

THERMAL WATER TREATMENT
SUSTAINABLE SOLUTIONS VIABLE FOR THE FUTURE







INNOVATIVE THERMAL PROCESSES FOR INDUSTRIAL WATER TREATMENT AND FOR THE PRODUCTION OF DRINKING WATER

Thermal water treatment processes are today widely used in various branches of industry. Besides simple heating these processes include, for example, distillation, sterilization and rectification (thermal material separation). The advantage of these methods is that the technologies are often relatively simple and robust designed. Thermal energy supply can generally be achieved without great technical efforts by means of direct firing, process vapor or electric heating.

On the other hand, thermal treatment methods are mostly energy-intensive. New technical solutions are necessary to ensure a responsible use of energy resources and to offset the increasing cost pressure.

Solutions viable for the future are required

Thermal methods offer many possibilities for use in the context of the secondary utilization of energy by means of waste heat and the application of thermal solar technology. The Fraunhofer Institute for Interfacial Engineering and Bio-

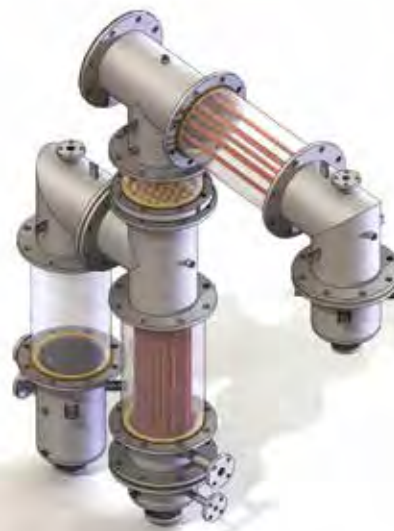
technology IGB has set itself the objective – by developing innovative concepts as well as optimizing and combining various methods – to realize efficient and inexpensive thermal treatment methods in order to be able to use these sources of energy. Solar seawater desalination, producing water from air humidity and the concentration of industrial wastewater are examples of applications that are being worked on at the Fraunhofer IGB.

Thermal treatment methods are especially well suited for decentralized solutions and those independent of the infrastructure, as they can have a simple set-up and locally accruing thermal solar energy and/or waste heat become available.

The solution of customer-specific problems demands flexible and optimized, adaptable concepts. As a result of the interdisciplinary composition of our expertise and the independence from specific technology solutions, we can carry out these tasks objectively and in a customer-oriented way.



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EFFICIENT SOLAR SEAWATER DESALINATION BY MEANS OF GRAVITY-ASSISTED VACUUM EVAPORATION

Motivation

In many regions of the earth, intensive utilization of drinking water and climate change are resulting in a shortage of natural drinking water resources. The precipitation quantities in many areas are declining, at the same time the demand for water is increasing. In coastal areas such as in Southern Europe and on many islands in the Mediterranean, the groundwater has already become salty as a result of the infiltration of seawater. Some islands and even cities on the coast such as Barcelona already have to be supplied at times by tankers with drinking water. The increasing pressure caused by population development and the tourist industry, especially in coastal regions, means that this situation will deteriorate even further in the coming years. Thus producing drinking water from renewable freshwater sources will become more and more a matter of urgency, but also more and more difficult.

Desalination technologies and CO₂ emissions

In many areas the supply of drinking water can often only be guaranteed by the desalination of sea or brackish water. Current technologies for water desalination such as reverse osmosis and conventional thermal methods are energy-intensive and consume large quantities of fossil fuels. This not only pushes up the operating costs because of the increasing prices for fossil fuels, but also results in considerable CO₂ emissions. The use of renewable energy sources for seawater desalination makes an important contribution to a sustainable supply. As these energies are generally scattered over an area and are not concentrated locally, they are especially suitable for decentralized plants. The Fraunhofer IGB, together with European partners from industry and research, is working on such sustainable and inexpensive process concepts for water desalination in long-term research and development activities.

Mode of operation

Basis is a multistage vacuum evaporation process that permits the efficient use of heat at low temperatures. As a result of the vacuum it becomes possible to recover the energy internally by means of several pressure stages in the plant. The energy is used multiple times, thus reducing the specific amount of energy needed significantly. Additionally, the boiling temperature in the vacuum is considerably lower, so that simple solar thermal collectors or waste heat from approximately 60 °C can be used for the energy supply. Although this is a vacuum process, no vacuum or jet pumps are required. The vacuum is generated and maintained by means of an innovative solution making use of gravity. Only two simple water pumps are required in the entire plant. The process is controlled to a large extent using hydraulic and/or mechanical principles and components, so that the need for electric metrology and process control components is reduced to a minimum.

Independence from fossil fuels and the mains supply network is achieved by the use of simple solar thermal collectors to provide thermal energy and the limited need for photovoltaic collector surfaces for the electric components of the process control. Thus it becomes possible to produce desalinated water in a simple and decentralized way.

Areas of application

Basically, the technology is suitable for small to medium-sized plants for decentralized, sustainable drinking water treatment (100 liters/day to approximately 10 m³/day).

Examples are:

- Small-scale consumers (individual households)
- Hotels and holiday complexes
- Small housing developments with their own water supply
- Small or medium-sized industrial firms (production and/or treatment of demineralized water or process water)

1 *Test-rig for solar seawater desalination.*

2 *CAD drawing of laboratory plant.*



PRODUCING DRINKING WATER FROM AIR HUMIDITY – A SUSTAINABLE OPTION FOR THE SUPPLY OF DRY REGIONS

In regions with a dry (arid) or mainly dry (semi-arid) climate the production of drinking water is an existential problem. On average, more water evaporates here than is compensated as a result of precipitation. The ground is therefore dried out and the generally salty groundwater is often only found at great depths. Additionally, in many cases the groundwater level is steadily dropping or so-called fossil, non-renewable aquifers are used. A sustainable production of drinking water from groundwater that can also be used for future generations is thus not possible. The use of surface waters is also difficult in these regions, especially at a great distance from the sea.

Producing water from the air

Even though there is a shortage of surface or groundwater in arid regions, in often considerable quantities of water are to be found in the air (see example in the box). Moreover, as a result of global warming it is to be expected that the water content of the atmosphere will increase further because of the rising temperatures.

Example

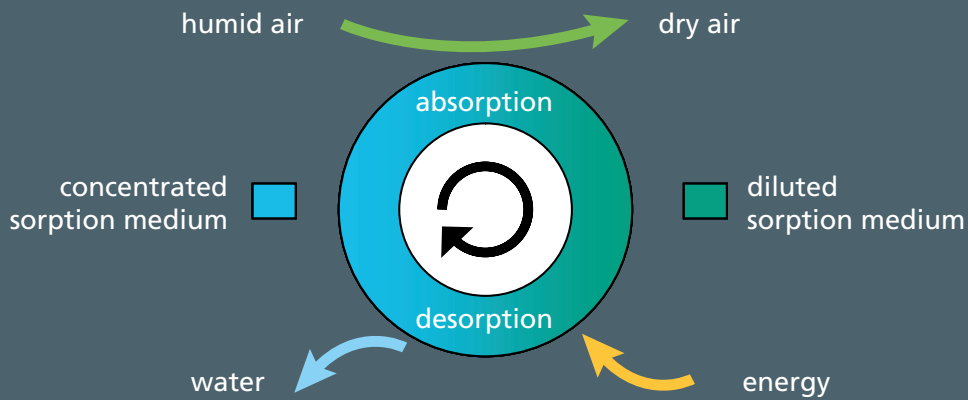
Beer Sheva, Negev Desert, Israel

The annual mean for relative air humidity is 64 % at 19.5 °C. This corresponds to 11.5 ml water/m³ air.

So that this water resource can be developed as a source of drinking water, the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB is working in cooperation with the Institute for Interfacial Engineering IGVT of the University of Stuttgart as well as further, medium-sized industrial partners on a new process concept. The entire process consists of two parts (Fig. 3). First, the humidity from the air is absorbed by a highly concentrated saline solution (brine) and thus bound. Then this diluted saline solution is distilled and the water separated from the saline solution is condensed as drinking water (desorption).

1 *Desiccated soil.*

2 *Schematic drawing of process principles.*



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THE SUB-PROCESSES

Absorption of air humidity

In order to make the absorption of the air humidity in the saline solution as efficient as possible, a large interface with the air and a long contact time are necessary. This is done by allowing the saline solution to flow slowly down sorption strings in tower-shaped, naturally ventilated plant modules and to absorb the water from the air. By means of a special design of the sorption strings an efficient mass transfer is achieved and the saline solution is diluted by the substantial absorption of water.

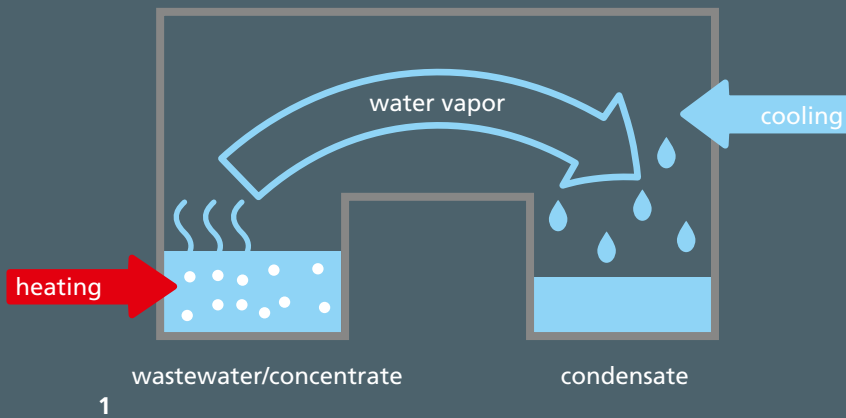
Desorption: distillation and condensation

The water has to be separated from the circulating saline solution (desorbed), and so a distillation process follows. The distillation is effected by means of gravity-assisted, multiple-stage vacuum evaporation. To do this, the saline solution, diluted with water, is subjected to a vacuum, which considerably reduces the evaporation temperatures. The advantage of this is that these temperatures can be achieved with simple solar thermal collectors or also with waste heat. Since the plant works with a negative pressure, it is also possible to use the thermal energy employed several times in various evaporation stages with different pressures. The water vapor produced in the distillation is condensed and can be used as high-quality drinking water.

A combined tower-construction for the sorption and desorption makes it possible to use the gravity of the process flows to create the required vacuum. Energy-intensive vacuum pumps are no longer needed.

Decentralized and sustainable

The method described enables a sustainable production of drinking water from air humidity in decentralized and independent facilities. This is especially important in the arid or semi-arid regions where the building density is loose and the infrastructure poorly developed. The various system components display very good synergies. Both the gravity-assisted vacuum evaporation and the absorption are designed for energy efficiency and the careful use of resources. The energy supply can be effected purely by renewable energy sources. In such cases, the electric components such as pumps and process control are supplied by photovoltaics or by wind power. The thermal energy required is provided by solar thermal collectors. The plant does not produce any wastewater or salt concentrate that has to be disposed of, as in the case of the desalination of sea or brackish water. There is 100 % circulation of the sorption medium. As a result of the combination with a renewable energy supply, the technology is CO₂ neutral and does not cause any emissions. The technology is robust, without any demanding requirements as regards operation and maintenance; it can be used universally and is completely self-supporting.



VACUUM EVAPORATION FOR THE CONCENTRATION OF AQUEOUS SOLUTIONS AND WASTEWATER

Initial situation

Industrial production companies such as in the metal or printing industry, and also in the chemical and pharmaceutical industry, frequently produce highly polluted wastewater which may not be discharged into the communal sewage system. Some of the contaminations (heavy metals, cyanide salts, solvents, complex chemical compounds, etc.) are very complex and difficult to break down.

For many companies this is a problem. Even if treatment were possible, especially at small firms, where often only limited quantities of wastewater are produced, a conventional water treatment plant mostly cannot be operated economically and/or efficiently by the firm itself.

Therefore in many cases the waste water has to be disposed of externally as special waste. The cost of external disposal amounts to up to € 700/m³ plus the transport costs of up to € 500/m³, depending on the branch of industry and/or the type of wastewater. Typical of such kinds of wastewater is that there is a pollutant contamination in a high degree of dilution with, in some cases, 90 % or more water. Since the disposal

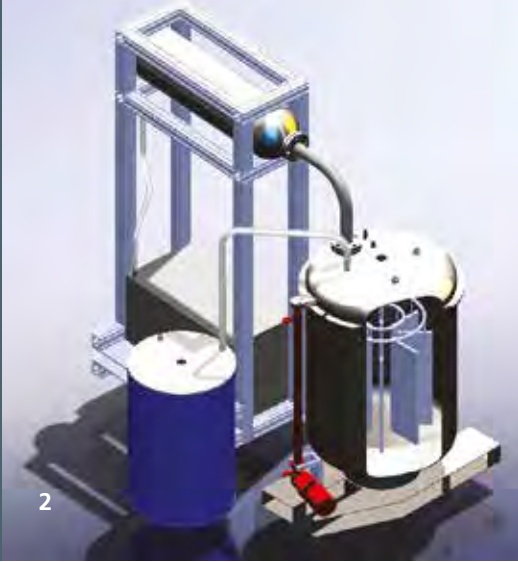
costs are calculated on the basis of the volume of waste, the percentage of water is of decisive importance. Also, as a result of the disposal of the waste material, the company loses both the water and valuable substances such as organic solvents without any possibility of recovering them.

Proposed solution

The distillation is a common process for material separation (Fig. 1) and here offers a way of solving the problem. The principle of this thermal separation process is to remove the water and other volatile components by means of evaporation and condensation – at the same time retaining the residual wastewater contents. Generally, the necessary evaporation temperature depends on the pressure, whereby the temperature is significantly reduced as the pressure drops, i.e. in a vacuum.

Vacuum evaporation to reduce the volume

Building on this, the Fraunhofer IGB has developed, in cooperation with Maschinenbau Lohse GmbH, an inexpensive and modular vacuum evaporation process which has already been implemented in a first prototype (Figs. 2 and 3).



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The system is based on simple technologies and therefore involves only low investment and operating costs and requires very little maintenance. An innovative plant design was developed, especially to the advantage of small and medium-sized companies. This brings about an evaporation of the wastewater direct in the customer's disposal container, thus minimizing the expenditure for decanting and cleaning. In addition, deposits or incrustations in the plants and the resulting stoppages are avoided.

As a result of the reduced boiling temperature by vacuum, heat flows from a temperature of approximately 40–50 °C can be used for this process. In particular, it enables the use of low-temperature waste heat or solar heat as a source of energy. Moreover, the energy set free again in the condensation of the vapor can be used, for example, to preheat the wastewater or various process flows in the production plant. The water removed in this process can in many cases be re-used in production or also for rinsing processes. Organic solvents can in principle also be separated and re-used in this process. Even wastewater contents of varying volatility can be separated and recovered individually by condensing the vapor in several steps at different temperatures.

Application

The system described here aims in particular at flexible use in small and medium-sized companies, which up till now have not been able to treat their wastewater at all or only partially in their own plants and thus are dependent on providers of disposal services. In such cases, the quantities of wastewater for which disposal has to be paid for can be reduced significantly. In addition, an optimized use of raw materials and of process water and/or heat flows often becomes possible. The branches of industry aimed at are, for example, the paint and dye, printing or textile industries as well as the metal-producing, metal-working and electroplating industries.

- 1 *Principle of distillation process.*
- 2 *CAD model (draft).*
- 3 *Prototype during set-up.*



SERVICES OFFERED

We work together with our customers from the first preliminary investigations by way of the process development to the planning and commissioning of a prototype plant. We co-operate with a network of qualified mechanical engineering and plant construction firms in order to implement the plant concepts developed.

- Carrying out feasibility studies, market and technology analyses
- Optimization and modification of thermal processes to increase efficiency
- Customized developments in the field of thermal materials treatment
- Process design and technical/scientific project support by an interdisciplinary team from the fields of process technology, mechanical engineering, environmental technology, chemistry, biology and electrical engineering

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Fraunhofer IGB brief profile

The Fraunhofer IGB develops and optimizes processes and products in the fields of medicine, pharmacy, chemistry, the environment and energy. We combine the highest scientific quality with professional expertise in our fields of competence – Interfacial Engineering and Materials Science, Molecular Biotechnology, Physical Process Technology, Environmental Biotechnology and Bioprocess Engineering, as well as Cell and Tissue Engineering – always with a view to economic efficiency and sustainability. Our strength lies in offering complete solutions from laboratory scale to pilot plant. Customers benefit from the constructive cooperation of the various disciplines at our institute, which is opening up novel approaches in fields such as medical engineering, nanotechnology, industrial biotechnology, and wastewater purification. The Fraunhofer IGB is one of more than 80 research units of the Fraunhofer-Gesellschaft, Europe's largest organization for application-oriented research.

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