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Cyclone as Particle Separating Unit from Water and Wastewater

[1]Ali Reza Rahmani and [2]Amir Hossein Mahvi
[1]School of Public Health, Hamadan University of Medical Sciences,
P.O. Box 4171 65175, Iran
[2]School of Public Health, Institute of Public Health Research,
Center for Environmental Research,
Tehran University of Medical Sciences, P.O. Box 14155-6446, Iran

Abstract: The main purpose of this study was to conduct experimental investigation of particle separating by using the cyclone. A cyclone was designed with 10 cm diameters. Mud sample is pumped to the system with varied flow and concentration and the efficiency of system was determined. Obtain results showed that the removal efficiency was increased with speed of fluid and particle size and was 79 to 93.5% for particles over 144 μ. Results suggest cyclones can be considered as a suitable unit in separation of particles in water and wastewater treatment.

Key words: Water, suspended particles, treatment, cyclone

INTRODUCTION

Suspended solids is one of the most important physical properties of water and wastewater which representative of particles quantity being in liquids. Existing of this material from organic or mineral caused a reduction in the consumption of water and several difficulties in purification of wastewater[1-3]. Reducing of settle able solids is necessary to prevent from sludge formation, reducing of biochemical oxygen demands and preparation of solids for next purification or water reentry in process. The most widely used methods for removing suspended solids from polluted water are simple or chemical sedimentation, floatation and mechanical procedure[4]. In mechanical procedure the suspended material can be separated by passing liquid from environment with pressure force to particles by centrifuging[1,5]. The latter procedure is under cyclone sedimentary and the main objective of this research was investigation of cyclone in separation of particles from water and wastewater.

Cyclones sedimentary have been widely used in air refinement since 1886[6]. This system separated the solid material from fluid by using centrifuge. Thus this function of systems depends to particles that in occasion of fluid changing direction keep its axis and leads to cyclone[7].

The collection of particles by cyclone is complex and one cannot present it by theory but can show the effectives forces to particles and investigate it easily. Two groups of forces are interference in cyclone operation, one is centrifuging force, which moves particles to wall and the second is resistant of fluid to particle in the opposite direction. When these forces balanced from each other, particles under effect of inertia forces moves to wall direction with steady movement[3].

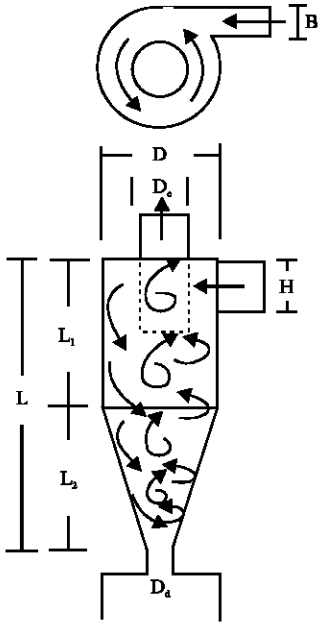
Use of cyclone as a particle-separating unit from air is well known and air pollution control book from planning, shape and structure has been considered[2,4,6-8]. In spite of introducing these systems as a particle-separating unit from water, there is no enough technical information in planning and use it has not been offered.

MATERIALS AND METHODS

In this study for making a hydro cyclone, the overall shape of system adapted with consuming cyclone in removing particles from air. In recent cyclones the main value of planning is diameter of cyclone with proper speed selection and then determination of other system dimension by using table in Fig. 1. By use of relation between centrifuge force and resistance, it determines speed for particles and then with Eq. 1 the cyclone diameter is accounted, the other dimensions by using relation in Fig. 1 selected and planning accomplished[9].

$$D = \sqrt{\frac{Q}{900 \times \pi \times V}} \quad (1)$$

Corresponding Author: Ali Reza Rahmani, School of Public Health, Department of Environmental Health, Hamadan University of Medical Sciences, P.O. Box 4171 65175, Hamadan, Iran
Tel: 98811 8255963-4 Fax: 98811 8255301



Name	Sign	Dimension
Cylinder diameter	D	D
Cylinder length	L_1	2D
Cone length	L_2	2D
Outlet diametre	D_e	1/2D
Particule outlet diametre	D_d	1/4D
Total length of cyclone	L	4D
Height of inlet	H	1/2D
Weight of inlet	B	1/4D

Fig. 1: The relative dimensions of a cyclone

Where:
Q (m^3 h^{-1}) is the volume of fluid passing through the cyclone
D (m) is the cyclone diameter
V (m sec^{-1}) is the fluid speed in inlet portion

In cyclones, efficiency of particle removal depends on several factors. In general the efficiency is obtained from the ratio of centrifugal force to resistant force. In Eq. 2 the effect of these factors in fixed dimensions cyclone is shown:

$$\eta = \frac{V\rho d^2}{R\mu} \quad (2)$$

Where:
η (%) Represents efficiency of cyclone
V (m sec^{-1}) is the speed of particle with circling
ρ (kg m^{-3}) represents particle density
d (m) is the particle diameter
R (m) is the particle entry distance point to cyclone wall
μ (kg m sec^{-1}) is the fluid viscosity

In this research the main criteria for designing of hydro cyclone, diameter of inlet pipe to cyclone is considered and with selecting of liquid speed 10 m sec^{-1} the inlet pipe diameter was determined. The other system dimension obtained from Table 1 and system was constructed (Fig. 2).

The hydraulic test with measuring of pump flow accomplished and speeds were accounted in inlet pipe. In this study, the ranges of flow were selected between 4 to 9l sec^{-1} and the liquid speeds were determined 8 to 18 m sec^{-1}.

Determination function of cyclone: In this study for providing of raw water sample with concentration of 2 g L^{-1}, 200 g of slime from granite stonecutter were added to 100 L water and to homogenized of particles in liquid, the mixture mixed continually. Then for determination of

Table 1: Recommendation dimensional ratio for hydro cyclone

Name	Size	Dimension	Sign
Inlet diameter	D_{in}	D_{in}	2.5
Outlet diameter	D_{out}	D_{in}	2.5
Particule outlet diamètre	D_d	D_{in}	2.5
Cylinder diameter	D_c	$4D_{in}$	10
Cylinder length	L_1	$8D_{in}$	20
Cone length	L_2	$8D_{in}$	20
Total length of cyclone	H	$16D_{in}$	40

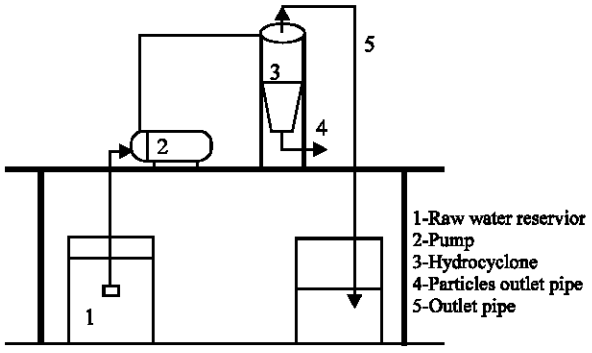


Fig. 2: The layout of hydro cyclone in system

Table 2: Weight distribution of particles in inlet and outlet of cyclone in limited speed

	V (m sec^{-1})							
	18		16		12		8	
Sieve No. mesh	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
30	108.4	0.5	97.2	1.9	118.4	3.8	125.3	6.1
40	115.7	0.9	112.6	1.5	103.5	3.9	98.3	4.6
50	130.5	3.5	99.2	8.0	132.1	10.2	163.0	17.2
70	103.7	4.5	125.5	9.7	122.7	18.8	135.6	24.8
80	108.2	7.1	106.2	11.0	98.3	14.3	89.4	19.2
100	145.1	9.4	126.3	14.0	109.5	19.2	112.5	23.3
200	91.6	19.1	131.7	35.3	98.3	36.5	109.1	44.6
325	125.1	44.7	125.7	55.9	106.2	47.5	93.8	43.7
325>	907.3	607.9	984.7	727.7	903.6	680.4	930.2	719.6
Total	1835.6	697.6	1892.5	865.0	1792.6	834.6	1857.2	903.1
TSS	1941.4	716.4	1917.3	811.0	1889.3	825.6	1934.1	943.8

size and particles weight percent in sample, one liter of liquid was passed from 8 plane sieves based on U.S. standard mesh numbers 30, 40, 50, 70, 80, 100, 200 and 325 (600, 420, 300, 210, 177, 144, 74 and 44 μ) with use of shaker in lower part of sieves. Time duration for separation and categorized of particles were selected 3 min. After expiring this time, the collected containing of each sieve washed with water and collected into dish, then with using of bokhner funnel and using of prepared wattman paper, the samples filtered. To determination of particle weight taken on filter it kept in 200°C for 30 min and then after cooling on desecrator measured the weight sample with sensitive scale. The liquid passed from ending sieve with mesh 325 containing particles smaller than 44 μ, passed from 5 μ filter and then after drying it into the foor, the weight of particles measured and reported for particles 5 to 44 μ.

For determining of cyclone efficiency, 100 L of raw water with variable speed between 8 to 18 m sec^{-1} pumped to cyclone, respectively and distribution of size and weight of particles with same method determined in outlet. After each run, sieve examination was done on particles that collected in cyclone. So TSS in inlet water, outlet water and collected portion in cyclone were measured[10].

RESULTS AND DISCUSSION

The results show that overall measuring of suspended solids in study samples more than concentration of particles in separates the achieved result from performed (Table 2). The efficiency of particles removal has direct relation with liquid speed and size of particle (Table 3).

In Table 4 efficiency of cyclone with use of two series of examinations based on total suspended solids and collected overall solids in each size of sieves were shown. Results showed that in each speed, the efficiency of system using of overall examination of suspended solids has high quantity than others.

Table 3: Particle removal efficiency by cyclone in limited speed

	V (m sec^{-1})			
Particle size (μ)	18	16	12	8
600	99.5	98.1	96.8	95.1
420	99.2	98.7	96.2	95.8
300	97.3	91.9	92.3	89.5
210	95.7	92.3	84.7	81.6
177	93.4	89.6	85.5	78.5
144	93.5	88.9	82.5	79.3
74	79.1	73.2	62.9	59.1
44	64.3	55.5	55.3	53.4
44>	33.0	26.1	24.7	22.6
Total	62.0	54.3	53.4	48.6
TSS	63.1	57.7	56.3	51.2

Table 4: Comparison of cyclone efficiency with consideration of fluid speed, TSS and overall suspended solid collected in sieve examination

	Efficiency (%)			
	Fluid speed in inlet pipe V (m sec^{-1})			
Solid collected	18	16	12	8
Total solids	62.0	54.3	53.4	48.6
TSS	63.1	57.7	56.3	51.2

Result showed that the speed of liquid entering to cyclone has key role in efficiency increasing of particle removal. In speed 8 m sec^{-1} the removal efficiency for particles over 144 μ is 79% and for speed 12, 16 and 18 m sec^{-1} are 82.5, 88.9 and 93.5%, respectively. This efficiency for particles 44 μ was obtained 53.4, 55.3, 55.5 and 64.3%, respectively.

Although the cyclone function in removal of particle in range of 5 to 44 μ is rare, but efficiency between 22.6 to 33% can be considerable. But notice to overall efficiency of cyclone that computed from ratio of entry and exit suspended solids show that for limited speed are variable between 48.6 to 62%. The more exact result also based on overall examination perform of suspended solids in entry and exit (TSS) for studied speeds show that the efficiency

are between 51.2 to 63.1%. The resulted from performed study in a water purified unit in pipe manufacture in former USSR show that the used cyclone for particle 100 to 500 μ have efficiency of 42 to 92%. In this research efficiency 92% for sample with 14% particles weight smaller than 100 μ achieved[11]. The results are comparable whit this study. Peavy[2] and Corbitt[8] believed that the size of particles, fluid pressure, size of unit and speed of entering gas are effective in cyclone performance. Since in this research only one cyclone with steady pump pressure was used thus the present result also show the effect of particle size and speed of fluid in cyclone efficiency.

So, in general result can tell that the plenty of solid can separate by using of cyclone. The resulted of this operation is availability to more water and then altering access to loss compensatory water. The use of cyclone also reduces the sludge dewatering procedures.

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