtained by Pilon et al. (2019). Figure 4 shows lettuces in the final production cycle using irrigation with reclaimed water.

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Figure 4 – Visual aspect of curly lettuce irrigated with reused water used for irrigation (Agricultural phase of the ReAqua System).

Below is the set of suggested good practices:

1. Application of reused water should preferably be carried out through the use of localized drip irrigation or other system that prevents contact with the edible part of the plant;
2. It is recommended to use ground cover through the use of plastic mulching (mulching) or straw from plant residues (or vegetable mulching);
3. When using drip irrigation, the hose should be installed under the plastic cover of the straw;
4. Sowing or transplanting seedlings in periods of extreme weather (extreme heat or cold) should be avoided;
5. The use of reused water for irrigation should be avoided when the Electrical Conductivity (EC) is greater than 3 dS/m;
6. The feasibility of use should also be evaluated when the Na contents and Na saturation are very high. This information is especially relevant for areas that have significant water deficit and where soils are already experiencing a natural or anthropogenic process of salinization, such as in the Brazilian semi-arid region. To this end, it is suggested to consult the defined values for irrigation water proposed by Ayers & Westcot (1987);

7. Attention should be paid to the phytotechnical recommendations for the cultivation of the plant species that is being used. Additionally, the reuse of water for irrigation must be adopted without prejudice to the use of other practices and processes of soil and water management and conservation recommended for each situation;
8. Plant fertilization, as well as soil correction, should be carried out following the recommendations for fertilization described for the location where the production system will be installed. The quantities of fertilizers and correctives used should also be defined considering the concentrations already existing in the irrigation water, as a way to reduce negative environmental impacts. In the pilot developed, the highest concentrations in reuse water were found for N, P, S and Ca. However, the characteristics of the reuse water depend on the characteristics of the sanitary sewage affluent to the treatment system and, therefore, for each case, it must be monitored frequently, depending on the legal requirements. If there are no legal instruments that regulate the frequency of analyses, it is suggested that they be carried out at least once a month. Portable equipment can be used so that monitoring is carried out more easily.
9. For the design of the ReAqua System, those defined by Regulation (EU) 2020/741 of the European Parliament and of the Council of May 25, 2020 for unrestricted agricultural reuse were used as water quality objectives to be achieved, which are more restrictive than those defined by the World Health Organization (WHO, 2006), used as a reference for most sewage treatment and reuse systems currently available in Brazil, in order to increase the microbiological safety of the food produced and that, perhaps, is consumed raw;
10. In the event of regulations at the level of the federation or municipality, the parameters of water quality for agricultural reuse defined therein must be followed.

SYSTEM EFFICIENCY AND NUTRIENT LEVELS IN REUSED WATER

The ReAqua System was developed based on the minimum recommendations of the European Parliament Regulation number 724 of 2020. In tests conducted during 42 months of operation using a prototype operating on a full scale, it presented effluent with compatible quality for use of the final effluent in unrestricted agricultural reuse. The main results are presented below.

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Figure 5 shows the visual aspect of the sanitary sewage affluent to the sewage treatment stage of the prototype installed at Embrapa Vegetables. Figure 6, in turn, presents the visual aspects of effluent samples in the Septic Tank and after complete treatment (final effluent or reused water).

Figure 5 – Visual aspect of the sanitary sewage affluent to the sewage treatment stage of the prototype installed at Embrapa Vegetables.

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Figure 6 – Image of the effluent sample collected in the Septic Tank (right) and the reuse water (left) produced by the ReAqua System.

Table 1 describes the main results (average values) related to the removal of organic load measured in the affluent sanitary sewage and in the reuse water of the sewage treatment phase of the prototype of the ReAqua System installed at Embrapa Vegetables (Brasília – DF). Table 2 shows the values of total coliforms and E. coli determined in the different stages of treatment. Finally, Table 3 shows the mean values of these same indicator microorganisms determined in 10 sequential weeks.

Table 1 – Characterization of the sanitary sewage affluent to the sewage treatment phase and in the reuse water (final effluent) of the sewage treatment phase of a prototype of the ReAqua System installed at Embrapa Hortaliças, Brasília - DF. Mean values after three years of monitoring.

	ph	OD	Colour	Turbidity	BOD5.20	EC
		mg/L	µH	UNT	mg/L	dS/m
Sanitary sewer	7,74	2,8	708,5	177	540	1,15
Reused water	7,37	5,6	22	<7^	2,5	1,02

pH – Hydrogen Potential; DO – Dissolved Oxygen; BOD5.20 – Biochemical Oxygen Demand; CE – Electrical Conductivity. ^Equipment Detection Limit.

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Table 2 – Concentration of Total Coliforms and E. Coli determined in different stages of treatment determined in effluent samples from the sanitary sewage treatment phase of a prototype of the ReAqua System installed at Embrapa Hortaliças, Brasília – DF.

	TS	AGO	FB3	FB0	FAM	FAF	CLO	EF
	UFC/100 mL							%
CT	7,7 x 104	1,1 x 103	38	21	2	1	0	100
E. Coli	3,0 x 103	1,0 x 103	34	22	2	0	0	100

TC – Total Coliforms; E. Coli – Escherichia Coli; TS – Septic Tank; FA – Anaerobic Filter; FB3 – Gravel Filter 3; FB0 – Gravel Filter 0; FAM – Medium Sand Filter; FAF – Fine Sand Filter; CLO – After chlorination; EF – Efficiency.

Table 3 – Monitoring of Total Coliform and E. Coli concentrations for ten consecutive weeks maintained in samples of reuse water (final effluent) from the sanitary sewage treatment phase of a prototype of the ReAqua System installed at Embrapa Hortaliças, Brasília – DF.

	1	2	3	4	5	6	7	8	9	10
	UFC/100 mL									
CT	3	4	15	15*	8	8	0	0	0	0
E. Coli.	0	0	0	0	0	0	0	0	0	0

*Sand filters cleaned.

The high efficiency of removing organic load and microbiological contaminants is clear from the results previously described. The values of BOD5.20, and E. Coli meet the limits established by Resolution 724 of 2020 of the European Parliament (≤ 10 mg/L and ≤ 10 CFU/100 mL, respectively) for unrestricted agricultural reuse. The same resolution sets the standard of ≤ 5 UNT for this type of reuse. Although the values determined in samples of reuse water from the sewage treatment phase of the ReAqua System prototype are described as <7 UNT, which is the detection limit of the available equipment, it is probable, due to the visual characteristics of the samples used and the other analytical results determined, that these values are within the limits established by the aforementioned resolution (≤ 5 UNT).

Table 4 shows the average concentrations of some trace elements in the reuse water from the sanitary sewage treatment stage of the ReAqua System. Such results, together with those obtained by the microbiological analyses and by the other chemical and physicochemical analyses previously shown, point to the existence of a good safety margin of the practice of water reuse in the ReAqua System for unrestricted agricultural irrigation.

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Table 4 – Average concentrations of trace elements determined in the reuse water of a prototype of the ReAqua System installed at Embrapa Hortaliças, Brasília - DF. Mean values after three years of monitoring.

	To the (mg/L)	With (mg/L)	Cr (mg/L)	Fe (mg/L)
Average	0,061	0	0,009	0,052
Median	0,027	0	0,009	0,072
DP	0,06	0	0,010	0
IC	0,009	0	0,003	0,023
LS	0,052	0	0,012	0,029
READ	0,069	0	0,006	0,075

Legend: DP – Standard Deviation; CI – Confidence Interval; LS – Upper Limit; LI – Lower Limit

Table 5 shows the mean values of the concentrations of nitrogen, phosphate, sulfate and calcium forms. The values obtained correspond to an annual availability of the quantities shown in Table 6.

Table 5 - Mean values, median, standard deviation, confidence interval and upper and lower limits of Electrical Conductivity (EC); N-NH3; N-NO2; N-NO3; SO4-2; PO4-3 and Ca2+ determined in reuse water samples from a prototype of the ReAqua System installed at Embrapa Hortaliças, Brasília – DF. Mean values after three years of monitoring.

	THAT	N-NH3*	N-NO2*	N-NO3*	$SO4^{-2}$	PO4-3	Ca+2
	µS/cm	mg/L					
Average	1017,84	25,38	26,78	136,36	25,90	14,43	86,53
Median	1037,92	20,6	22,00	136,90	25,00	14,80	86,00
DP	250,75	15,69	26,81	62,80	4,96	4,47	8,07
IC	88,72	5,35	9,15	21,76	1,75	1,63	2,84
LS	1106,11	30,73	35,96	158,12	27,65	16,06	89,37
READ	929,57	20,02	17,63	114,60	24,16	12,81	83,69

Legend: DP – Standard Deviation; CI – Confidence Interval; LS – Upper Limit; LI – Lower Limit; N-NH3 – Ammonia Nitrogen; N-NO2 – Nitrite Nitrogen; N-NO3 -Nitrogen Nitrate; SO4-2 – Sulfate; PO4-3 – Phosphate; Ca2+ - Calcium; CE – Electrical Conductivity.
*The use of nitrogenous active ingredients for the disinfection of the final effluent may have influenced the higher concentrations of nitrogenous forms compared to those values normally observed in the literature.

Table 6 - Annual load of N-NH3; N-NO2; N-NO3; SO4-2; PO4-3 and Ca2+ determined in the reuse water of the ReAqua System operating under real conditions at Embrapa Hortaliças, Brasília, DF, Brazil. Mean values after three years of monitoring.

	Annual Charge
	kg/year
N-NH3	185,26
N-NO2	195,47
N-NO3	995,44
$SO4^{-2}$	189,09
PO4-3	105,36
Ca+2	631,69

It is clear, therefore, that in addition to the safe use as an alternative source of water for irrigation, the reuse of water provided by the ReAqua System is also a relevant source of nutrients for agriculture. It is, therefore, an important strategy to reduce external

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dependence on fertilizers and fits into the principles of the bioeconomy and the circular economy.

FINAL CONSIDERATIONS

The results demonstrated were achieved at the prototyping level, during the conduction of experiments carried out at Embrapa Vegetables, Brasília – DF. The first pilot of the ReAqua System that will operate on a full scale is being implemented by the Secretariat of Agrarian Development of Ceará, in partnership with Embrapa Vegetables and the Inter-American Institute for Cooperation on Agriculture (IICA) in an agrarian reform settlement in the municipality of Monsenhor Tabosa – CE. The unit will serve 110 families, treating the sanitary sewage generated and making reuse water available for agricultural activities. From this unit, it will be possible to advance in the maturity level of the technological asset to TRL/MRL scale 7 and 8, increasing the reliability of the results obtained and configuring system operation strategies. In addition, it will ensure a better quality of life, bringing sewage treatment and generating reused water for the population previously not served by these services, resulting in better public health and food and nutritional security.

Revista ARACÊ
ISSN: 2358-2472

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