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Development and evaluation of gas sucking machine for tubewell pit

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The use of tubewell irrigation has made it possible to increase crop productivity. While installing and using of tubewells cause many accidents to occur every year. Such accidents are reported by media in the rainy season. The purpose of this study was to develop a gas sucking machine for minimizing such fatalities. 30 tubewell pits were selected for the study, where such accidents happened. It was found that the depth and diameter of tubewell pits were in the range of 4.5 to 7.4 m and 1.2 to 2.2 m respectively. A portable gas analyzer was used to measure the concentration of CO_2 and CO. The acute concentration of CO_2 gas was found in the tubewell 2.4 to 3.6 m below the ground surface. The poisonous gas sucking machine was developed for complete removal of poisonous gases present in the tubewell. The developed machine was evaluated at selected tubewell pits, operated at five different tractor power take off (PTO) speeds. Volume flow rate, power requirement and time taken for complete removal of harmful gases were recorded.

Key words: Tube well safety, poisonous gas removal, gas sucking machine.

INTRODUCTION

Success of green revolution in Punjab State (India), one of the main factors is irrigation. 1382000 Total numbers of tubewells are present in Punjab (Statistical Abstract of Punjab, 2010-11). Centrifugal pumps are widely used for irrigation and are most common where pumping from surface or shallow ground water is being carried out (Hal, 2002). The problem of accumulation of harmful gases has been found in tubewell pits, immediately after the onset of monsoon period that is, from the month of July to September (Anonymous, 2007). In case of repair and maintenance of pump set, a person descends into the tubewell pit, he feels difficulty in respiration and becomes unconscious after a few minutes and dies to *asphyxia* (Anonymous, 2012). Susan (2004), reported that acute high level CO_2 exposure can produce significant adverse health effect including headaches, attacks of vertigo, poor memory and ability to concentrate, difficult sleeping, tinnitus, double vision, photophobia, lose of eye movement, visual field defects, deficient dark adaption. Sylvain et al. (2009) reported that confined environments are indoor spaces in which the air is not renewed or very poorly renewed by fresh outdoor air. In these environments, indoor air quality is expected to be highly influenced by homogeneous and heterogeneous chemistry.

The concentration of carbon dioxide (CO_2) present in the atmosphere is 392 parts per million (ppm) (CCOHS, 2005). In terms of worker safety, Occupational Safety and Health Administration has set a permissible exposure limit PEL for CO_2 of 5,000 ppm over an 8 h work per day, with a ceiling exposure limit of 30,000 ppm for a 10 min period based on acute inhalation data (MDPH, 2005; NIOSH, 1976). Suruda (1994), reported that an average of 89 work-related deaths in confined spaces per year,

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Table 1. Specifications of blower for the removal of poisonous gas from tube well.

S/N	Description of parts	Size (mm)
1	Diameter of impeller	500
2	Diameter of Blower	600
3	Breadth of Blower's body	80
4	Diameter of gas inlet	55
5	Diameter of gas outlet	55
6	Overall dimension of machine Length x Breadth x Height	775 × 620 × 935
7	Diameter of pulley on P.T.O shaft	400
8	Size of Pulley on Blower shaft	35
9	Power Source	Tractor PTO
10	Approximate price, Rs.	40,000

and approximately 26.5% of those who died were persons attempting rescue. Asphyxiation by atmospheric hazards was the primary cause of death of those persons attempting rescue. Due to the poisonous gases and lack of oxygen gas present in the wells, accidents happen resulting in fatalities every year. 16% accidents of the total agricultural accidents were found related to tubewells (Chhuneja and Singh, 2004). To minimize such accidents, a study was planned to develop a gas sucking machine for removal of accumulated gases present in tubewell pits and to provide safe and comfortable working environment for worker.

MATERIALS AND METHODS

Tubewell pit is considered as a confined space open from the top (Pettit and Linn, 1987). A hazardous atmosphere expose workers to the risk of death, incapacitation, impairment of ability to self-rescue (escape unaided from a permit space), injury, or acute illness from an insufficient amount of oxygen for the worker to breathe that is, oxygen concentration below 19.5% (Anonymous 2002; Pettit and Linn, 1987). Tubewells pits were surveyed; concentration of carbon dioxide and carbon monoxide (CO) were recorded at different depth of tubewell pit by portable gas analyzer. CO_2 is a colourless, odorless, non-flammable gas that is a product of cellular respiration and burning of fossil fuels. It has a molecular weight of 44.01 g/mol (NIOSH, 1976). CO_2 is heavier than the air by weight and deposited at the bottom of a pit. Blowers and fans provide mechanical dilution ventilation (Anonymous, 2002). Therefore, a tractor operated gas sucking machine was developed and its performance was evaluated for complete removal of CO_2 from tubewell pit.

Development of gas sucking machine

A tractor power take off (PTO) operated vacuum generator is developed to suck out poisonous gas from the bottom of the tubewell pits and replace it with fresh air. Specifications of the machine are given in Table 1. Machine is operated by tractor PTO, suction pressure is generated by rotation of an impeller is fitted inside the machine. The power is transmitted to the impeller shaft by mean of a belt pulley mechanism which also increases the rotation per minute (RPM) of impeller. The speed ratio of PTO shaft to the impeller shaft is 1:11.5. A commercially available 10 m long poly vinyl chloride (PVC) pipe of 60 mm diameter is used as inlet/suction pipe of the poisonous gas sucking machine. The flexible PVC pipe attached with inlet of the sucking machine to suck out the poisonous gases from the tube well pit. The end of the inlet pipe is perforated but closed at the lower end to avoid sucking of water, mud and other foreign materials. The whole assembly of impeller is mounted on a frame made up of metal sheet 'L' angle and hollow square bar of 50 × 50 × 5 mm. The machine is able to mount on tractor by three point linkages (Figures 1 and 2).

RESULTS AND DISCUSSION

This machine was evaluated at the farmer's field located near Village Hambra, Dist. Ludhiana, Punjab (India). The machine was connected with PTO shaft of 35 hp tractor. Whole setup of machine was kept little bit away from the tubewell pit and the outlet of gases was kept in the direction of air flowing, so that the gases cannot be re-circulated in the well.

The depth and diameter of surveyed tubewell pits were found in the range of 4.5 to 7.3 m and 1.2 to 2.1 m respectively (Table 2). The acute concentration of carbon dioxide was found in tubewell pit 2.4 to 3.6 m below the ground surface. The concentration of CO_2 and CO was measured by an infra red based portable gas analyzer. It was found that in the 50% of tubewell pits the concentration of CO_2 was below the permissible exposure limit that is, below 5,000 parts per million (ppm) and in 8 tubewell pits the concentration was above 50,000 ppm. The concentrations of carbon mono oxide in all the tube well pits are under permissible exposure limit that is, 7 to 9 ppm.

Air flow rate

The gas sucking machine was operated at five different tractor PTO Speed (RPM) and the corresponding air velocity at outlet pipe were measured by digital anemometer. The different tractor PTO speed and corresponding impeller speed were measured by digital tachometer and the air velocity was measured by digital anemometer. The air flow rate is the volume of air flowing per unit of time which was calculated.

The internal diameter of outlet pipe of gas sucking machine was 0.055 m. So, the cross sectional area of outlet was:

$$A = \pi /4 \times D^2$$
$$= 2.37 \times 10^{-3} \ m^2$$

and,

Air flow rate(Q)
$$Q \ (m^3/s) = A \ (m^2) \times \text{Air velocity} \ (m/s)$$

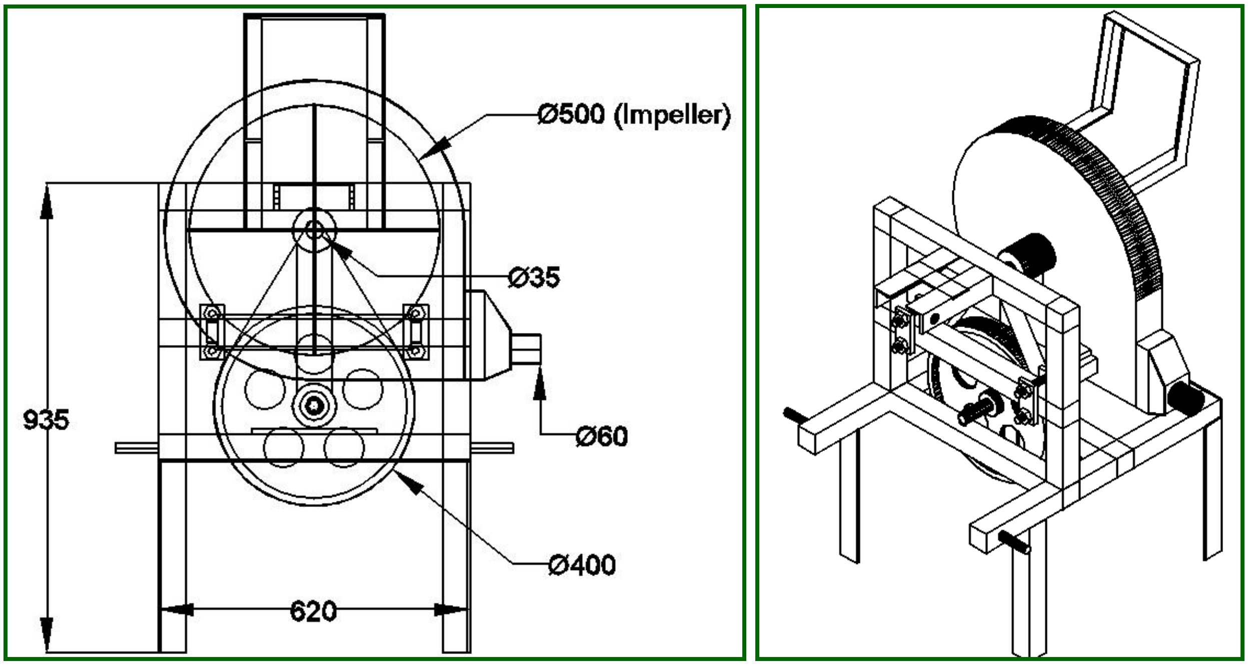

Figure 1. Front and isometric view of gas sucking machine (All dimensions are in mm).

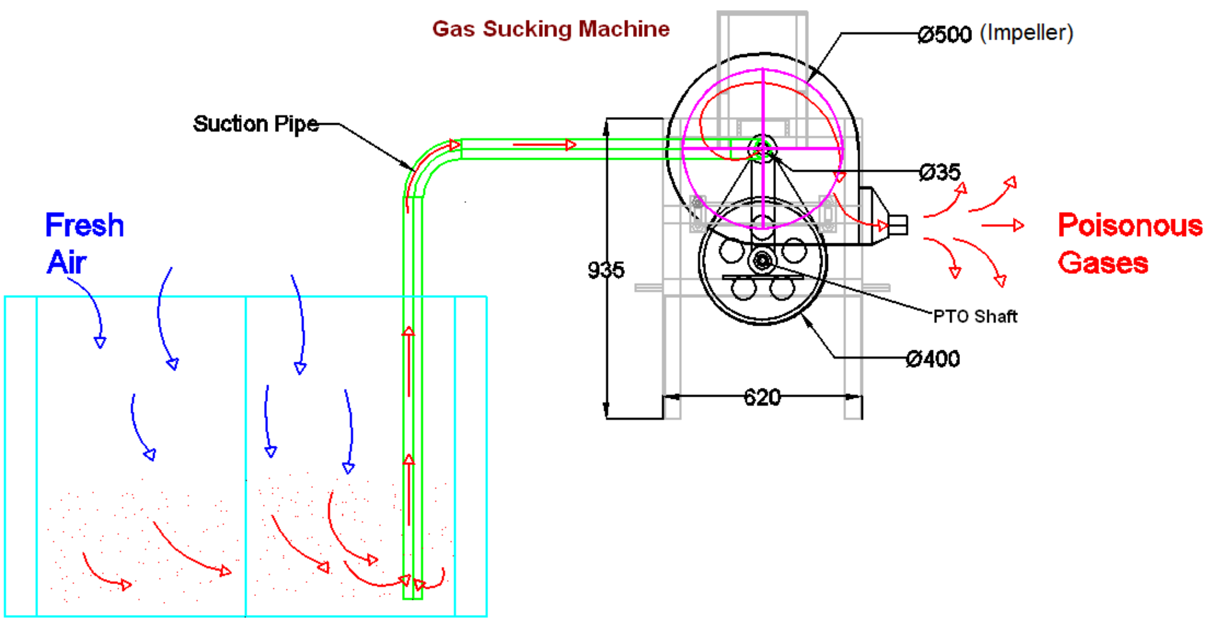

Figure 2. Line diagram of working procedure of poisonous gas sucking machine.

Table 2. Theoretical time required to replace gases with different dimensions of tubewell pit.

S/N	Depth of well (m)	Diameter of well (m)	Volume of tubewell pit (m^3)	Air flow rate (m^3/s)	Time required to replace gases (s)
Minimum	4.6	1.2	6.4		84
Maximum	7.3	2.1	16.8	0.0760	221
Mean	5.7	1.6	11.6		152

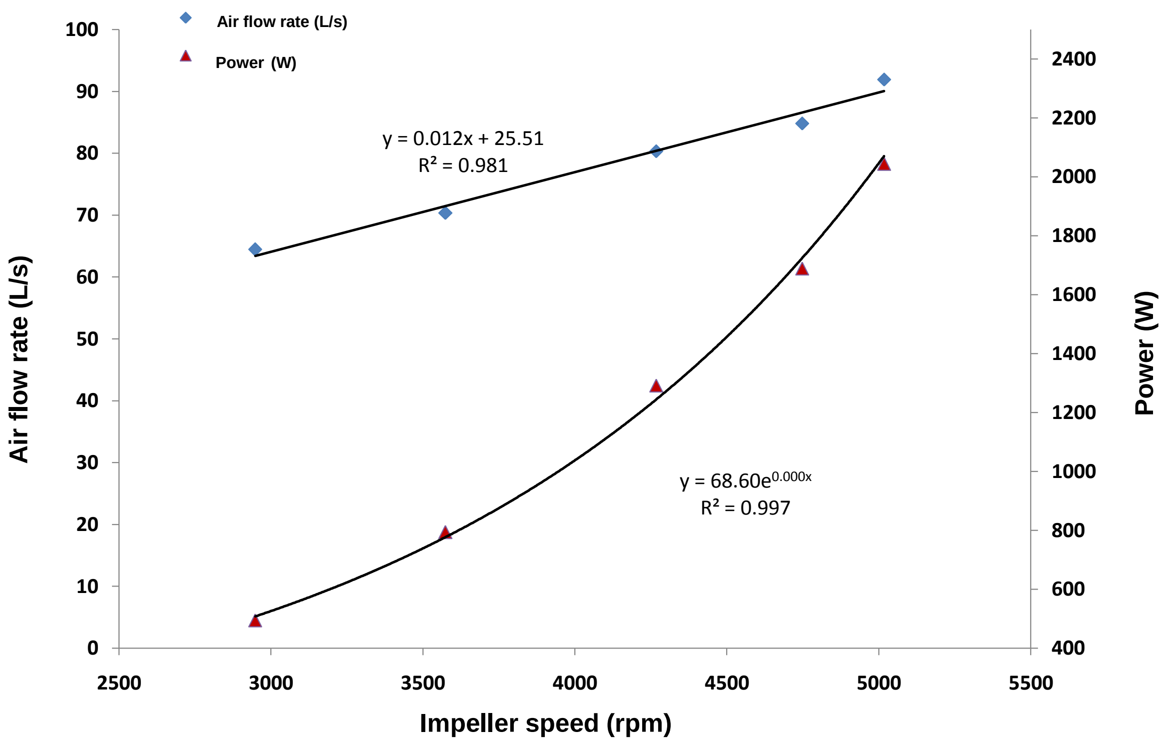

Figure 3. Air velocity at different impeller speed as well as tractor PTO speed.

Power requirement

Power requirement to operate the machine was calculated by the formulae (Malcolm, 1993).

Pressure at gas outlet, $p_r = \rho \times u^2$
Power consumption, $P_o = Q \times p_r$

where,

p_r = pressure at gas outlet (Pa)
ρ = Density of air (kg/m^3)
u = impeller peripheral velocity (m/s)
Q = air flow rate (m^3/s)

Air flow rate increased with increasing impeller speed. The linear trend was found between impeller speed and air flow rate (Figure 3). Air flow rate was found as 64.5 L/s and 92.2 L/s at minimum PTO speed of 284 RPM and rated PTO speed 548 RPM respectively. Power requirement also increased with impeller speed. The exponential trend was found in power consumption and impeller speed. Power required to operate the machine at minimum and rated PTO speed was 495 watt and 2044 watt respectively (Figure 3).

Theoretical time required to suck out poisonous gases

The sucking machine replaces the poisonous gases by diluting concentration of carbon dioxide with fresh air (Figure 2). Time required to suck out poisonous gases is depends upon the volume of gas present in tubewell pit. For complete replacement of poisonous gases, the volume of gases was considered as total volume of tubewell pit. The machine was operated at 4200 RPM (impeller speed) at which the air velocity was 32.4 m/s and the air flow rate was 0.076 m^3/s.

The calculated average time required to replace the poisonous gases was 152 s. Minimum and maximum time required to replace these gases was 84 and 221 s respectively.

Actual time required to suck out poisonous gases

The machine works on dilution process, as machine runs the poisonous gases sucked through the suction/inlet pipe and the fresh air enters in the pit (Figure 2). Thus the fresh air dilutes the gases present in the well pit. The volume of well and concentration of CO_2 was not same for all well pits. Volume of well was found in the range of 6.4 to 16.8 m^3, whereas, CO_2 concentration was found in the range of 400 to 70,000 ppm. Therefore the data was collected for maximum volume of well and maximum CO_2 concentration. The machine was operated at 350 PTO RPM, until the CO_2 concentration was reached at safe level as present in the fresh air. It is observed that the concentration of CO_2 was decreased rapidly from 71,450 to 13,890 ppm in face-A, after 100 s of operation. Further moderate reduction in concentration was observed during

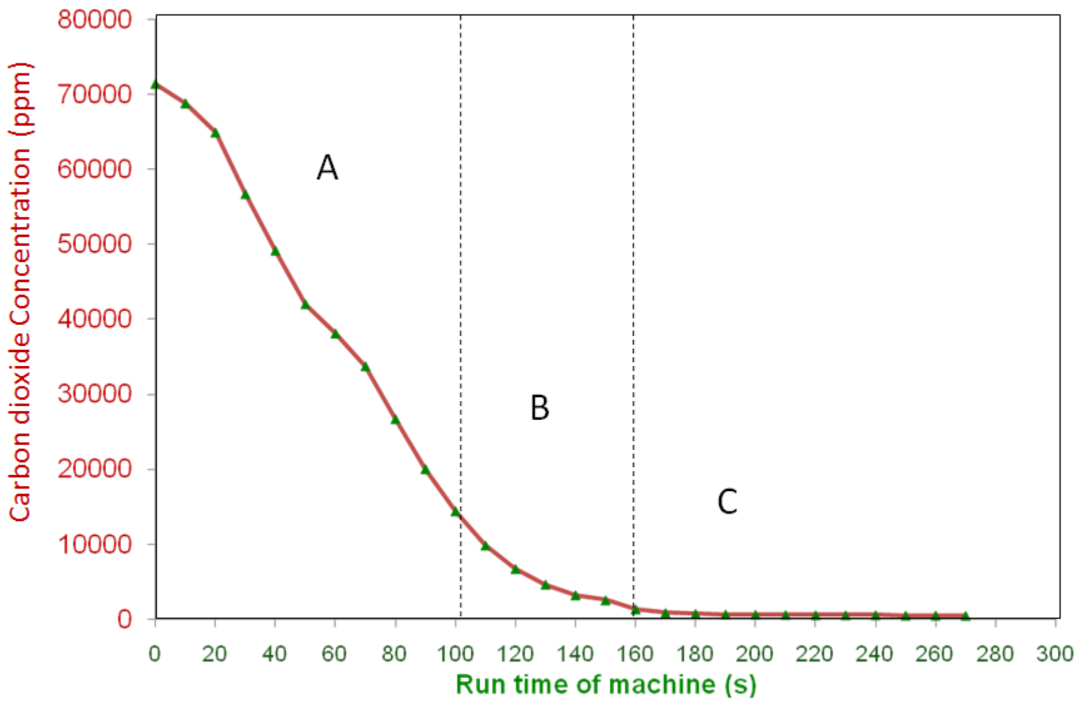

Figure 4. CO_2 concentration versus run time of machine during removal of gases from well pit.

Figure 5. Measument of CO_2 concentration during removal of gases from tubewell pit

next 70 s from 13500 to 620 ppm in face-B (Figure 4). In the last face-C the dilution process of CO_2 was very slow, after 270 s the reading was reached near to the normal concentration (fresh air 400 ppm).

Acute concentration of CO_2 was found in the tubewell pits. The CO_2 was 1.5 times heavier than the air by weight (Anon, 2002); and was deposited in the bottom of the tubewell pit. For effective ventilation, suction pressure was used for removing the heavier gases (CO_2, H_2S, etc.) and blower for removing of lighter gases (CO, CH_4, etc.) effectively form pit. Therefore decision was made to develop a gas sucking machine for tubewell pits. The developed machine worked satisfactorily; it completely removed CO_2 from tubewell pit within five minutes. The machine replaces the CO_2 by dilution with fresh air; therefore theoretical time required to replace the CO_2 from a tubewell pit was 18% less than the actual time (Figure 5).

Conclusions

The developed machine was evaluated at farmers' field and operated at five different tractor PTO RPM. Volume flow rate of air was found as 64.5 and 92.2 L/s at minimum PTO speed of 284 RPM and rated PTO speed of 548 RPM respectively. Power required to operate the machine at minimum and rated PTO speed was 495 and 2044 watt respectively. The machine was operated at 4200 RPM (impeller speed) at which the air flow rate was 0.076 m^3/s. The calculated average time required to replace the poisonous gases was 152 s with minimum and maximum value of 84 and 221 s respectively. The machine works on dilution process therefore the calculated time was 18% lesser than the actual time to replace the gases. It was observed that 270 s are required to replace the gases with fresh air for 16.8 m^3 volume of well.

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