

## FogEvaporator Process

What we call **FogEvaporation** is an accelerated process of natural evaporation in between from Flash Drying and Spray Drying, well calculated and calibrated by our department of engineering after five years of tests and trials in real industrial sites.

Let us reviewing this process together:

**Evaporation** is a type of vaporization of a liquid that occurs from the surface of a liquid into a gaseous phase that is not saturated with the evaporating substance. The other type of vaporization is boiling, which is characterized by bubbles of saturated vapor forming in the liquid phase. Steam produced in a boiler is another example of evaporation occurring in a saturated vapor phase. Evaporation that occurs directly from the solid phase below the melting point, as commonly observed with ice at or below freezing or moth crystals (naphthalene or paradichlorobenzine), is called sublimation.

On average, a fraction of the molecules in a glass of water have enough heat energy to escape from the liquid. Water molecules from the air enter the water in the glass, but as long as the relative humidity of the air in contact is less than 100% (saturation), the net transfer of water molecules will be to the air. The water in the glass will be cooled by the evaporation until an equilibrium is reached where the air supplies the amount of heat removed by the evaporating water. In an enclosed environment the water would evaporate until the air is saturated.

With sufficient temperature, the liquid would turn into vapor quickly (see boiling point). When the molecules collide, they transfer energy to each other in varying degrees, based on how they collide. Sometimes the transfer is so one-sided for a molecule near the surface that it ends up with enough energy to 'escape'.

Evaporation is an essential part of the water cycle. The sun (solar energy) drives evaporation of water from oceans, lakes, moisture in the soil, and other sources of water. In hydrology, evaporation and transpiration (which involves evaporation within plant stomata) are collectively termed evapotranspiration. Evaporation of water occurs when the surface of the liquid is exposed, allowing molecules to escape and form water vapor; this vapor can then rise up and form clouds.

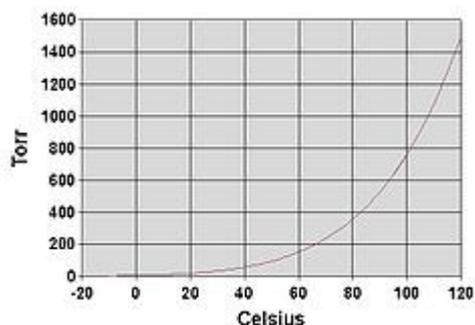


For molecules of a liquid to evaporate, they must be located near the surface, be moving in the proper direction, and have sufficient kinetic energy to overcome liquid-phase intermolecular forces. When only a small proportion of the molecules meet these criteria, the rate of evaporation is low. Since the kinetic energy of a molecule is proportional to its temperature, evaporation proceeds more quickly at higher temperatures. As the faster-moving molecules escape, the remaining molecules have lower average kinetic energy, and the temperature of the liquid decreases. This phenomenon is also called evaporative cooling. This is why evaporating sweat cools the human body. Evaporation also tends to proceed more quickly with higher flow rates between the gaseous and liquid phase and in liquids with higher vapor pressure. For example, laundry on a clothes line will dry (by evaporation) more rapidly on a windy day than on a still day. Three key parts to evaporation are heat, atmospheric pressure (determines the percent humidity) and air movement.

On a molecular level, there is no strict boundary between the liquid state and the vapor state. Instead, there is a Knudsen layer, where the phase is undetermined. Because this layer is only a few molecules thick, at a macroscopic scale a clear phase transition interface can be seen.

Liquids that do not evaporate visibly at a given temperature in a given gas (e.g., cooking oil at room temperature) have molecules that do not tend to transfer energy to each other in a pattern sufficient to frequently give a molecule the heat energy necessary to turn into vapor. However, these liquids *are* evaporating. It is just that the process is much slower and thus significantly less visible.

## Evaporative equilibrium



Vapor pressure of water vs. temperature. 760 Torr = 1 atm.

If evaporation takes place in enclosed area, the escaping molecules accumulate as a vapor above the liquid. Many of the molecules return to the liquid, with returning molecules becoming more frequent as the density and pressure of the vapor increases. When the process of escape and return reaches an equilibrium the vapor is said to be "saturated", and no further change in either vapor pressure and density or liquid temperature will occur. For a system consisting of vapor and liquid of a pure substance, this equilibrium state is directly related to the vapor pressure of the substance, as given by the Clausius–Clapeyron relation:

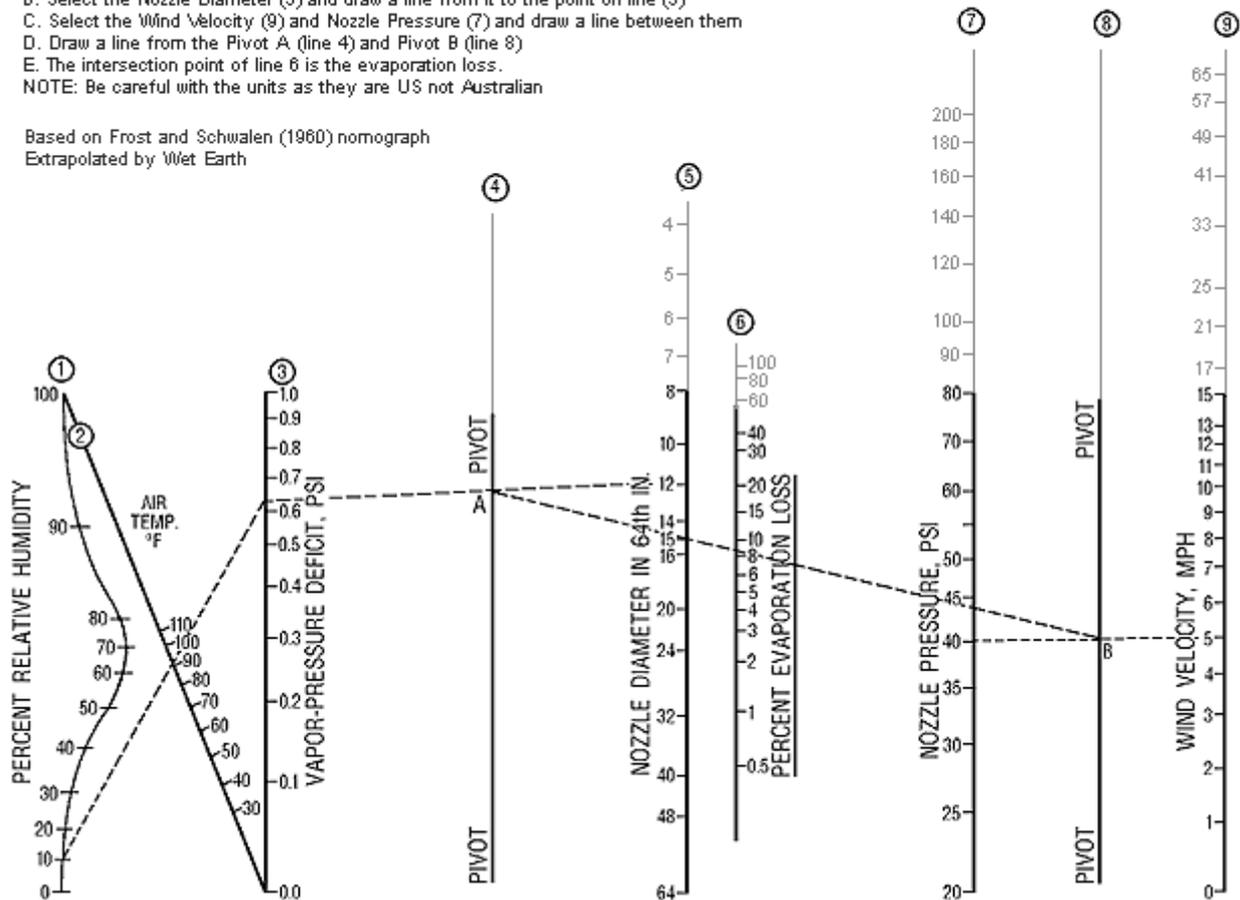
$$\ln \left( \frac{P_2}{P_1} \right) = - \frac{\Delta H_{vap}}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$$

where  $P_1$ ,  $P_2$  are the vapor pressures at temperatures  $T_1$ ,  $T_2$  respectively,  $\Delta H_{vap}$  is the enthalpy of vaporization, and  $R$  is the universal gas constant. The rate of evaporation in an open system is related to the vapor pressure found in a closed system. If a liquid is heated, when the vapor pressure reaches the ambient pressure the liquid will boil.

The ability for a molecule of a liquid to evaporate is based largely on the amount of kinetic energy an individual particle may possess. Even at lower temperatures, individual molecules of a liquid can evaporate if they have more than the minimum amount of kinetic energy required for vaporization.

- Select the Relative Humidity (1) and Air Temperature (2) and draw a line between them to intersect line (3)
  - Select the Nozzle Diameter (5) and draw a line from it to the point on line (3)
  - Select the Wind Velocity (9) and Nozzle Pressure (7) and draw a line between them
  - Draw a line from the Pivot A (line 4) and Pivot B (line 8)
  - The intersection point of line 6 is the evaporation loss.
- NOTE: Be careful with the units as they are US not Australian

Based on Frost and Schwalen (1960) nomograph  
Extrapolated by Wet Earth



### Factors influencing the rate of evaporation are:

Note: Air used here is a common example; however, the vapor phase can be other gasses.

Concentration of the substance evaporating in the air

If the air already has a high concentration of the substance evaporating, then the given substance will evaporate more slowly.

Concentration of other substances in the air

If the air is already saturated with other substances, it can have a lower capacity for the substance evaporating.

Flow rate of air

This is in part related to the concentration points above. If fresh air is moving over the substance all the time, then the concentration of the substance in the air is less likely to go up with time, thus encouraging faster evaporation. This is the result of the boundary layer at the evaporation surface decreasing with flow velocity, decreasing the diffusion distance in the stagnant layer.

## Inter-molecular forces

The stronger the forces keeping the molecules together in the liquid state, the more energy one must get to escape. This is characterized by the enthalpy of vaporization.

## Pressure

Evaporation happens faster if there is less exertion on the surface keeping the molecules from launching themselves.

## Surface area

A substance that has a larger surface area will evaporate faster, as there are more surface molecules that are able to escape.

## Temperature of the substance

If the substance is hotter, then its molecules have a higher average kinetic energy, and evaporation will be faster.

## Density

The higher the density the slower a liquid evaporates.

**Flash (or partial) evaporation** is the partial vapor that occurs when a saturated liquid stream undergoes a reduction in pressure by passing through a throttling valve or other throttling device. This process is one of the simplest unit operations. If the throttling valve or device is located at the entry into a pressure vessel so that the flash evaporation occurs within the vessel, then the vessel is often referred to as a flash drum.

If the saturated liquid is a single-component liquid (for example, liquid propane or liquid ammonia), a part of the liquid immediately "flashes" into vapor. Both the vapor and the residual liquid are cooled to the saturation temperature of the liquid at the reduced pressure. This is often referred to as "auto-refrigeration" and is the basis of most conventional vapor compression refrigeration systems.

If the saturated liquid is a multi-component liquid (for example, a mixture of propane, isobutane and normal butane), the flashed vapor is richer in the more volatile components than is the remaining liquid.

Uncontrolled flash evaporation can result in a boiling liquid expanding vapor explosion (BLEVE).

### ***Flash evaporation of a single-component liquid***

The flash evaporation of a single-component liquid is an isenthalpic process and is often referred to as an **adiabatic flash**. The following equation, derived from a simple heat balance around the throttling valve or device, is used to predict how much of a single-component liquid is vaporized.

$$X = \frac{H_u^L - H_d^L}{H_d^V - H_d^L}$$

where:

$X$  = weight fraction vaporized

$H_u^L$  = upstream liquid enthalpy at upstream temperature and pressure, J/kg

$H_d^V$  = flashed vapor enthalpy at downstream pressure and corresponding saturation temperature, J/kg

$H_d^L$  = residual liquid enthalpy at downstream pressure and corresponding saturation temperature, J/kg

If the enthalpy data required for the above equation is unavailable, then the following equation may be used.

$$X = \frac{c_p(T_u - T_d)}{H_v}$$

where:

$X$  = weight fraction vaporized

$c_p$  = liquid specific heat at upstream temperature and pressure, J/(kg °C)

$T_u$  = upstream liquid temperature, °C

$T_d$  = liquid saturation temperature corresponding to the downstream pressure, °C

$H_v$  = liquid heat of vaporization at downstream pressure and corresponding saturation temperature, J/kg

Here, the words "upstream" and "downstream" refer to before and after the liquid passes through the throttling valve or device.

This type of flash evaporation is used in the desalination of brackish water or ocean water by "Multi-Stage Flash Distillation." The water is heated and then routed into a reduced-pressure flash evaporation "stage" where some of the water flashes into steam. This steam is subsequently condensed into salt-free water. The residual salty liquid from that first stage is introduced into a second flash evaporation stage at a pressure lower than the first stage pressure. More water is flashed into steam which is also subsequently condensed into more salt-free water. This sequential use of multiple flash evaporation stages is continued until the design objectives of the system are met. A large part of the world's installed desalination capacity uses multi-stage flash distillation. Typically such plants have 24 or more sequential stages of flash evaporation.

### ***Equilibrium flash of a multi-component liquid***

The **equilibrium flash** of a multi-component liquid may be visualized as a simple distillation process using a single equilibrium stage. It is very different and more complex than the flash evaporation of single-component liquid. For a multi-component liquid, calculating the amounts of flashed vapor and residual liquid in equilibrium with each other at a given temperature and pressure requires a trial-and-error iterative solution. Such a calculation is commonly referred to as an equilibrium flash calculation. It involves solving the *Rachford-Rice equation*:

$$\sum_i \frac{z_i (1 - K_i)}{1 + \beta (K_i - 1)} = 0$$

where:

- $z_i$  is the mole fraction of component  $i$  in the feed liquid (assumed to be known);
- $\beta$  is the fraction of feed that is vaporised;
- $K_i$  is the equilibrium constant of component  $i$ .

The equilibrium constants  $K_i$  are in general functions of many parameters, though the most important is arguably temperature; they are defined as:

$$y_i = K_i x_i$$

where:

- $x_i$  is the mole fraction of component  $i$  in liquid phase;
- $y_i$  is the mole fraction of component  $i$  in gas phase.

Once the Rachford-Rice equation has been solved for  $\beta$ , the compositions  $x_i$  and  $y_i$  can be immediately calculated as:

$$x_i = \frac{z_i}{1 + \beta(K_i - 1)}$$
$$y_i = K_i x_i.$$

The Rachford-Rice equation can have multiple solutions for  $\beta$ , at most one of which guarantees that all  $x_i$  and  $y_i$  will be positive. In particular, if there is only one  $\beta$  for which:

$$\frac{1}{1 - K_{\max}} = \beta_{\min} < \beta < \beta_{\max} = \frac{1}{1 - K_{\min}}$$

then that  $\beta$  is the solution; if there are multiple such  $\beta$ 's, it means that either  $K_{\max} < 1$  or  $K_{\min} > 1$ , indicating respectively that no gas phase can be sustained (and therefore  $\beta=0$ ) or conversely that no liquid phase can exist (and therefore  $\beta=1$ ).

It is possible to use Newton's method for solving the above water equation, but there is a risk of converging to the wrong value of  $\beta$ ; it is important to initialise the solver to a sensible initial value, such as  $(\beta_{max} + \beta_{min})/2$  (which is however not sufficient: Newton's method makes no guarantees on stability), or, alternatively, use a bracketing solver such as the bisection method or the Brent method, which are guaranteed to converge but can be slower.

The equilibrium flash of multi-component liquids is very widely utilized in petroleum refineries, petrochemical and chemical plants and natural gas processing plants.

### ***Contrast with spray drying***

Spray drying is sometimes seen as a form of flash evaporation. However, although it is a form of liquid evaporation, it is quite different from flash evaporation.

In spray drying, a slurry of very small solids is rapidly dried by suspension in a hot gas. The slurry is first atomized into very small liquid droplets which are then sprayed into a stream of hot dry air. The liquid rapidly evaporates leaving behind dry powder or dry solid granules. The dry powder or solid granules are recovered from the exhaust air by using cyclones, bag filters or electrostatic precipitators.

### ***Natural flash evaporation***

Natural flash vaporization or flash deposition may occur during earthquakes resulting in depositing of minerals held in supersaturated solutions, sometimes even valuable ore in the case of auriferous, gold-bearing, waters. This results when blocks of rock are rapidly pulled and pushed away from each other by jog faults.

**Spray drying** is a method of producing a dry powder from a liquid or slurry by rapidly drying with a hot gas. This is the preferred method of drying of many thermally-sensitive materials such as foods and pharmaceuticals. A consistent particle size distribution is a reason for spray drying some industrial products such as catalysts. Air is the heated drying medium; however, if the liquid is a flammable solvent such as ethanol or the product is oxygen-sensitive then nitrogen is used.

All spray dryers use some type of atomizer or spray nozzle to disperse the liquid or slurry into a controlled drop size spray. The most common of these are rotary disks and single-fluid high pressure swirl nozzles. Alternatively, for some applications two-fluid or ultrasonic nozzles are used. Depending on the process needs, drop sizes from 10 to 500  $\mu\text{m}$  can be achieved with the appropriate choices. The most common applications are in the 100 to 200  $\mu\text{m}$  diameter range. The dry powder is often free-flowing.

The most common spray dryers are called single effect as there is only one drying air on the top of the drying chamber. In most cases the air is blown in co-current of the sprayed liquid. The powders obtained with such type of dryers are fine with a lot of dusts and a poor flow ability. In order to reduce the dusts and increase the flow ability of the powders, there is since over 20 years a new generation of spray dryers called multiple effect spray dryers. Instead of drying the liquid in one stage, the drying is done through two steps: one at the top (as per single effect) and one for an integrated static bed at the bottom of the chamber. The integration of this fluidized bed allows, by

fluidizing the powder inside a humid atmosphere, to agglomerate the fine particles and to obtain granules having commonly a medium particle size within a range of 100 to 300  $\mu\text{m}$ . Because of this large particle size, these powders are free-flowing.

The fine powders generated by the first stage drying can be recycled in continuous flow either at the top of the chamber (around the sprayed liquid) or at the bottom inside the integrated fluidized bed. The drying of the powder can be finalized on an external vibrating fluidized bed.

The hot drying gas can be passed as a co-current or counter-current flow to the atomiser direction. The co-current flow enables the particles to have a lower residence time within the system and the particle separator (typically a cyclone device) operates more efficiently. The counter-current flow method enables a greater residence time of the particles in the chamber and usually is paired with a fluidized bed system.

Alternatives to spray dryers are:

1. Freeze dryer: a more-expensive batch process for products that degrade in spray drying. Dry product is not free-flowing.
2. Drum dryer: a less-expensive continuous process for low-value products; creates flakes instead of free-flowing powder.
3. Pulse combustion dryer: A less-expensive continuous process that can handle higher viscosities and solids loading than a spray dryer, and that sometimes gives a freeze-dry quality powder that is free-flowing.

A spray dryer takes a liquid stream and separates the solute or suspension as a solid and the solvent into a vapor. The solid is usually collected in a drum or cyclone. The liquid input stream is sprayed through a nozzle into a hot vapor stream and vaporized. Solids form as moisture quickly leaves the droplets. A nozzle is usually used to make the droplets as small as possible, maximizing heat transfer and the rate of water vaporization. Droplet sizes can range from 20 to 180  $\mu\text{m}$  depending on the nozzle. There are two main types of nozzles: high pressure single fluid nozzle (50 to 300 bars) and two-fluid nozzles: one fluid is the liquid to dry and the second is compressed gas (generally air at 1 to 7 bars).

Spray dryers can dry a product very quickly compared to other methods of drying. They also turn a solution, or slurry into a dried powder in a single step, which can be advantageous for profit maximization and process simplification.

### ***Micelle Packing Parameter***

The micelle packing parameter equation is utilized to help "predict molecular self-assembly in surfactant solutions":

$$\frac{v_o}{a_e * l_o}$$

where  $v_o$  is the surfactant tail volume,  $l_o$  is the tail length, and  $a_e$  is the equilibrium area per molecule at the aggregate surface.



### ***Inverse/reverse micelles***

In a non-polar solvent, it is the exposure of the hydrophilic head groups to the surrounding solvent that is energetically unfavorable, giving rise to a water-in-oil system. In this case, the hydrophilic groups are sequestered in the micelle core and the hydrophobic groups extend away from the center. These inverse micelles are proportionally less likely to form on increasing head group charge, since hydrophilic sequestration would create highly unfavorable electrostatic interactions.

## ***Uses***

Although micelles are often depicted as being spherical, they can be cylindrical or oblate depending on the chemical structure of the amphiphile. Micellar solutions are isotropic phases.

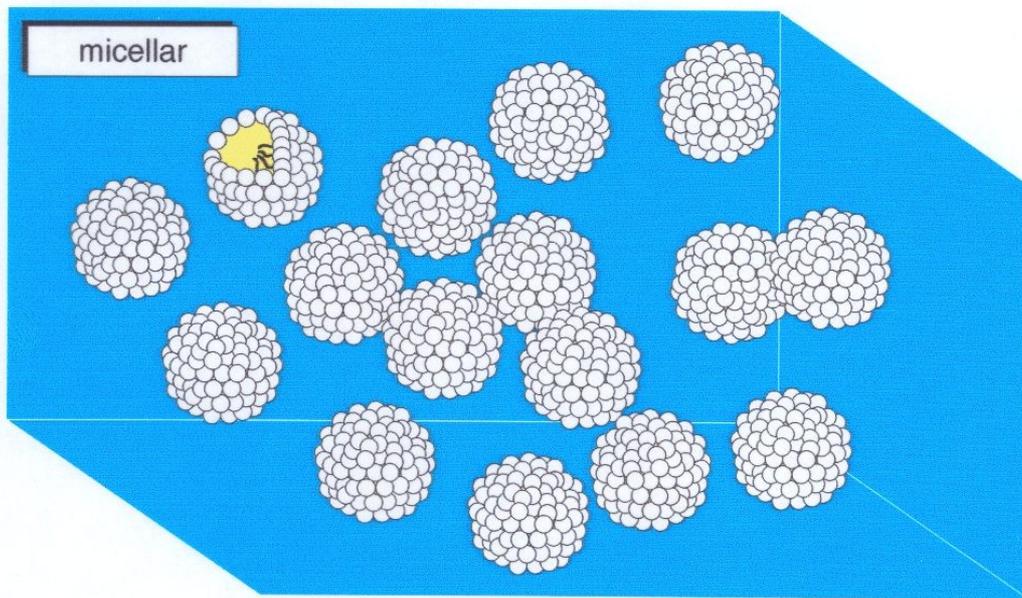
Water micelling process is also obtained mechanically by fractioning the water itself by multiple centrifugally effect in order to generate cavitation on propeller centrifugal disks between the water goes throw.

Suction cavitation forms when the propeller is operating at high rotational speeds or under heavy load (high blade lift coefficient). The pressure on the upstream surface of the blade (the "suction side") can drop below the vapor pressure of the water, resulting in the formation of a vapor pocket. Under such conditions, the change in pressure between the downstream surface of the blade (the "pressure side") and the suction side is limited, and eventually reduced as the extent of cavitation is increased. When most of the blade surface is covered by cavitation, the pressure difference between the pressure side and suction side of the blade drops considerably, as does the thrust produced by the propeller. This condition is called "thrust breakdown". Operating the propeller under these conditions wastes energy, generates considerable noise, and as the vapor bubbles collapse it rapidly erodes the screw's surface due to localized shock waves against the blade surface.

Tip vortex cavitation is caused by the extremely low pressures formed at the core of the tip vortex. The tip vortex is caused by fluid wrapping around the tip of the propeller; from the pressure side to the suction side. Tip vortex cavitation typically occurs before suction side surface cavitation and is less damaging to the blade, since this type of cavitation doesn't collapse on the blade, but some distance downstream.

Cavitation can be used as an advantage in design of very high performance propellers, in form of the supercavitating propelle. In this case, the blade section is designed such that the pressure side stays wetted while the suction side is completely covered by cavitation vapor. Because the suction side is covered with vapor instead of water it encounters very low viscous friction, making the supercavitating (SC) propeller comparably efficient at high speed. The shaping of SC blade sections however, make it inefficient at low speeds, when the suction side of the blade is wetted.

In this way the water get squeezed and mixed as in the water falls and generate itself a phenomenon of micelling with the natural salts present inside the water naturally.



In other words the micellling effect obtained by the [Evaporation](#) does delay the steam point of solvents or alchools or inquinants in the water in order to precipitate them back to the pond and not into the air evaporation, this process is also performed due to the liquid soap adding by a kit able to additive the odor control soap N3 at 1% into the spraying water and keep the odor under 25 ppb, so not detectable by human nose.

More than this [Evaporation](#) does operate at 15 bar of pressure generated by booster pump, it kills any kind of bacteria or viruses because the pathogenics do not survive at 150 meters deep into the sea.

More than this [Evaporation](#) does spray the stream at 10mt distance circa so very much confined area.

Moreover the area can be contained buy [www.dusttexnet.com](http://www.dusttexnet.com) in order to totally limit ate the micro drops.





### Conclusions:

We can evaporate a huge quantity of gray water and/or sludge's in a while combining flash drying with spray drying under defined, efficient 80% minimum.

We can micelling the evaporating fluid in order to drop down odors and retard the vaporization of chemical organic or not but contaminants or pollutant, so the cannot going into the air. Indeed the precipitate back to the pond.

We can kill all the bacteria's or viruses into the evaporating water before to evaporate it due to the pressure and due to the additive of liquid soap antibacterial and antibiotics.

We can contain the evaporating process into a small area 20x20 meters.

The power consumption of this system compared to traditional one is ten time more efficient and 90% cheaper.