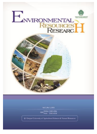

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Designing Low Impact Wastewater Discharge from Solar Distillation Site to Sea

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Abstract

Dry areas near the sea can obtain fresh water through solar distillation of saline sea water resources. However, these solar distillation sites produce wastewater as a result of desalination of sea water with high salt concentration. Waste must be disposed of with the least effect on the receiving environment (sea, in most cases). Initial dilution and its characteristics play important roles in designing effluent disposal into the sea. Application of a mixing model is a common approach for estimating the initial dilution. The present study, using empirical equations, has applied jet system for waste disposal of Kish Port solar desalination site. Initial dilution is related to water depth, diameter, flow rate, the distance between the opening outlets and velocity of water. The results showed the critical and the best initial dilution with regard to different environmental conditions. Effluent disposal systems were compared including jet system of solar distillation in Kish Port and the disposal system of Khamir Port. The minimum velocity and density occurred in the vertical channels zone which shows a well-dilution system that prevents deposition of wastewater into the sea floor. The performance of the T-shaped diffuser for waste disposal is cheaper than the jet system, and it occupies the length of duct from beach to sea.

Keywords: Desalination unit, Saltwater, Mixing zone, Initial dilution, T form Diffuser, Jet system for waste disposal.

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1. Introduction

There are many areas for which access to fresh water and healthier facility is not possible; therefore, research is needed on different methods of saltwater desalination. The use of fresh water seems a very good option when the required water supply is low; however, when the volume is high, there are financial costs of implementation for the land supply system, and installation of facilities and structures (such as intakes, pipelines and water disposal system). Another drawback of this type of desalination is destructive environmental effects such as increasing salinity which could be dangerous or deadly for fish and other animals in the ocean near the wastewater. Damaging the plant tissue is the other negative point which could be caused by disruption of chemical, salinity, and temperature of the seawater. It might also be threatening for human life or living in areas near the sea due to the increase of ground water resources salinity. With regard to the above mentioned destructive effects of desalination on the marine environment and coastal areas, designing of desalination disposal system must be carried out carefully. This study describes the marine depletions and plume jet by mixing mechanism system. Then, the governing equations and the expression characteristics of Kish and Khamir desalination sites are described and initial dilution by diffusers and jet system are defined.

2. Material and Methods

When sewage is discharged into the sea, it immediately mixed with the environment. Initial mixing is conducted through diffusers in a radius about "100 meters and few minutes after discharging wastewater to the environment that is called near field zone. The incorporation of this region is determined by intensity of mixing due to turbulence that is generated by buoyancy force and momentum of the discharged jet. Processes in this area include a mix of free plume, plume hitting to water surface, the horizontal distribution, and additional mixing beyond the final height of plume. Near field zone ends when the turbulence due to discharge is less than the effect of turbulence due to buoyancy force. For a layer that is distributed below the surface, the loss of momentum is due to stable distribution of the density profile inside the layer. Beyond the "near field", the plume of contamination moves with the acceptor environment flow that is distributed by turbulence of this area and is defined as "far field". Mixing in a far field is slowest than near field. Finally input waste water with initial concentration is mixed with near field and far field. Then, average pollutant concentrations will reduce to acceptable standards in coastal water (Figure 1). Although the concentrations of pollutants in near field may damage the marine ecosystems, but given the small size of the area compared to the sea, the adverse effects of waste water discharge are normally ignored. Discharging a fluid with the initial momentum from a hole or groove into a large volume of fluid is called jet. The initial velocity is caused by the movement of the jet and the amount of discharge from the jet is important for the jet movement. Discharge of water from a tube into a pool is a clear example of a jet. The plume stream is similar to a jet, but the difference is that the initial velocity is not the reason for plume flow movement, but the reason is the difference in the density with the recipient environment. Air flow caused by the fire plume is a clear example; the plume is created without any initial velocity and as a result of the density difference due to the air warming. The discharge of pollutants into the sea usually cause a combination of jet and plume and that is rarely due to only jet or simple plume. Primarily, discharge of pollutants into the sea acts as jet due to the initial velocity and momentum flux and then acts as plume because of energy dissipation of velocity operation. By the motion of the tube, the behavior of pollutants can also take a layer or turbulent condition which is above 4000 based on turbulence criterion of Reynolds numbers. The pollutant shaves more density in the tube than that of the sea water, and they may deposit on the sea bed. Discharge of pollutants must be the same as the jet mode at the beginning to move into the water environment that is caused dilution by creating more turbulence with the water environment. The U.S. Environmental Agency mentions that standards for the proposed discharge of pollutants process must be assessed in a maximum radius of 200 meters from the beginning of the tube (US Environmental protection agency- USEPA, 1994).

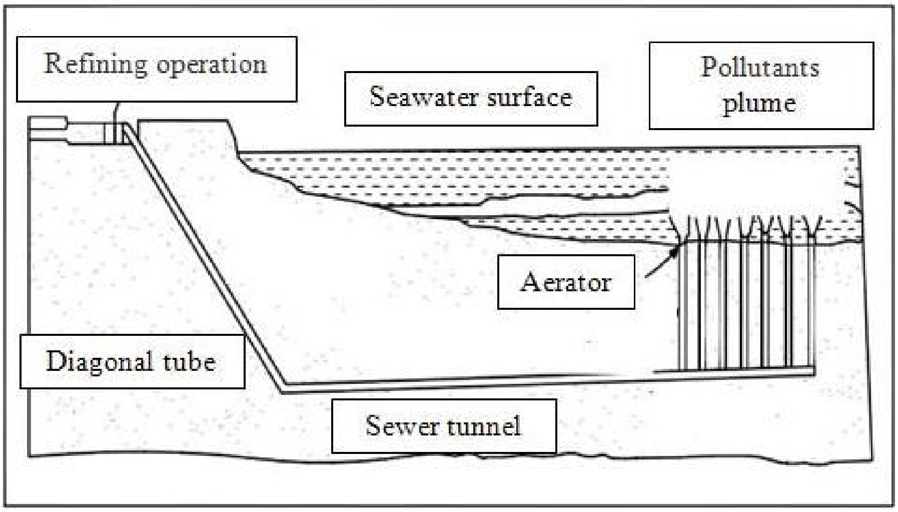

Figure 1. A typical sewer tunnel to discharge sewage into the sea
(Source: Nezhad Naderi *et al.*, 2013)

Sewage outflow can occur through single-diffuser or multiport diffuser. Multiport diffuser in the thermal discharge shows greater rates than single-diffuser in initial dilution. A multiport diffuser has linear structure that includes a few branches with large ducts spaced from each other that forces the heat sewers out. Sewage outflow from a T-shaped diffuser in multiport diffusers is parallel to the stream environment in the present study. Adams (1982) offered the initial dilution equation in T-shaped diffuser using the Bernoulli equation and the momentum equation for the pressure continuity along the axis of multiport diffuser. In T shaped diffuser, the momentum loss is caused due to the surrounding environment flow between the front and rear sections of the T-shaped diffuser (Figs. 2 and 3). Then, by combining the energy equation and the momentum equations, the amount of dilution in the near-depletion of T-shaped diffuser can be calculated as follows:

$\frac{S_t}{S_o} = 1 - C_d M_r$ (1)$\frac{S_t}{S_o} = 1 - C_d M_r$

where S_t is T-shaped diffuser minimum dilution level and C_d is effective coefficient of the inertia of the flow and M_r is proportion between momentum of depletion discharge by T-shaped diffuser and the momentum of discharge by surrounding environment flow that is calculated as follows:

(2) $M_r = \frac{(U_a)^2 H}{(U_O)^2 D}$

In this formula, H is depletion depth and D is the diameter of the discharge tube, U_O is the depletion discharge rate and U_a is the flow rate in the surrounding environment. S_o is initial dilution of the surrounding flow in inertia state that is as follows (Adams, 1982):

(3) $S_0 = \sqrt{\frac{H\cos\theta_0}{2B}}$

θ_0 is the angle between the urethra and the sea floor which is usually less than 45 degrees. Won Seo *et al.,* (2001) obtained constant coefficients of the equation with experimental data in the following way:

(4) $$\frac{S_t}{S_o} = \frac{1}{1-[60\exp(-5M_r^{0.2})]M_r}$$

By substituting equation (3) in equation (4) we reach:

(5) $$S_t = [1 - [60\exp(-5M_r^{0.2})]M_r]\sqrt{\frac{H\cos\theta_0}{2B}}$$

It is first necessary to define B parameter for T-shaped diffuser. This parameter which is denoted by the letter B is the area of each hole of T-shaped diffuser to the distance between holes in the T-shaped diffuser:

(6) $B = \frac{A_0}{l}$

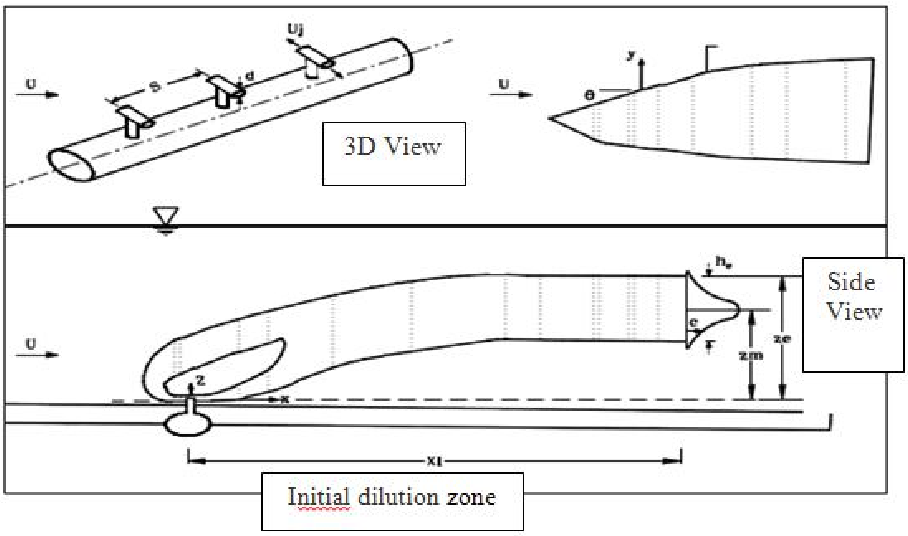

Figure 2. Exit of effluent plume from diffuser into the sea with marine parameters (Takdastan *et al.,* 2006)

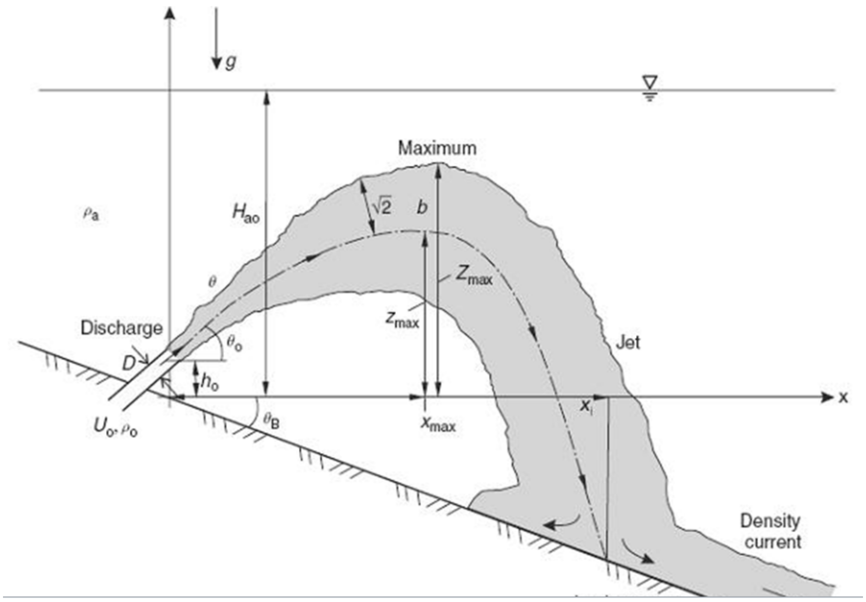

Figure 3. Exit of effluent jet from tube into the sea with marine parameters (Takdastan *et al.,* 2006)

Kish Port Solar Distillation and Surrounding Area

RO technology is used in Kish port solar distillation in Hormozgan Province. For reasons mentioned in the introduction, one of the most important sections of the solar distillation site is effluent disposal system. Importance of this issue is because of its environmental impacts and economic costs. According to the information gathered from the desalination system and the efficiency of the system, the effluent characteristics are illustrated in Table 1.

3. Results

Calculation of the Minimum Dilution Level of the Jet System

For comparison of the effluent disposal systems, application of jet system in Kish Port solar distillation is investigated. Eight tubes with diameter of 20 cm are used at the end of one main duct. The end ofthe main duct is 2500 meters and the location of the slope fracture from 4% to 1% is 500 meters from the beach. Cormix and Fluent software have been used to obtain the result of dilution by jet system in effluent disposal systems of Kish Port solar distillation as shown in Table4, Figure 5, and Figure 6.

Table 1. Characteristics of effluent of Kish Port solar distillation

Effluent discharge	1.2 m^3/s
Effluent density	90000 mg/lit
Effluent temperature	45°C

Table 2. Characteristics of effluent of surrounding areas of Kish Port solar distillation

Velocity of flow	3 m/s
Wind velocity	2 m/s
Environment temperature	40°C
Coefficient of Darcy-Weisbach near the sea	0.04
Coefficient of Darcy-Weisbach in depletion area	0.13
near the sea Slope	4%
Slope near depletion area	1.2%
Environment density	45000 mg/lit

Table 3. Characteristics of effluent of surrounding areas of Kish Port solar distillation

Diameter of tubes	20cm
Number of tubes	8

Table 4. Result of dilution by jet system in effluent disposal systems of Kish Port solar distillation

S(dilution)	X(distance)	S(dilution)	X(distance)
14.1	17.43	1	0
15.1	18.38	1.8	0.73
15.2	18.62	2.3	1.67
15.2	18.99	2.4	2.62
15.2	19.36	2.6	3.58
15.3	19.73	3	4.53
15.3	20.11	3.5	5.38
15.4	20.45	4	6.32
15.4	20.85	4.7	7.26
25.8	45.35	5.4	8.2
35.5	69.15	6.1	9.13
40.7	93.31	6.9	10.07
43.5	117.11	7.7	10.93
45.3	140.91	8.5	11.87
46.6	165.07	9.4	12.81
47.7	188.87	10.3	13.75
48.5	213.02	11.3	14.96
49.8	236.82	12.2	15.55
50.3	260.63	13.1	16.49

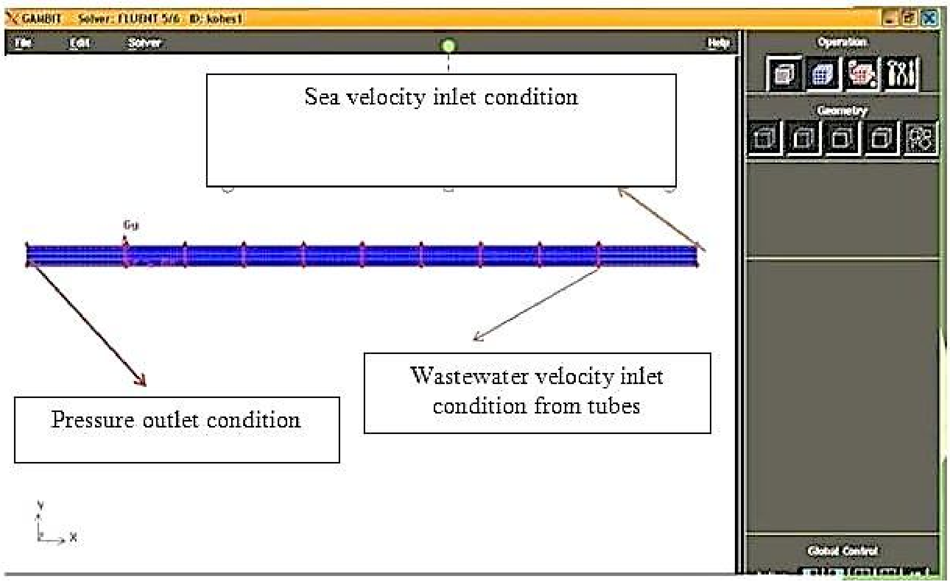

Figure 4. Exit of effluent jet from tubes into the sea in Gambit software.

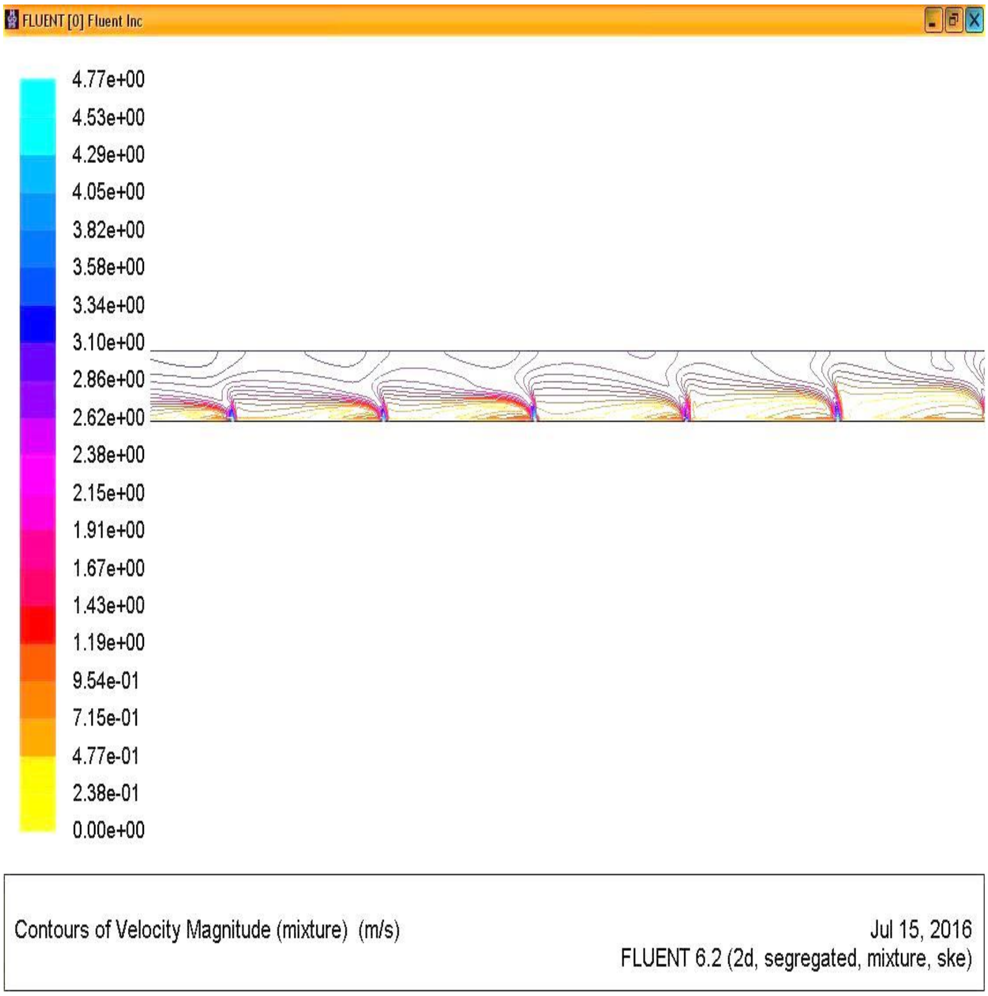

Figure 5. The contours of velocity as a result of numerical simulation for desalination site wastewater flow to the sea through a multichannel system. Wastewater of desalination site is discharged through vertical channels into the sea and is drawn by flow velocity toward the coast. The minimum velocity occurred between the vertical channels zone which shows a well-dilution system and prevents deposition of wastewater into the sea floor.

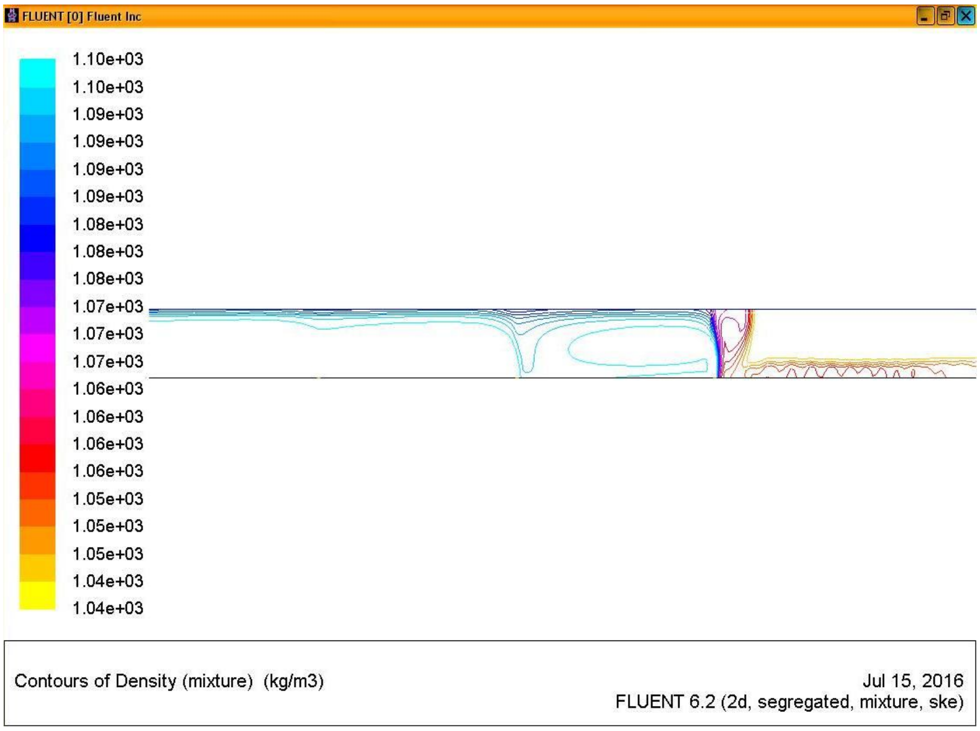

Figure 6. The contours of density as a result of numerical simulation for desalination site wastewater flow to the sea through a multichannel system. The minimum density occurred between the vertical channels zone which shows a well-dilution system and prevents deposition of wastewater into the sea floor.

4. Discussion and Conclusion

The use of saline water resources by solar distillation is available in many areas that are affordable to provide drinkable water. However, the site desalination plant produces a much higher salt concentration compared to the sea water. Using the mixing models is very common for estimating the initial dilution. In this study, the performance of the jet system was investigated for waste disposal of Kish port solar desalination site using empirical equations. Initial dilution is related to water depth, diameter, flow rate, distance between openings, and water velocity. The best initial dilution is determined after considering different environmental conditions and the most important conditions. Using the jet system as an effluent disposal system for Kish Port solar distillation, we have concluded that the minimum velocity and density occurred between the vertical channels zone which shows a well-dilution system and prevents deposition of wastewater into the sea floor.With increasing of effluent discharge from 0.463 m^3/s in the Khamir port to 1.2 m^3/s in Kish port, length of the main duct must be increased. The performance of the T-shaped diffuser for waste disposal is cheaper than that of the jet system since the jet system occupies the length of duct from beach to sea.

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