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Research article

Study of sweetened seawater transportation by temperature difference

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ABSTRACT

This study evaluates the vapor transportation by transmission pipelines during seawater desalination. This study seeks to reach a high rate of water transportation during desalination. Hence, the results obtained from this research are closer to reality than other analyses. Other benefits of this research include increasing efficiency, studying the element-to-element transmission, and considering flow as a compression case. The water desalination system comprises three parts of evaporation, transportation, and condensation. In the transportation part, equations of continuity, momentum, and energy are implemented, and the temperature of the vapor is calculated at the beginning of the condensation pipe. Other achievements of this study include the division of transportation lines to small elements and the implementation of vapor condensation in transportation lines. This study used pipelines with diameters of 1, 2, and 4 m to transmit vapor to Ramsar city and the heights of Takhte Soleiman, 16 km away from the city with the elevation of 2000 m. The results show that diameter, transportation length, and temperature differences are, respectively, the most influential factors on the efficiency of sub-atmospheric vapor transportation. The outcomes of this study were presented as the outflow of condensed water at the destination. Considering the margin of safety in calculations, it was scientifically proved that the results obtained in this study were approximately 10% more than results derived from other studies in the literature that are based on the incompressibility of fluids.

1. Introduction

Water is a national capital. Until twenty years ago, the most important national asset of the countries was energy, but soon, they would exchange water with oil. Not to be outdone, it is enough to note that there are no less inexpensive alternatives to energy than oil, but there is no substitute for water right now, and today the emphasis is on saving. The evaporation of seawater in warm regions, its transportation with clouds, and finally its condensation as rain in low temperatures is a clear example of the natural desalination of seawater, which annually provides billions of tons of desalinated water for various parts of the world. The basis of such natural desalination is the meaningful difference between the warm source or sea and the condensation location or Mountaintop, which has become the purpose of studies for some researchers to investigate desalination through natural potentials [1, 2]. Among the requirements for this method, there is the existence of a cold area that provides a sufficient temperature difference for the transportation and the condensation of vapor.

Desalination methods of seawater generally contents, including Multi Stages Flash distillation (MSF), Multi-Effect Distillation (MED), and also, membrane methods which include Reverse Osmosis (RO). The energy consumption in these methods is variable from 1.75-40 Kwh/m3 that depending on the technology utilized and plant size [3, 4, 5, 6]. Moreover, energy consumption for desalinated water transfer should be calculated and considered separately. According to the RO method, the efficiency of thermal energy conversion into electrical energy should also be considered. The method of this article is natural, the seawater sweetening and transferred without using any energy.

There is a great deal of research into seawater desalination using seawater evaporation and condensation by temperature difference [1, 2, 4, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19]. This study used a formulation to calculate the transfer of mass and energy in evaporation and condensation parts, technically studied vapor transportation for long distances. To achieve a circulated mass flow rate of raw water in the evaporation part as well as the length of condensation line (Line) in the destination, a trial-and-error approach was used to solve related equations by establishing connections between three parts of evaporation,

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transportation, and condensation. Other assumptions of this study include the incompressibility of vapor; to deal with this assumption; an average value is assigned to the density of water vapor [1]. In the present study, (1) the use of a larger and a more detailed model, together with (2) more thermal and cooling details, (3) the use of transmission pipes with various diameters, (4) the creation of more realistic and compatible climatic conditions for the origin and the destination, (5) in the large diameters of pipe the calculations are more accurate and there is not any limitation for Reynolds number, and, finally, (6) the assumption of vapor compressibility are the contributions of this study that can lead to the advancement of knowledge and technology in this method. To conduct a field survey, the coastal city of Ramsar with particular characteristics of the warm area was studied along with the heights of Takhte Soleiman 16 km away from the city, as the cold area.

2. Materials and method

Same as the parent article, this research includes three parts of evaporation, transportation, and condensation. The assumptions made throughout this study are as below:

- The sub-atmospheric pressure exists in all parts of evaporation, transportation, and condensation.
- The latent heat of vaporization of raw water is stored in the evaporation part.
- Throughout all stages, the pipes and their joints are sealed and resistant to water entrance.
- The pipe used in the transportation part is adiabatic and no heat exchange has occurred with the environment.
- The existing and defined parameters are assumed to be fixed through time.
- The transportation and condensation parts are made of round and smooth pipes.

Evaporation part: In this section, raw water is evaporated by the internal energy of seawater or saline water. A pipe with the diameter that is four times the diameter of transportation pipes enters the seawater vertically and causes it to evaporate as a result of atmospheric pressure in the pipe. It should be noted that it is better to de-aerate the seawater before these operations. The reason for seawater de-aeration is to remove non-condensable gasses that reduce the efficiency of operations. The evaporation part performs naturally, which is the result of decreasing the temperature around the water. Two factors can increase the efficiency of evaporation within the evaporation part. The first factor is the water inflow to the vertical pipe, and the second factor is the increase of temperature difference between seawater and inside of the pipe, which is the temperature equivalent with the internal pressure of the pipe.

Transportation part: After the evaporation, the vapor enters the transportation part. In this part, water vapor tends to move towards high elevations because of less pressure and temperature in them. In this stage, the atmospheric pressure of the pipe is decreased as a result of the increase of elevation and the compressibility of vapor.

Condensation part: After the water vapor has reached the highest point, the condensation part starts. In this stage, a pipe with the same diameter as transportation pipes is directed towards the consumption sector. Since the pipe is not adiabatic in the condensation part, vapor heat is transferred from inside of the pipe to the environment, which causes the act of condensation.

3. Formulation for desalination system

3.1. Evaporation

In this part, the temperature of the raw water is decreased due to evaporation. After that, the water flows and warm water replaces cold raw water. In this process, the temperature decrease due to heat emission from raw water is equal to the latent heat of vaporization and, thus, the following equation is driven:

$$C_p(T_s - T_{l,e})M = m_e \cdot \lambda \tag{1}$$

where M is the circulated mass flow rate of raw water (kg/s), m_e is the amount of water evaporated (kg/s), T_S is the temperature of the seawater (K), $T_{l,e}$ is the temperature of the vapor water (into the pipe) (K), c is the specific heat capacity of the water which is determined according to the temperature and salinity of the seawater (J/K.kg), and λ is the latent heat of vaporization of water that is determined in terms of temperature (J/kg).

However, another formulation is needed to calculate circulated mass flow rate of raw water, which is derived from energy equations as below [20]:

$$Q_{C.V.} + \sum m_i\left(h_i + \frac{v_i^2}{2} + gz_i\right) = \sum m_e\left(h_e + \frac{v_e^2}{2} + gz_e\right) + W_{C.V.} \tag{2}$$

From which the equation below can be driven:

$$(Mh_l = m_e(h_e + 9.81 * 10) + m_0 h_2, M = m_e + m_0)$$

where M, m_e, m_0 and h indicate the circulated mass flow rate of raw water, the extracted water, the water returned to the tank and the enthalpy, respectively.

3.2. Transportation

In short pipes and nozzles, one can ignore the effects of viscosity, but in long pipes, the effects of flow friction on the wall of the pipe must be considered. In order to provide a practical formulation, considering the friction, a limited volume of a pipe is considered, and by equations of continuity, energy, and momentum, the equations governing the fluid transfer will be derived. Finally, the result of the formulation for the total length of transfer is presented. The physical recognition of the problem and the aristocrats over the nature governing the problem, including the linear distance, and the height between the cold and the warm points, and the range of temperature variations between these points are considered as the most critical primary knowledge of the problem. The pipeline can be composed of a large number of interconnected pipes; the thermodynamic conditions at the beginning and the end of the pipe are different, and each element has its specific fluid velocity.

Figure 1 depicts an inclined pipeline (α degree) with a constant diameter as an example of a transportation pipeline, in which mass and momentum balance can be generally shown with Eqs. (3), (4), (5), (6), (7), (8), and (9). The transfer generally takes place from point 1 and continues to point 2. Pressure, density, velocity, and fluid height are shown with the symbols P, ρ, U, and Δz, respectively.

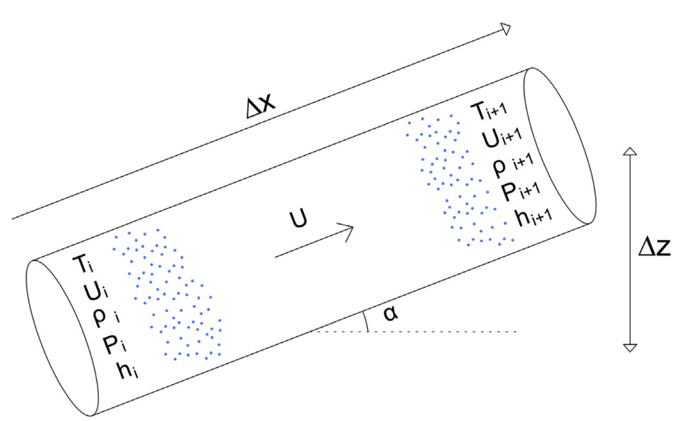

Figure 1. A schematic diagram for an element of pipeline transportation.

Continuity equation [21, 22, 23]:

$$\frac{\partial\rho}{\partial t}+\frac{\partial(\rho U)}{\partial x}=0 \tag{3}$$

$$\rho_i u_i=\rho_{i+1}u_{i+1} \tag{4}$$

where ρ is the density of water vapor (kg/m^3) and *u* is the vapors velocity (m/s).

Momentum equation [22], [23]:

$$\frac{\partial(\rho U^2)}{\partial x}-\frac{\partial P}{\partial x}-\frac{4}{D}\tau_w-\rho g\sin(\alpha)=\frac{\partial(\rho U)}{\partial t} \tag{5}$$

ρ, U, P, D, τ_W, g, and α represent vapor density, vapor velocity, vapor pressure, pipe diameter, wall shear stress, gravitational acceleration, and the angle of pipeline relative to the horizon, respectively. Using the definition of the friction coefficient f in the equation $\tau_w=\frac{1}{2}f\rho U^2$, τ_w can be omitted from Eq. (2). Therefore, we have

$$\frac{\partial(\rho U)}{\partial t}+\frac{\partial}{\partial x}\left(\rho U^2+P\right)+\rho g\sin(\alpha)+\frac{2f\rho U^2}{D}=0 \tag{6}$$

In this study, in order to solve an analytic problem with the assumption of steady state and compressible that is as close as possible to reality, the basis of the calculation will be considered. Considering the pipe length to be L, and the slope of the transportation line (α), Eq. (5) will be obtained which contains three pressure drops, including compressible pressure drop ($\Delta P_\rho=\Delta\rho\cdot U^2$), hydrostatic pressure drop ($\Delta P_H=\rho g L\cdot\sin(\alpha)$), and friction pressure drop $\left(\Delta P_f=\frac{2fL\rho U^2}{D}\right)$. Moreover, we have $L\sin(\alpha)=\Delta z$.

$$p_i-p_{i+1}=\rho g\Delta z+\rho_{i+1}u_{i+1}^2-\rho_i u_I^2+\frac{2fL\rho U^2}{D} \tag{7}$$

where *p* is the vapor pressure (Pa), *g* is the acceleration due to gravity (m/s^2) and Δz is the height difference between the two ends of the element (m).

Energy Equation: according to the first law of thermodynamics [20]:

$$\left(h_i+\frac{u_i^2}{2}+g\Delta z\right)-\left(h_{i+1}+\frac{u_{i+1}^2}{2}\right)=\frac{dE}{dt}-Q+W=0 \tag{8}$$

where *h* is the vapor enthalpy (J/kg), Q is the amount of heat flow extracted per unit length (W/m), Δx is the length of the element.

Simultaneously, solving Eqs. (3), (4), (5), (6), (7), and (8), variations of density, velocity, temperature and pressure along the transportation pipe can be calculated.

By analyzing the transport pipe and achieving related parameters and information, the flow of mass through the pipe can be calculated:

$$m_t=\rho_i\frac{\pi D^2}{4}u_i \tag{9}$$

Where m_t, is the transportation rate (kg/s) and D is the pipe diameter (m).

According to continuity equation, since the rate of steam transport leads to only one result for each element, it is not necessary to write any of equations above for any of them.

3.3. Condensation

In the condensation part, to avoid energy use, the pipe insulation is removed so that the steam will condense and convert to distilled water by getting heat from the environment.

The latent heat of condensation is driven from the water vapor, and the condensation operation occurs in this section due to the loss of heat Q (in Eq. (10)). Precise formulation based on the theory and analysis regarding condensation and evaporation of crossover flow is presented in the literature review [24].

$$Q=\frac{T_I-T_O}{\frac{R_I}{2\pi r_1}+\frac{\ln\left(\frac{r_2}{r_1}\right)}{2\pi\lambda_k}+\frac{R_O}{2\pi r_2}} \tag{10}$$

where Q is the amount heat flow extracted per unit length of this part (W/m), T_I is the temperature of the liquid inside the pipe (end of transportation pipeline temperature) (K), T_O is the external air temperature (K), R_I is the inner surface heat transfer resistance between fluid and material of the pipe (m^2.k/w), R_o is the outer surface heat transfer resistance between fluid and material of the pipe (m^2.k/w), λ_k is the thermal conductivity of pipe (W/m.K),r_1 is the internal radius of the pipe (m), r_2 is the external radius of the pipe (m).

As water and steam are exist in the condensation pipe, all converted heat is consumed on condensation of the water vapor while the water temperature stays constant and therefore gives the following equation for the equilibrium between (m) the amount of the heat flow exhausted to outside and the latent heat released by condensation of the steam (Kg/s).

$$L_c=\frac{\lambda m_c}{Q} \tag{11}$$

Where L_c, is the length of condensation part (m), and λ is the latent heat of condensation of water (J/kg).

3.4. Calculation method

The computational element algorithm for this study is presented in Figure 2. The small number of spatial variations will slow down the calculation and be disregarded for the final answers. On the other hand, if these steps are significant, although the computational speed will be high, the accuracy of the outputs will be significantly reduced. Hence, after obtaining the experience in the numerical solution of transportation Eqs, taking a spatial step of 100 m will result in an increased speed of the numerical calculations and the desired accuracy.

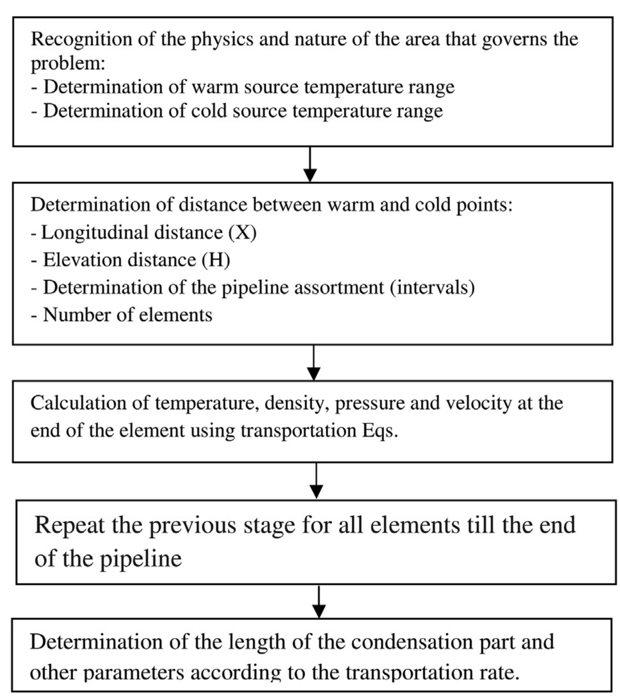

Figure 2. Flow chart of the pipeline iterative calculation.

Table 1. (Compare the results of the previous work with this research).

	M	(kg/s)	
D(m)	[1]	Reynolds number	Present study
4	3.3	39000	3.42
2	0.56	110000	0.56

4. Validation

If the incompressible fluid is considered, the term of $\Delta\rho$ and U^2 in Eq. (7) will be omitted. The steady-state conditions and incompressibility will only remain two terms of the pressure drop, $\rho gL\sin(\alpha)$ and $\frac{2fL\rho U^2}{D}$, which will include the unknown velocity U. The designation of this study is the velocity determination with the assumption of the compressibility to estimating the parameters iteratively until achieving proper answer (3 terms for pressure drop). The another paper with an important limitation ($3\times10^3 < Re < 10^5$) attempts to determine the velocity by the following empirical equation [1]:

$$u = \left(\frac{2\Delta P_f}{0.3164L}\right)^{\frac{4}{7}}\left(\frac{D^5}{\rho^3\mu}\right)^{\frac{1}{7}} \tag{12}$$

Holding $f = \frac{f_D}{4}$ and substituting $\frac{S}{A} = \frac{\pi D}{\frac{\pi D^2}{4}} = \frac{4}{D}$ in Eq. (7) and by simplifying formula (7), above equation is obtained.

Now that we have assured of the accuracy and precision of the equations and formulations suggested in this study, we can proceed to validate the accuracy of the program written by these equations. For this purpose, the current assumptions and results were compared to those conducted in previous studies [1]. The parent article has assessed two cities of Sana and Al-Quran as its case studies. Assuming the fluid to be non-compressible and the number of elements for transportation to be equal (to one) in both studies, a comparison of results obtained in this study with those of parent article is shown in Table 1. The reason for the discrepancy for the pipe with 4 m of diameter is that the Reynolds number has exceeded its allowed threshold in Blasius formula, resulted in some errors in the parent article. Nevertheless, in the program of this study, the Blasius formula is not used and, thus, any value of the Reynolds number can be used in the program.

5. Case study

The magnitude of the difference between the cold and the warm source temperatures, as well as the short path, is a convenient and feasible application point of view. In case these two priorities are met, the only technical and operational concern would be the inclination of the path. In any case, the mentioned items can have efficient results. A case study with satisfying results was observed in the desalinated water transfer through cold vapor method from the coastal city of Ramsar in the north of Iran to the cold 2,000-meters high 2000 summit in mount Takhte Soleiman region 29 km away. Meteorological data related to sea-level temperature in Ramsar (a warm source) and the Takhte Soleiman heights (a cold source) have been depicted in Table 2. In this figure, each temperature that is shown with a point is the average of the recorded temperatures for one month. The average daily (maximum) and nightly (minimum) temperatures were reported each month, whereas, for Caspian sea owing to the negligible difference between day and night temperatures at sea level, only one monthly average was reported [25, 26].

6. Result

Table 2 shows the values of seawater temperature on the coast of Ramsar as well as the maximum and minimum cold temperature in the heights of mount 2000. These results are obtained for the pipes with 1, 2, and 4 m of diameters. As it was expected, at the times when the average temperature difference between warm and cold resources is higher, the condensation of cold water is increased and, which results in higher production of freshwater. In all diameters of pipes, the highest condensation rate has occurred in the summertime, including May, June, and July. These data sets are related to climate conditions at mount 2000, and

Table 2. Air temperature and seawater temperature for target regions.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
minimum temperature of mount 2000	2.4	3.6	5.7	6.2	9.9	11.8	10.5	10.4	10	8.5	5.6	3.4
maximum temperature of mount 2000	11.6	14.2	18	18.2	21.1	21.2	20.3	20.4	18.7	18.3	13.8	12.4
minimum temperature of Ramsar	27.6	28.3	31.5	35.1	36.2	36.4	37.1	36.4	35.9	35	32.1	28.6
minimum temperature of Ramsar	14.8	19.5	23.2	24.2	25.7	26.2	26.4	24.9	23.6	22.6	19.8	18.2
Mount 2000 average temperature	7	8.9	11.85	12.2	15.5	16.5	15.4	15.4	14.35	13.4	9.7	7.9
Ramsar average temperature	21.2	23.9	27.35	29.65	30.95	31.3	31.75	30.65	29.75	28.8	25.95	23.4
seawater average temperature	21.9	24.6	28.1	30.4	32.1	32.2	32.6	31.5	30.9	29.7	26.8	24.1

Table 3. (The information of pipeline between Ramsar to mount 2000 for the diameters of 1, 2 and 4 m in steady state.).

D = 1m			D = 2m			D = 4m		
m (kg/s)	T_o (c)	L_c (km)	m (kg/s)	T_o (c)	L_c (km)	m (kg/s)	T_o (c)	L_c (km)
0.19	10.23	1.24	1.25	10.03	5.78	8.15	9.39	48.5
0.21	11.92	1.46	1.33	11.73	6.58	8.68	11.15	56.4
0.26	16.36	1.22	1.64	16.2	5.34	10.63	15.7	80.5
0.29	18.63	0.95	1.86	18.46	4.16	12	17.98	92.3
0.3	19.81	1.46	1.99	19.64	6.73	12.85	19.16	98.8
0.31	20.2	1.76	2.05	20.04	8.11	12.26	19.56	95.8
0.32	20.59	1.29	2.09	20.43	5.82	12.46	19.95	97.3
0.3	19.61	1.50	1.97	19.45	6.81	12.7	18.97	99.2
0.29	18.63	1.44	1.86	18.46	6.41	12	17.95	88.2
0.27	17.65	1.33	1.76	17.48	6.04	11.38	17	87.5
0.23	14.88	0.93	1.52	14.71	4.25	9.88	14.2	72.6
0.21	12.42	0.98	1.36	12.23	4.40	8.85	11.66	58.2

Table 4. (Information on the diameter of 1, 2 and 4 m for Al-Quran.).

Month	D = 1m			D = 2m			D = 4m		
	[1]	This Work		[1]	This Work		[1]	This Work	
	m (kg/s)	m (kg/s)	Error (%)	m (Kg/s)	m (Kg/s)	Error (%)	m (Kg/s)	m (Kg/s)	Error (%)
Jan	0.121	0.125	3.16	0.481	0.517	6.96	2.652	2.955	10.25
Feb	0.136	0.142	3.96	0.412	0.439	6.15	2.346	2.634	10.93
Mar	0.178	0.184	3.37	0.393	0.422	6.87	2.234	2.512	11.07
Apr	0.196	0.205	4.60	0.324	0.348	6.90	1.727	1.924	10.24
May	0.265	0.275	3.73	0.261	0.279	6.45	1.389	1.526	8.98
Jun	0.283	0.293	3.47	0.246	0.263	6.46	1.343	1.492	9.99
Jul	0.365	0.379	3.69	0.252	0.271	7.01	1.382	1.517	8.90
Aug	0.31	0.324	4.32	0.243	0.261	6.90	1.445	1.624	11.02
Sep	0.264	0.275	4.00	0.265	0.284	6.69	1.765	1.978	10.77
Oct	0.292	0.301	2.99	0.471	0.506	6.92	2.747	3.025	9.19
Nov	0.209	0.217	3.69	0.432	0.461	6.29	2.324	2.612	11.03
Dec	0.179	0.186	3.76	0.594	0.637	6.75	3.334	3.714	10.23

Table 5. (Information on the diameter of 1, 2 and 4 m for Sana).

Month	D = 1m			D = 2m			D = 4m		
	[1]	This Work		[1]	This Work		[1]	This Work	
	m (kg/s)	m (kg/s)	Error (%)	m (Kg/s)	m (Kg/s)	Error (%)	m (Kg/s)	m (Kg/s)	Error (%)
Jan	0.101	0.105	3.81	0.412	0.439	6.15	2.667	2.95	9.59
Feb	0.115	0.119	3.36	0.354	0.376	5.85	2.142	2.364	9.39
Mar	0.163	0.169	3.55	0.367	0.387	5.17	2.245	2.459	8.70
Apr	0.183	0.192	4.69	0.381	0.406	6.16	2.361	2.645	10.74
May	0.242	0.248	2.42	0.393	0.419	6.21	2.431	2.684	9.43
Jun	0.263	0.274	4.01	0.426	0.458	6.99	2.658	2.894	8.15
Jul	0.334	0.347	3.75	0.485	0.512	5.27	2.753	3.029	9.11
Aug	0.305	0.315	3.17	0.481	0.511	5.87	2.752	3.069	10.33
Sep	0.247	0.256	3.52	0.625	0.658	5.02	3.575	3.968	9.90
Oct	0.282	0.289	2.42	0.566	0.603	6.14	3.324	3.698	10.11
Nov	0.201	0.209	3.83	0.578	0.618	6.47	2.851	3.145	9.35
Dec	0.183	0.192	4.69	0.451	0.482	6.43	2.625	2.965	11.47

several differences might emerge in the most productive months of different case studies.

As shown in Table 3, the increase of pipe diameter results in the amount of purified water to increase; moreover, the rate of changes in water production is more than the rate of diameter changes, such that the approximate rate of water produced through pipes with four meters of diameter is 13 kg per second. It can be witnessed that by increasing the diameter of pipes that produces more freshwater, the length of the condensation pipe also increases and may, in some cases, reach up to 100 km. Hence, one should consider the most significant length of the condensation pipe when assembling such systems.

In this stage, it is possible to implement the calculations and formulations of this study on the cities of Sanaa and Al-Quran (case studies of the parent article). In the columns with the header [1], the water productions are included based on the calculations done in the parent article. These comparisons lead to the formation of Tables 4 and 5, the content of which is similar to Table 3. In Tables 4 and 5, the mass values calculated using this research methodology are also higher than those calculated in the parent article.

In a material comparison, it can be easily understood that the mass of materials used in the warm zone and the cold destination are minimal compared to the mass that is considered for transportation. From an engineering point of view, this fact draws on the importance of capital investment for pipelines, and it is likely that in terms of project management, significant attention will be devoted to this phase. Even though beyond the length of the vapor transportation line, presently, the industry producing high-quality and light pipes in various diameters with acceptable strength, mass, heat-insulation, ease of installation, and operation skill is at an assuring stage and due to an investment return in due time, there seem to be no limitations for piping. Therefore, transportation methods can be made applicable by performing general, environmental, and meteorological studies, with proper oversight on the temperature conditions of the origin, destination, and selection of the correct points for transportation. The geometries of the transportation pipeline can reduce the system efficiency, but which is essential in the transportation part is the length of the pipe.

Another point that has to be considered is that in case the temperature falls below zero in the mountain, the system will clog due to freezing, and it will be disabled. This limitation has to be considered in selecting the piping location based on the climatological and weather history of the region. In case water provision is necessary for places with the possibility of the temperature dropping below zero at the destination, LC can be determined through calculations and fluid discharge and collection equipment, such as a pressure or vacuum-maintaining valve, and a reservoir.

7. Conclusion

Physically and following the current principles in the transport phenomena, by considering the technology and the ability of humankind in the construction of long pipelines, the vapor pipeline is both practical and logical. There are many benefits to the production of desalinated water through this transfer, which has attracted the attention of researchers in the development of this method. Transitional cross-section and excessive temperature differences are active factors in transporting. Increasing the diameter as far as possible, choosing the climatic regions that provide maximum natural temperature difference at a minimum distance, and the raw-water options with salinity values less than seawater (such as in effluents and brackish water) can improve the system efficiency. The calculations of vapor transport without simplifying assumptions, and without interfering assumptions and presumptions about the condensation part, and the consideration of the maximum salinity and the fact that the fluid is compressible provides more reliable numbers increasingly for vapor transfer relative to the modeling of the previous researcher.

Declarations

Author contribution statement

Koosha Aghazadeh: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Reza Attarnejad: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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