Available online on 15.02.2026 at http://jddtonline.info

Journal of Drug Delivery and Therapeutics

Open Access to Pharmaceutical and Medical Research

Open Access Full Text Article

Check for updates

Research Article

Cow Urine Distillate and Its Therapeutic Applications: An Experimental Investigation

Vikrant P. Katekar *

Assistant Professor, Department of Mechanical Engineering, J D College of Engineering and Management, Nagpur, Maharashtra, India.

Article Info:

Article History:

Received 19 Nov 2025
Reviewed 10 Jan 2026
Accepted 01 Feb 2026
Published 15 Feb 2026

Cite this article as:

Katekar VP, Cow Urine Distillate and Its Therapeutic Applications: An Experimental Investigation, Journal of Drug Delivery and Therapeutics. 2026; 16(2):129-155 *DOI: http://dx.doi.org/10.22270/jddt.v16i2.7571*

For Correspondence:

Vikrant P. Katekar, Assistant Professor, Department of Mechanical Engineering, J D College of Engineering and Management, Nagpur, Maharashtra, India.

Abstract

The present research focuses on designing and testing a novel, cost-effective solar thermal hydrodistillation system for cow urine distillation. Experimental investigations have shown that the distillate's most significant ingredient was phosphonic acid (81.13%), a critical antiviral agent used in prodrug formulations to treat cancer, HIV, and hepatitis B. Solar-powered cow urine distillate is odourless and drinkable without dilution. This distillate had 0.88% ammonia and 2.25% nitrogen, which was 80% less than the market-based cow urine distillate. This investigation also showed that cow-urine distillate is anxiolytic and anti-depressant. A 40% cow urine distillate dosage is helpful in diabetes management. Cancer cell reduction increases as the cow urine distillate dose exceeds 10%. Thus, it can be concluded that prepared cow urine distillate is helpful in treating some life-threatening diseases.

Keywords: Ayurveda; Gau Arka; Gaushala; Gir Cows; Techno-economic analysis; Renewable energy

1. INTRODUCTION

A cow (Fig. 1) is a domesticated cattle animal, a species of Bos taurus [1]. Cows are raised in rural areas for various purposes, including the production of dairy products such as milk and cheese [2]. The majority of cows in today's society are housed in cow shelters. Cow shelters in India are not only places of religious significance but also sanctuaries for stray, abandoned, wounded, and aged cattle. Many cows are mistreated or abandoned as cities grow and agricultural techniques change [3].

Figure 1: Indian cow [4]

Cow urine is composed of 95% water, 2.5% urea, as well as minerals, salts, hormones, enzymes, and other substances 2.5% [5]. Cow urine has many molecular effects, including fighting free radicals, helping with diabetes, inhibiting tumour growth, and killing protozoa and molluscs. Ayurvedic medicine says that cow urine can heal leprosy, fevers, peptic ulcers, liver problems, kidney problems, asthma, some allergies, psoriasis, anaemia, and even cancer. There are many uses for distillate cow urine, such as a biopesticide in organic farming, a way to make tumour drugs more bioavailable, and to treat fungal diseases with an antifungal; studies have shown that cow urine is just as effective at killing germs as regular drugs.

Cow urine and its distillate have been in use since ancient times [6]. Neves [7] tested cow urine as a bluegrass fertiliser. Each treatment utilised 1250–5000 pounds of cow urine per acre. The author reported that the treated plot grass contained higher protein than the control plot grass. In most instances, urine application increased protein content. Using a short-term incubation approach, Limmer and Steele [8] showed that urine application affects the denitrification zone and rate in pastoral soil. The authors found that urine did not boost denitrification activity in soil with fully active enzymes. Mutnuri and Prabhu [9] mentioned that cow urine may produce struvite stones (urine becomes more alkaline). Cow urine and brine were mixed to find the best struvite crystallisation concentration. The authors noted that renewable struvite allows long-term agricultural expansion. Ledgard et al. [10] examined cow urine and its vital pasture components. Increased nitrogen boosts production significantly.

The efficacy of cow urine as a plant growth enhancer and an antifungal agent has been studied by Jandaik et al., [11]. According to the authors, the most effective concentration was 15% cow urine. When tested in 15% cow urine, Fusarium oxysporum (78.57%) inhibited growth best, followed by Rhizoctonia solani (78.37%) and Sclerotium rolfsii (73.84%). The authors observed that cow urine inhibits fungi. Hoh and Dhanashree [12] examined the antifungal properties of cow urine distillate against Candida. They found that concentration-dependent inhibition of Candida species by cow's urine distillate was effective against isolates resistant or sensitive to common antifungals. Sadhukhan [13] presented research on the use of cow urine as a bio-pesticide and fertiliser to support agriculture. Farmers reported increased soil microbial activity and crop yields after regularly using cow urine. Tapke [14] used cow dung and urine for a cheap, natural reformulation. Biological control uses beneficial organisms, their genes, and metabolites to decrease plant disease damage and stimulate plant responses. Grange [15] researched a cow's urine mixture. The intraperitoneal delivery of samples (a traditional convulsion drug) to fasting grey rabbits decreased plasma glucose. Jain et al., [16] evaluated cow urine therapy for cancer patients in Mandsaur District, India. The experimental data showed that cow urine therapy for at least 2-3 months was most beneficial. Suemitsu et al. [17] examined cow urine distillate using gas chromatography. The primary components of cow's urine oil are phenol and p-cresol. Mohanvel et al., [18] redistilled cow urine distillate as an antilastogen and bioenhancer for antibacterial and anti-proliferative action. The authors noted that cow urine distillate may enhance antibacterial and antiproliferative activity. Choudhary et al. [19] stated that cow urine is a natural disinfectant, insect repellent, and a critical ingredient in Indian farmers' organic crop enhancer. Cow urine treatment boosts yields of maize, mustard, and rice. Safitri et al., [20] evaluated fermented cow urine from Ngabab village in Pujon, Kab. Malang. They suggested that cow urine fermentation may be a green way to make environmentally friendly chemical fertilisers and pesticides. Shalaby and colleagues [21] conducted a field experiment to evaluate a novel approach as a complementary method to chemical control against Lepidopteran larvae of both Pink bollworms, Pectinophora gossypiella (Saunders) (Fam. Gelechiidae), and Spiny bollworms, Earias insulana (Boisduval) (Fam. Noctuidae). They used natural items such as cow urine-dung extract and crude neem oil. This research showed that cow urine-dung extract can be safely and successfully implemented in an integrated pest control programme to reduce bollworm complex density on cotton plants. Singh et al., [22] examined how cow urine affects rice growth, yield, and nitrogen absorption. This research found that rice crops responded well to nitrogen fertiliser alone and in combination with cow urine.

Jhalani et al., [23] examined cow-urine emulsification in diesel and other emission-reduction methods. A stationary C.I. engine tested 5%, 10%, 15%, and 20% cow urine emulsions. The 15% emulsion worked best, increasing brake thermal efficiency to 24.8% from 21.9% with base diesel. Bisen et al. [24] developed a technology to convert cow urine into electricity. The authors made ten necessary cells using plastic bottles, zinc and copper electrodes, and cow urine electrolytes. Each cow-urine-filled 150-mL cell generated 0.87 V. Series-connected batteries have an 8.6 V potential difference. The battery's current was 63 mA. Power output was 0.54 W. Hasan et al. [25] reported research on energy generation from cow urine. The authors observed the source outputs and tested them under load. Gidde et al. [26] tested cow urine and a micro-fuel cell-based buck converter for hybrid energy generation. Biswal et al. [27] produced hydrogen from cow urine. The authors obtained most of their hydrogen via steam reforming of gaseous fuel. So, it was another petroleum derivative. Kiran et al., [28] used cow urine to reduce automobile fuel pollution. Sodium, magnesium, calcium, and potassium in cow urine improve fuel characteristics.

The literature study revealed that research on cow urine and its distillate began around 1940. Fig. 1 depicts the number of research papers found in the Scopus database. Since 2011, research on this topic has intensified, and various scientists are now testing cow urine or its distillate in multiple applications. Fig. 2 shows that about 57.1% of the investigators employed cow pee and its distillate for agricultural uses, while 28.6% used cow urine to generate power or electricity. 14.3% of researchers have employed cow urine and its distillate for therapeutic reasons.

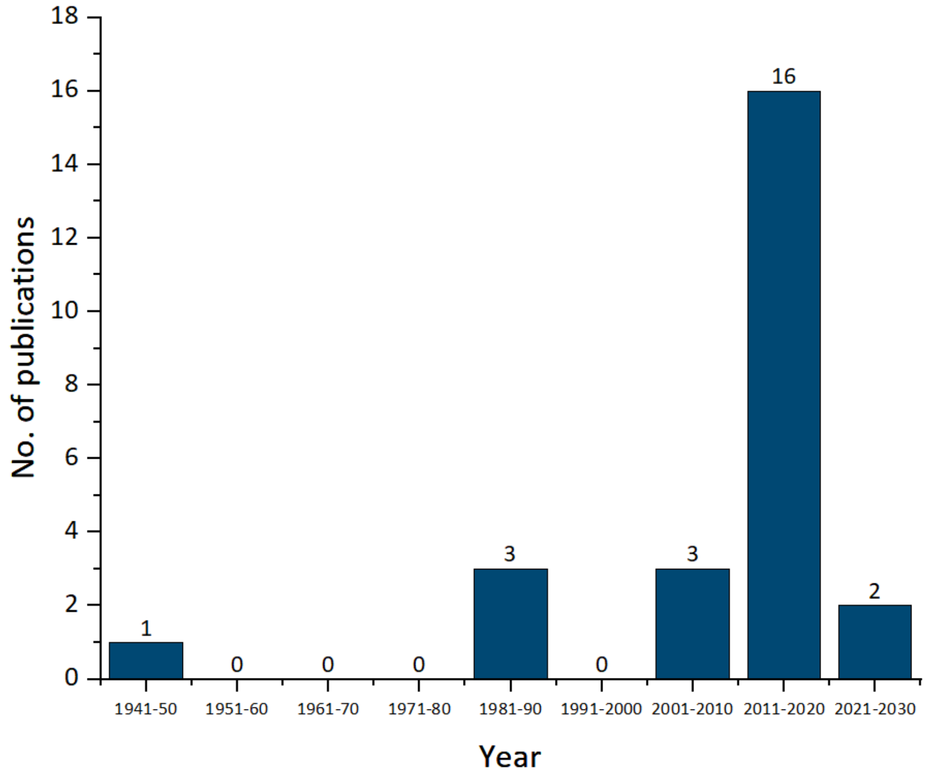


Figure 2: Number of publications found on cow urine and its distillate in the Scopus database

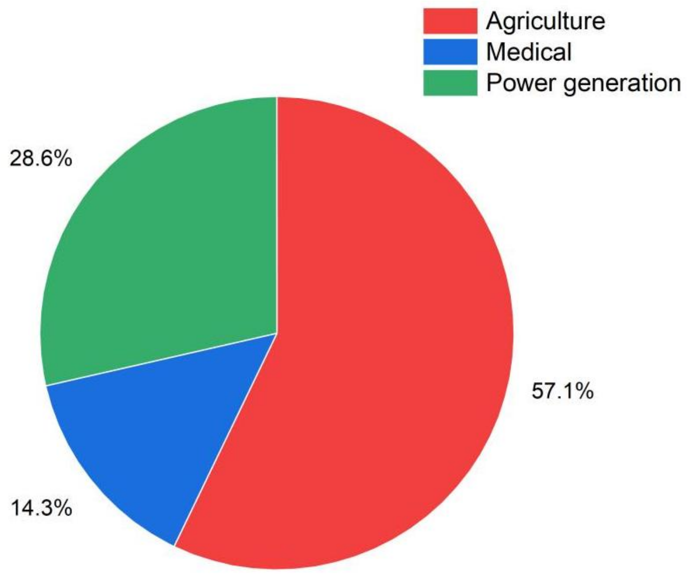


Figure 3: Applications of cow urine and its distillate

2. COW URINE DISTILLATION

From the literature review, it was noted that cow urine distillation was performed either using electrical energy (Fig. 4) or fossil fuels (Fig. 5). Cow urine was boiled in a container, and the vapour thus formed was condensed in a water-cooled condenser. But the challenge here is that dairy cows' mean cow urine pH was 8.10, ranging from 7.27 to 8.71 [29]. This pH value makes cow urine highly alkaline. The pH of a solution significantly affects the properties and behaviour of metals. When the pH is too high or too low, it leads to corrosion or oxidation, weakening or damaging the metal. Hence, cow urine distillation must be done in glass containers (Fig. 6) or spherical clay pots (Fig. 6). Distillation is also done in high-quality stainless steel containers on an industrial scale (Fig. 8). However, all these methods either use fossil fuels such as wood, coal, and LPG or electricity.

Figure 4: Production of cow urine distillate using a glass apparatus

Figure 5: Production of cow urine distillate using the spherical clay pot apparatus

Figure 6: Production of cow urine distillate using a high-quality stainless-steel apparatus

As mentioned earlier, current methods of cow urine distillation require either fossil fuels or electricity. Then the question arises: how much energy is needed for cow urine distillation, and what is its carbon footprint? Energy estimations have been performed to explore answers to these questions, which are presented in Table 4. It shows that, for just 100 kg of cow urine distillation per day, the total energy required for distillation is 2.9 kW. With firewood as the energy source to generate the heat needed, the total CO2 emissions are estimated at 22.6 kg/day (8.2 tons/year). And with LPG as a source of energy, CO_2 emissions per day are 17.4 kg (6.2 Tons) of CO2/year. This value is much higher (almost double) than the global per capita carbon emission (4.7 Tons of CO_2), as shown in Fig. 7. Hence, developing a distillation system with a very low carbon footprint is necessary. This is only possible when the distillation system runs on renewable energy. Solar thermal energy is the most suitable renewable energy source, as the distillation system requires heat for operation. Hence, the present research uses solar thermal energy for distilling cow urine.

Table 1: Estimation of energy, cost and carbon dioxide emission for 100 kg/day cow urine distillation

Sn.	Parameter	Value	Unit
1.	Inlet cow urine temperature	30	ºC
2.	Boiling temperature	100	ºC
3.	Mass of cow urine	1	kg
4.	Latent heat of cow urine	2,257	kJ/kg
5.	Specific heat of cow urine	4.2	kJ/kg K
6.	Sensible heat required for distillation	294	kJ/kg
7.	Latent heat required for distillation	2,257	kJ/kg
8.	Total heat required	2,551	kJ/kg
9.	Capacity: 100 kg of cow urine distillation per day	100	kg/day
10.	Total heat required to distillate the required capacity of cow urine	2,55,100	kJ/day
11.	Total heat required to distillate the needed capacity of cow urine in kW	2.9	kW
12.	The calorific value of firewood	18,000	kJ/kg
13.	The calorific value of LPG	44,000	kJ/kg
14.	Mass of firewood required for the given capacity of cow urine distillation	14.1	kg/day
15.	Mass of LPG required for the given capacity of cow urine distillation	5.8	kg/day
16.	The cost of 1 kg of firewood	15	₹/kg
17.	The cost of 1 kg of LPG	66.6	₹/kg
18.	Expenditure for the distillation of a given capacity of cow urine using firewood	212.5	₹
19.	Expenditure for the distillation of a given capacity of cow urine using LPG	386.5	₹
20.	Carbon emission per kg of firewood	1.6	kg/kg of firewood
21.	Carbon emission per kg of LPG	3	kg/kg of LPG
22.	Carbon emission for a given capacity of cow urine distillation using firewood	22.6	kg of CO_2/day
23.	Carbon emission for a given capacity of cow urine distillation using LPG	17.4	kg of CO_2/day

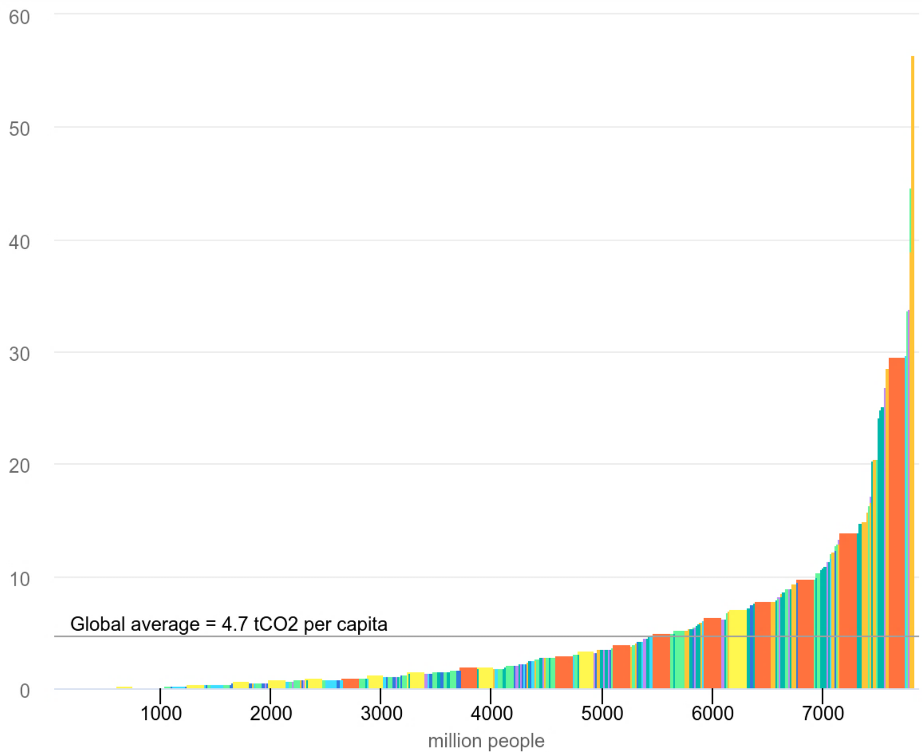


Figure 7: IEA, Energy-related CO_2 emissions per capita by income decile by regions, 2021, IEA, Paris https://www.iea.org/data-and-statistics/charts/energy-related-co2-emissions-per-capita-by-income-decile-by-regions-2021, IEA.

The specific objectives of the present research work are as follows:

a) To design and fabricate a cost-effective, environment-friendly cow urine distillation unit running on solar thermal energy for rural communities and cow shed owners.

b) To investigate the techno-economic performance of the developed system.

c) To check the therapeutic properties of distilled cow urine using solar thermal energy.

As mentioned earlier, the present cow urine distillation systems are expensive, energy-intensive, difficult to operate and maintain for a common person, and highly polluting to the environment. Hence, the present research illustrates a cost-effective, environment-friendly, easy-to-operate and maintain solar thermal hydrodistillation system for the production of cow urine distillate. The authors believe that no investigator has investigated such work to date.

The next section of the article outlines the materials used to build a solar thermal hydrodistillation system for distilling cow urine. It also shows the approach taken for experimental study and chemical analysis of the distilled cow urine using the constructed system.

3. MATERIALS AND METHODS

After the rigorous literature review [30-60], the solar thermal hydrodistillation system was designed and fabricated for the distillation of cow urine. High-quality cow urine typically refers to urine from healthy cows that are naturally raised (i.e., cows that have never been given growth-promoting hormones or antibiotics) and fed a natural diet [61]. The quantity of high-quality cow urine from only one type of breed of cows (not cow urine with a mixture of different kinds of cow breeds) is needed to make high-quality cow urine distillate. For the present research, cow urine of Gir cows was collected from "Gorakshan Gaudhala" (cow shed), Nagpur (21.1458° N, 79.0882° E), Maharashtra, India. The Kathiawar peninsula (20.7493° N, 70.9979° E) in Gujarat, India, is the birthplace of the Gir cow, a breed of Zebuine cattle. The name originates from the Gir Hills and the surrounding woods. The photograph of the Gir cows is shown in Fig. 8.

Figure 8: Indian Gir Cows [62]

The collected cow urine of the desired quality was filtered to remove impurities, then distilled. The fabricated solar thermal hydrodistillation system was tested at Nagpur (21.1458° N, 79.0882° E), Maharashtra, India. The hourly temperature readings were taken for (a) absorber plate, (b) cow urine, (c) inside vapour, (d) atmospheric temperature and (e) condenser glass cover. In addition, hourly cow urine distillate yield and wind velocity were recorded. These observations were used to investigate the thermodynamic and economic performance. In addition to thermodynamic analysis, pharmacological analysis was performed using gas chromatography and mass spectrometry. Anti-anxiety, anti-depression, anti-cancer and anti-diabetic trials were conducted on mice. The investigated chemical properties were also compared with cow urine distillates available on the market to assess their efficacy. Based on thermodynamic, economic and pharmacological test results, conclusions were drawn. Fig. 9 shows the steps used to conduct the present research work, which are self-explanatory.

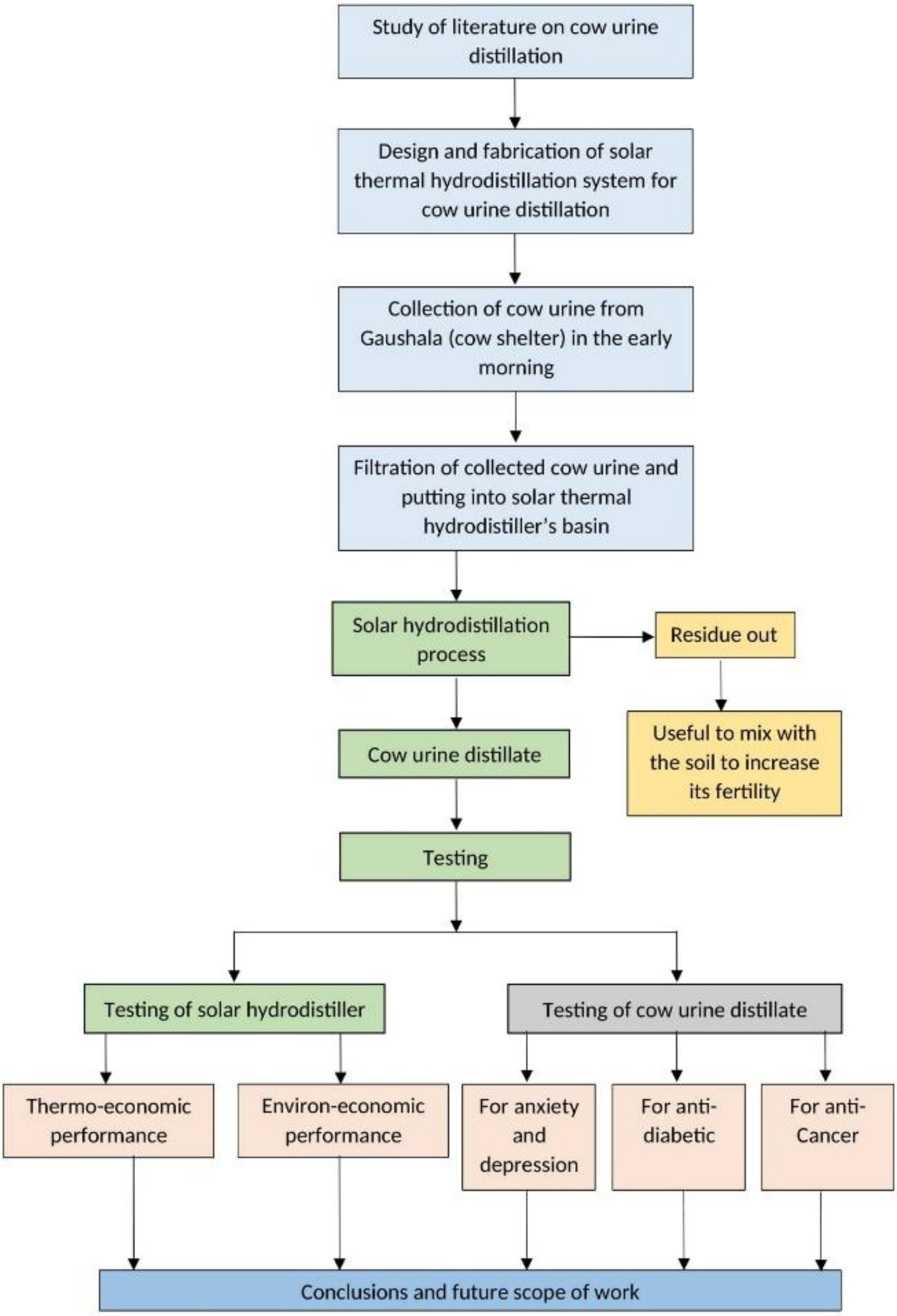


Figure 9: Steps used to conduct the present research work

The forthcoming section of the manuscript illustrates the design and fabrication of a solar thermal hydro-distillation system for cow urine distillation.

4. Design and fabrication of a novel solar thermal hydrodistillation system for cow urine distillation

4.1 Design of solar distiller for cow urine extraction

The first step before fabricating a solar thermal hydrodistillation system for cow urine distillation is to find and fix the dimensions of the distiller. This has been done by applying basic thermodynamic equations. However, some values and constants must be assumed before applying these equations. Table 5 illustrates the several values and constants used in the design process.

Table 2: Assumptions

Sn	Parameter	Notations	Unit	Value	Ref.
A-1	Average cow urine production	--	Kg per cow per day	7	[63]
A-2	Total farmers in India	--	million	120	[64]
A-3	Total cows in India	--	million	193	[65,66]
A-4	Average no. of cows per farmer	--	No.	2	Using A-2 & A-3
A-5	Total cow urine availability	--	Kg/day	14	Using A-1 & A-4
For a solar distiller					
A-6	Input quantity of cow urine for distillation per day	m_{ew}	kg/day	10	Using A-5 with some loss, such as filtration, etc. (5 kg/day per cow)
A-7	Useful sunshine	Time (9 am to 5 pm (8 hr)	Sec	28,800	From actual measurement
A-8	Average solar energy available at Nagpur	I(t)	kW/m^2	0.6	From actual measurement
A-9	Latent heat of cow urine	h_{fg}	KJ/kg	2,257	Same as water
A-10	transmissivity of glass	$(Tou)_g$	--	0.9	[67]
A-11	Absorptivity of the absorber plate	$(alpha)_p$	--	0.9	[67]
A-12	Transmissivity of cow urine	$(Tou)_{Cu}$	--	0.1	[67]
A-13	Heat loss coefficient (10%)	$(Q)_{loss}$	--	0.1	Assumed

After defining suitable assumptions (A-1 to A-13) in Table 5, thermodynamic and energy balance equations (as per the first law of thermodynamics) were used, and dimensions of the solar thermal hydrodistillation system were finalised. The detailed estimation of dimensions is given in the Table. 6. From this estimation, it has been found that to process 10 kg of cow urine per day, the size of the distiller required (i.e., its base area) is 2 m^2.

Table 3: Estimation of dimensions of solar distiller

Sn	Estimated value	Notation	Equation	Unit	Value
1.	Latent heat required (LH)	Q_{req}	$m_{ew} \times h_{fg}$	kJ/day	22570
2.	Total energy absorbed by the absorber plate	$(Q)_{in}$	$I(t) \times (Tou)_g \times (Tou)_{Cu} \times (alpha)_p \times Time$	kJ/m^2 per day	12597.12
3.	Heat loss from the surfaces of the solar still	$(Q)_{loss}$	$(Q)_{in} \times$ heat loss coefficient	kJ/m^2 per day	1259.71
4.	Actual heat input	$(Q)_{actual}$	$(Q)_{in}-(Q)_{loss}$	kJ/m^2 per day	11337.41
5.	The area of the absorber plate required	A	$(Q)_{required}/(Q)_{actual}$	m^2	1.99
6.	The Length of the solar still	L	Assumed	m	2.00
7.	The width of the solar still	W	Area/Length	m	1.00

4.2 Fabrication of solar thermal hydrodistiller

As per the estimated solar hydrodistiller's dimensions (as given in Table 6), the base area (called the absorber plate) was selected as 2000 mm × 1000 mm (L×W). The condenser glass cover angle was set to 210 ° (equal to the latitude of Nagpur city, 21.1458° N). The dimensions of the other surfaces of the solar hydrodistiller were calculated as shown in Fig. 10. The base plate, front, back, and side walls were fabricated from clear glass (4 mm thickness, thermal conductivity = 0.96 W/m · K [67]). The fabricated tank was covered with an openable door made up of clear glass (4 mm thickness, thermal conductivity= 0.96 W/m K [67]) fixed in the aluminium frame, as shown in Fig. 11. The outer surfaces were covered with insulation (thermal conductivity= 0.038 W/m K [67]) to reduce the heat transfer from the distiller during its operation. The entire assembly was kept on a mild-steel rectangular stand facing south, since India is located in the Earth's northern hemisphere, as shown in Fig. 12.

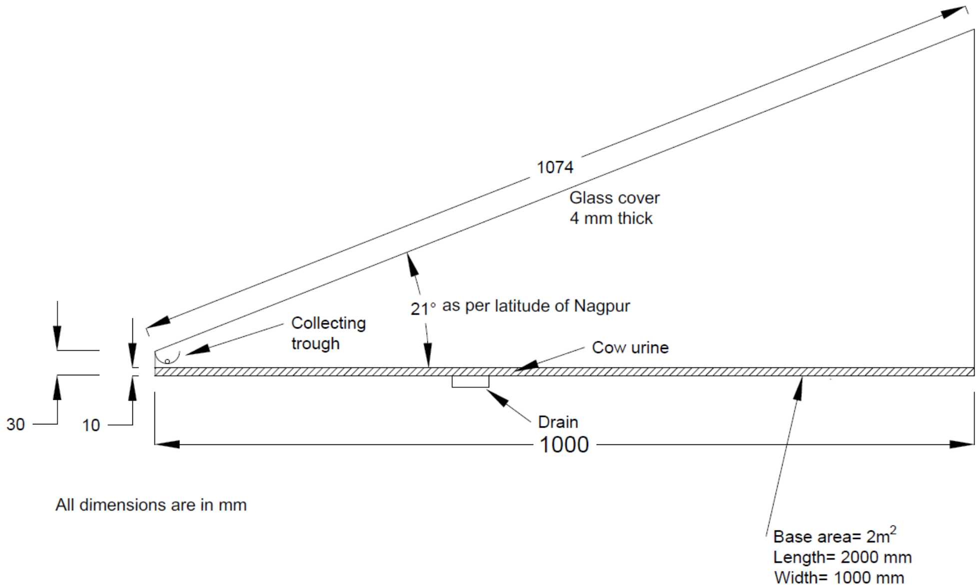


Figure 10: Dimensions of solar thermal hydrodistillation system for cow urine distillation

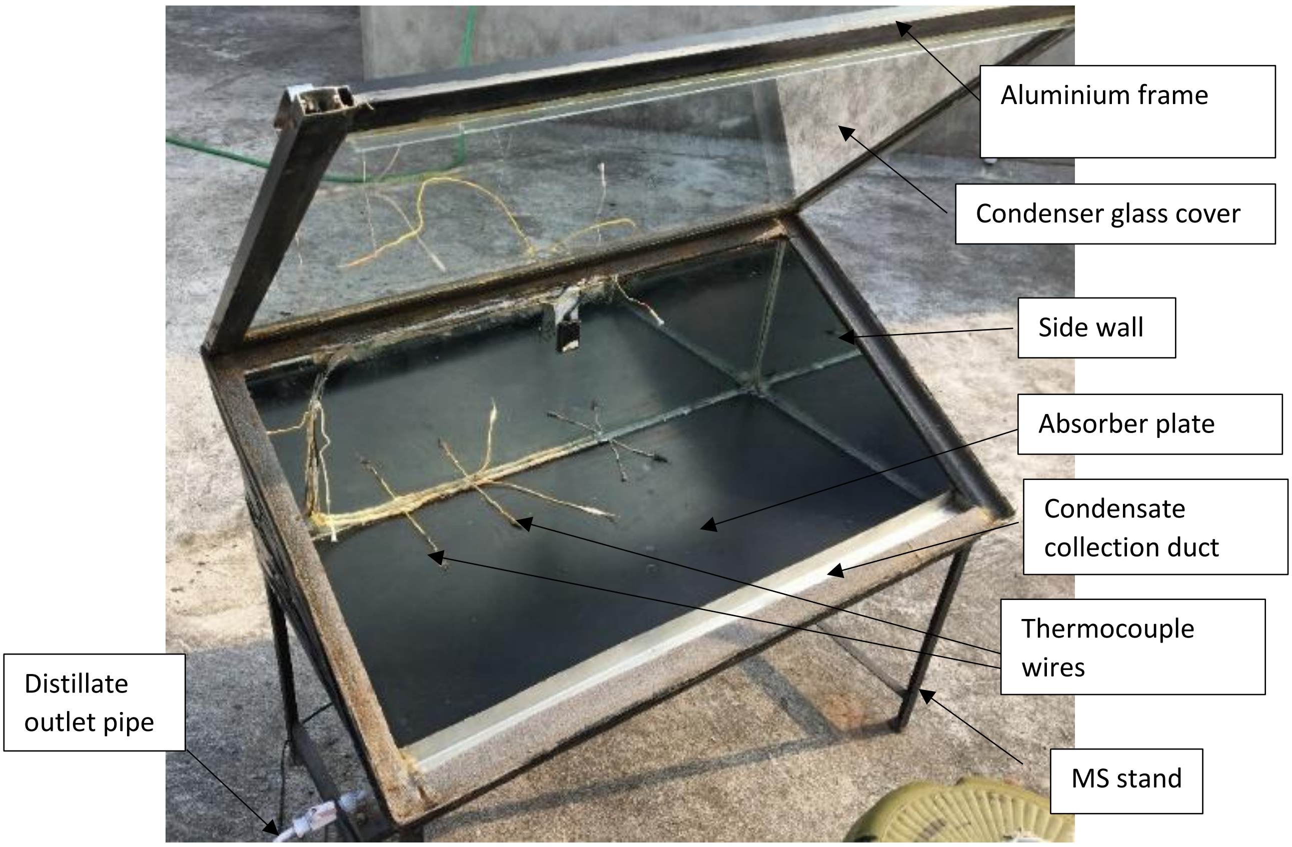


Figure 11: Photograph of the fabricated solar thermal hydrodistiller for cow urine distillation (glass door opened)

Figure 12: Photograph of a fabricated solar thermal hydrodistiller for cow urine distillation

(Glassdoor closed)

4.3 Working of solar thermal hydrodistiller for cow urine distillation

The high-quality cow urine from single-breed cows was kept in the distiller basin. When solar radiation enters the distiller through the top glass cover, cow urine, being dark brown, quickly absorbs solar energy. Cow urine vapour thus formed and travelled upwards. When they came in contact with the glass cover, they quickly condensed the underside of the glass cover by rejecting the heat to the atmosphere, as shown in Fig. 13. Since the condensing glass cover was inclined, all condensed droplets were slide down and collected in the condensate collection duct (which is shown in Fig. 14). The condensate collected in the duct, was taken out from the distiller (which is called as cow urine distillate) was stored in glass bottle and packed in the 100 ml size bottles for selling in the market as shown in Fig. 14 (a) and (b). The collected condensate was absolutely clean, transparent, and ready to drink.

Figure 13: Condensation of cow urine vapour, underside of the glass cover, which is called cow urine distillate

(a) Cow urine distillate stored in a glass bottle

(b) Cow urine distillate stored in a 100 ml bottle (ready to sell)

Figure 14: Cow urine distillate produced using a solar thermal hydrodistillation system

Figure 15:

Market sample 1- PDGA

Figure 16:

Market sample 2- SSGA

Figure 17:

Market sample 3- GVAK

Three types of cow urine distillate available in the market were procured to estimate the quality of the distilled cow urine using a solar-thermal hydrodistillation system. They are shown in Figs. 15, 16 and 17.

5. Results and discussions

After several months of testing, the observations were recorded and analysed to evaluate the performance of the fabricated solar thermal hydrodistiller for cow urine distillation. This section describes the experimental results and discusses their interpretation. In addition to this, chemical analysis of prepared cow urine distillate using a solar thermal hydrodistillation system and its effect on several diseases like anxiety, depression, diabetes, and cancer have also been discussed.

5.1 Analysis of experimental results of solar thermal hydrodistillation system

Fig. 20 illustrates the temperature differences between the absorber plate and the cow urine basin. The change in cow urine temperature and absorber plate temperature is practically the same, and there is very little difference between these two temperatures. This is a fascinating observation. This is because cow urine is dark brown, similar to the colour of the absorber plate. As a result, cow urine absorbs more heat from the sun in addition to absorbing the heat that arises from the absorber plate. The maximum absorber plate and effluent temperature values were 70^{0}C and 60^{0}C, respectively. Their average values were 57^{0}C and 55^{0}C, respectively.

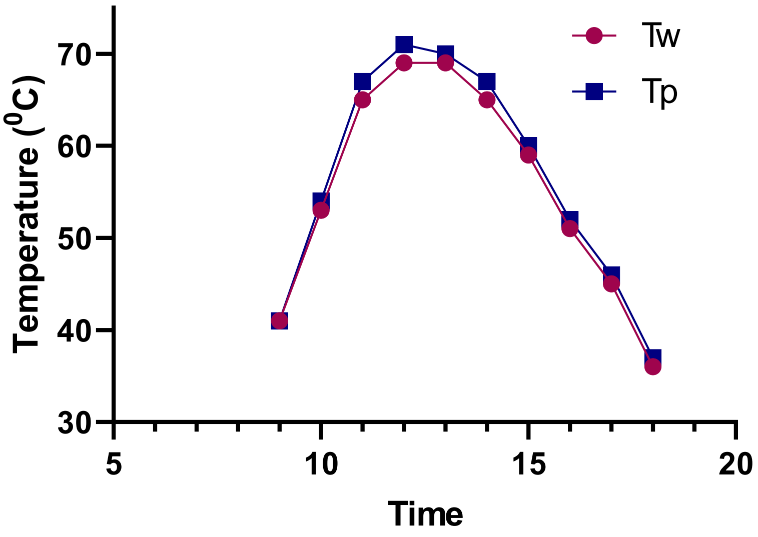


Figure 18: Variation in absorber plate temperature (Tp) and cow urine temperature (Tw) inside the solar thermal hydrodistillation system on a typical day

Fig. 19 depicts temperature fluctuations in the condenser glass cover (Tg), bottom surface temperature of the distiller (Tb), and air temperature (Ta). All of these temperatures exhibit comparable fluctuations. Their values were lower in the morning, but as the day proceeded, all temperatures rose to their maximum values of 60^{0}C, 49^{0}C, and 41.1^{0}C, respectively. Their average temperatures were 47^{0}C, 42.3^{0}C, and 38.8^{0}C, respectively.

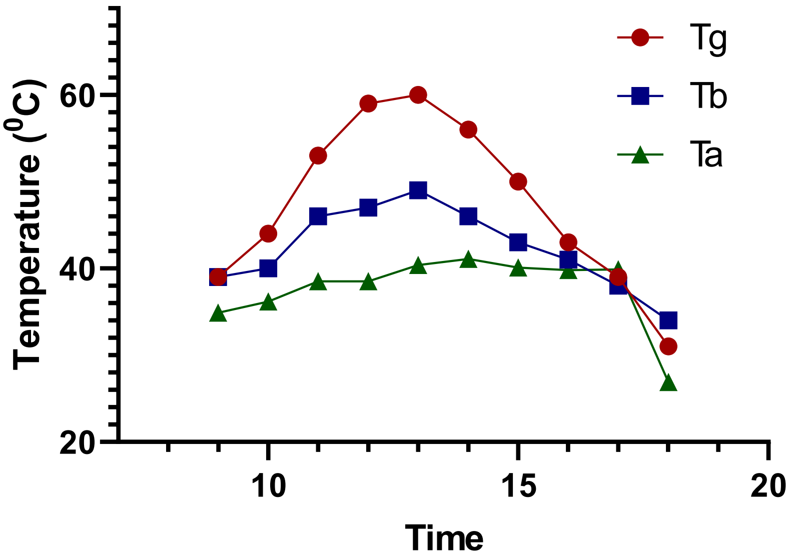


Figure 19: Variation in condenser glass cover temperature (Tg), bottom temperature (Tb) of solar thermal hydrodistiller and atmospheric temperature (Ta) on a typical day

The productivity of a solar thermal hydrodistillation system, measured per day or hour, is of the highest importance. This refers to the amount of cow urine distillate obtained per square metre of the absorber plate. The differences in hourly yield are shown in Fig. 20. It has been observed that it performs its function by attentively following the path of the solar radiation that falls on the solar still. At 2 p.m., when solar irradiance was 836 W/m2, the highest hourly yield was 0.337 kg/hr. The overall yield was 1.69 kg per day for a 0.45 square metre area. As a result, the expected yield was between 3 to 4 kg per day per square metre area of absorber plate.

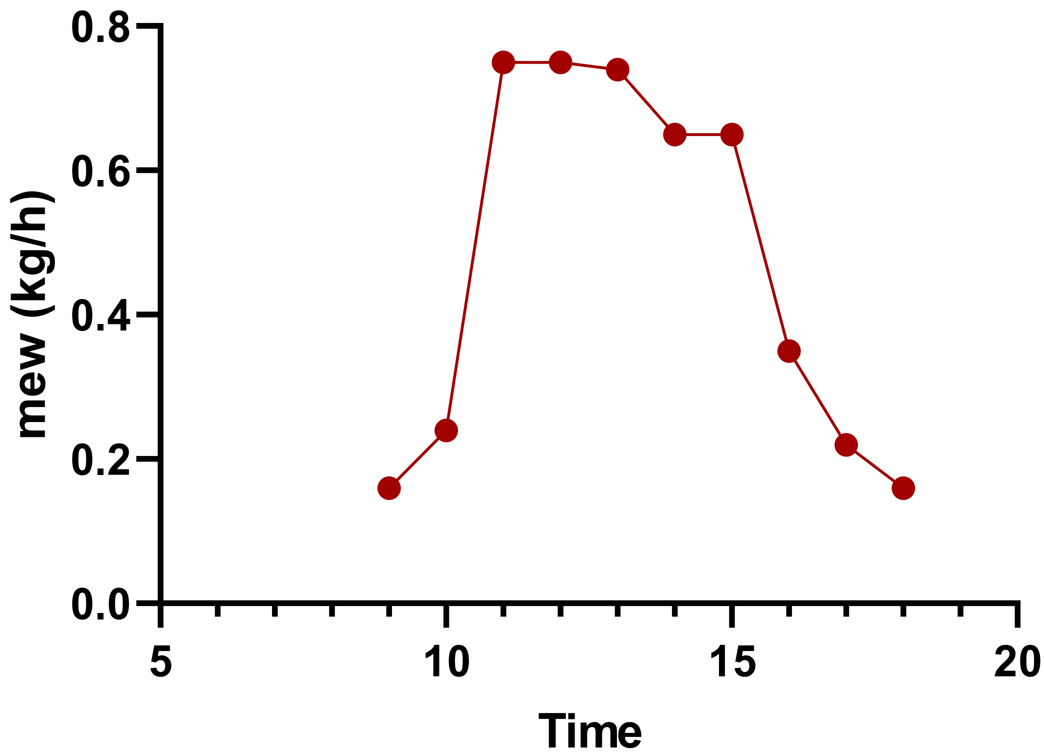


Figure 20: Variation in the yield of cow urine distillate from solar thermal hydrodistiller on a typical day

5.2 Chemical analysis of cow urine distillate prepared using a solar thermal hydrodistillation system and its comparison with the cow urine distillates available in the market

Gas chromatography-mass spectrometry (GC-MS) is a method used to identify chemicals present in a given sample. This technique is applicable for analysing volatile and non-volatile compounds, including sulphur [68]. GC-MS analysis of prepared cow urine distillate obtained by solar-thermal hydrodistillation was performed to identify chemical compounds. Table 7 presents all components in the prepared cow urine distillate and their composition, expressed as percentages by volume. It shows that the primary compound in the distillate was Phosphonic acid, phenyl-, bis [5-methyl-2-(1-methyl ethyl) cyclohexyl ester (81.13%). It is a chemical used to eliminate fungal infections. It is an essential antiviral medication used in various prodrug formulations to treat cancer, HIV, and hepatitis B. It also works as an antibiotic to treat urinary tract infections. Anti-nausea drugs often include it. It also works as an antimalarial. It may affect anxiety-related behaviour by reducing oxidative stress. It also works as an electrolyte in fuel cells and oxyhydrogen generators [69]. The benefits of other identified compounds in the prepared cow urine distillate, along with their percentage by volume, are given in the Table. 8.

Table 4: GC-MS of cow urine distillate prepared using a solar thermal hydrodistillation system

S.N.	Test Parameter	Sr. no.	Test Result	% contents
1.	Identification of compounds by GC-MS	1.	Dibutyl phthalate	3.26
		2.	Phthalic acid, di(2- propyl pentyl) ester	0.53
		3.	Hexadecanoic acid, 2,3- bis (acetyloxy) propyl ester	1.01
		4.	Squalene	0.61
		5.	Octadecanoic acid, 2-[(acetyloxy)-1-(acetyloxy) methyl]ethyl ester	4.21
		6.	Octadecanoic acid, 2,3-bis (acetyloxy) propyl ester	9.24
		7.	Phosphonic acid, phenyl-, bis [5-methyl-2- (1-methyl ethyl) cyclohexyl ester	81.13

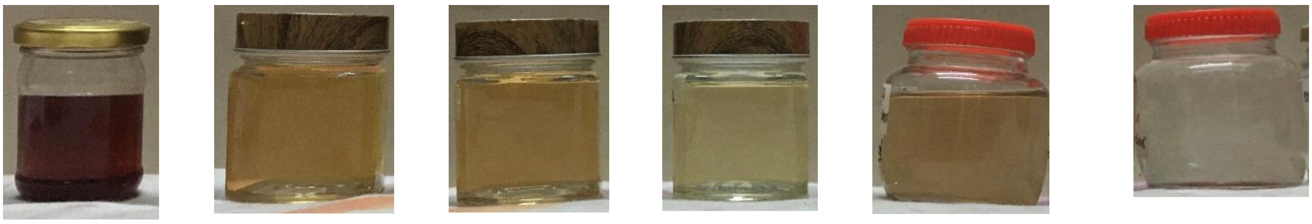
Table 5: Benefits of compounds found in cow urine distillate produced using solar energy

Sn	Compound	% contents	Effect of compound
1.	Dibutyl phthalate	3.26	It is an insect repellent
2.	Phthalic acid, di (2- propyl pentyl) ester	0.53	In addition to being cytotoxic, it also has antibacterial, antifungal, and anti-carcinogenic properties. It is very effective against breast cancer.
3.	Hexadecanoic acid, 2,3- bis (acetyloxy) propyl ester	1.01	It may help cure rheumatic symptoms. It possesses high antioxidant and radical scavenging properties. It promotes both skin health and metabolic wellness.
4.	Squalane	0.61	Squalane is an effective moisturiser that stops water loss from the skin. It may also help keep hair hydrated. Squalane may help improve the appearance of visual signs of ageing. Squalane may help protect the body from environmental stressors such as pollution and sun exposure. It may also help minimise inflammation and free radical damage.
5.	Octadecanoic acid, 2-[(acetyloxy)-1-(acetyloxy) methyl]ethyl ester	4.21	It promotes skin hydration and moisture retention, as well as softening and soothing the skin.
6.	Octadecanoic acid, 2,3-bis (acetyloxy) propyl ester	9.24	It has antimicrobial effects.
7.	Phosphonic acid, phenyl, bis [5-methyl-2- (1-methyl ethyl) cyclohexyl ester	81.13	A chemical used to eradicate fungal infestations. It is a crucial antiviral pharmaceutical used in different prodrug formulations to treat cancer, HIV, and hepatitis B. It is also an antibiotic used to treat urinary tract infections. Anti-nausea medications often include it. It also serves as an antimalarial. It may influence anxiety-related behaviour by lowering oxidative stress. It is also helpful as an electrolyte in fuel cells and oxyhydrogen generators.

5.3 Comparison of the prepared cow urine distillate with the cow urine distillate available in the market

After initial testing of the hydrodistiller and GC-MS analysis of the prepared cow urine distillate, it was essential to compare its quality with cow urine distillates available on the market. For this purpose, three cow urine distillate samples were purchased from the market.

Fig. 21 (a) to Fig. 21 (f) shows the appearance of different samples. It shows that the original cow urine was dark brown in colour. The cow urine distillate samples purchased from the market were light brown in colour. However, the cow urine distillate prepared using a solar-thermal hydrodistillation system was clear and transparent, resembling clean distilled water.



(a) Original cow urine sample | (b) Market sample PDGA | (c) Market sample SSGA | (d) Market sample GVAK | (e) Extracted using a pressure cooker | (f) Extracted using solar hydrodistillation

Figure 21: Appearance of different samples

To understand why there was so much difference in the appearance of the cow urine distillate, it was necessary to understand and model the industrial process of cow urine distillation. For this purpose, pressure cooker-based cow urine distillation was done, as shown in Fig. 21. And by observing the appearance of cow urine distillate obtained from the pressure cooker system, it can be quickly concluded that because of boiling the cow urine at comparatively higher temperature (usually more than 100^0C), the condensed distillate was light brown in colour as shown in Fig. 21 (e); hence the colour of all the distillate purchased from market was light brown. However, in the solar thermal hydrodistillation system, heating was slow and gentle by using solar radiation, and evaporation of cow urine occurred (not boiling. Boiling is the rapid vaporisation of a liquid at its boiling point throughout the liquid, while evaporation is the slow conversion of liquid into vapour at the liquid's surface [70]). Hence, the appearance and chemical properties of cow urine distillate prepared by solar hydrodistillation were significantly different from those of the cow urine distillate purchased from the market and prepared using a pressure cooker. Fig. 23 shows the condenser's top view photograph. Boiling a liquid at higher temperatures increases the thermal dissociation rate of its molecules [71]. Hence, a higher number of compounds were observed for cow urine distillates purchased from the market (9 to 40 compounds); however, the number of compounds were significantly less in the cow urine distillate produced by using solar thermal hydrodistillation system at gentle heating (only seven compounds) as shown in Fig. 24. The highest number of compounds found in market sample GVAK (40 compounds). It indicates that they are preparing cow urine distillate at a comparatively higher temperature. In this case, the number of chemical compounds was even more than in the original cow urine sample (18 compounds). Table 9 shows the significant compounds found in different samples using GC-MS. Another fascinating observation is that the compound p-Cresol was found in all samples except cow urine distillate prepared by a solar hydrodistiller. Cresols are corrosive chemicals that may severely irritate and burn the skin and eyes, perhaps causing eye injury [72]. However, phosphonic (phosphoric) acid was detected only in cow urine distillate prepared with a solar hydrodistiller. The usefulness of this compound is already stated in the earlier section of the article (please see Table 8).

Hence, by comparing and analysing the chemical composition of all samples, it can be easily concluded that the market-based cow urine sample prepared using a solar thermal hydrodistillation system is more effective against human diseases than other cow urine distillate samples. This was also demonstrated in an animal test (discussed in the forthcoming section).

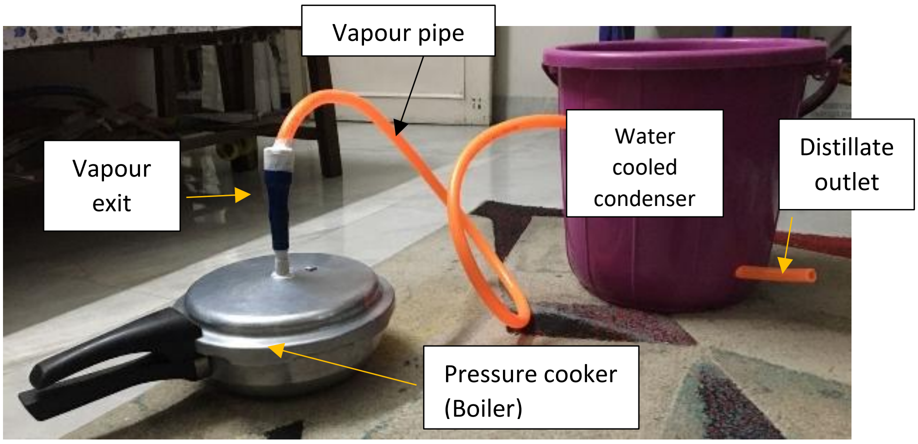


Figure 22: Cow urine distillation using a pressure cooker (to model the industrial cow urine distillation process)

Figure 23: Water-cooled condenser used to condense cow urine vapour generated by a pressure cooker (Top view)

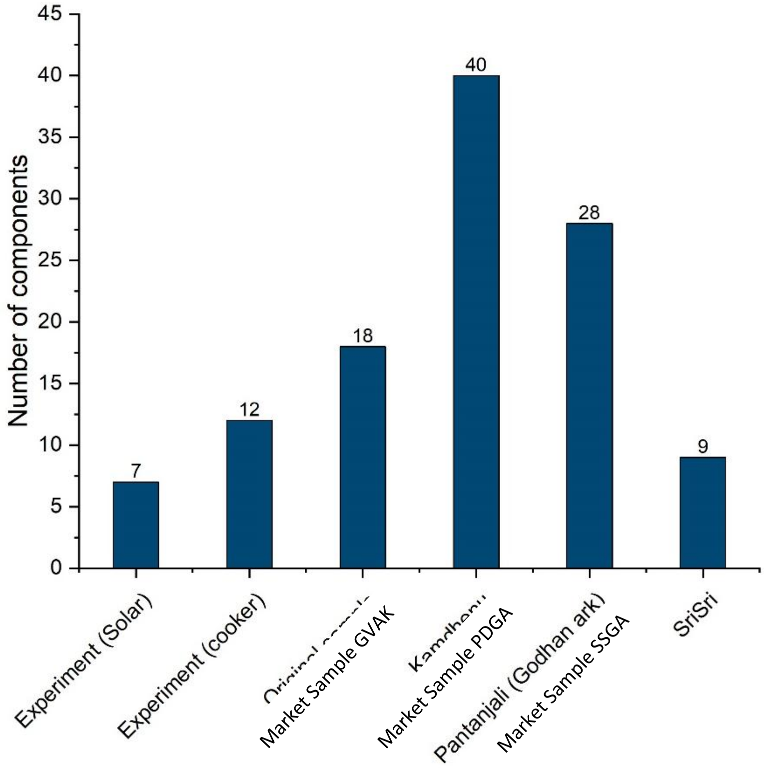


Figure 24: Number of compounds found in different samples of cow urine distillate

Table 6: Number of chemical compounds found in different samples

Type of CUD	Compounds	%
Gir-Solar	Phosphonic acid (Phosphoric acid), phenyl-, bis [5-methyl-2- (1-methyl ethyl) cyclohexyl ester]	81.13
	Octadecanoic acid, 2,3-bis (acetyloxy) propyl ester	9.24
Gir-Cooker	p-Cresol	43.55
	Di-butyl phthalate	20.13
	Phenol, 4-ethyl-	12.07
	4-Azido-2,7-dioxatricyclo l4.4.0.0(3,8)] decane	9.97
Gir-Cow Urine	p-Cresol	27.55
	Benzamide, 2-amino-N-(4-methoxyphenyl)	28.1
	Undeca-3,4-diene-2,10-dione, 5,6,6-trimethyl-	9.51
Market sample GVAK	p-Cresol	11.29
	Dibutyl phthalate	34.6
Market sample PDGA	p-Cresol	45.03
	Phenol, 3-propyl-	9.12
Market sample SSGA	p-Cresol	62.95
	Phenol, 3-propyl-	23.19

5.4 Comparison of the presence of Ammonia and Nitrogen

Ammonia has a pungent odour and unpleasant effects. It is an alkaline and caustic substance [73]. Nitrogen provides plants with the energy they need to grow. It is necessary for all life on Earth, but too much (above 70%) of it cannot be good [74]. However, nitrogen is vital to living things, too much of it can cause the blood to lack oxygen, a condition known as hypoxia. Hypoxia can hurt the brain very badly and damage it permanently [75]. It is experienced that cow urine and its many distillates (mainly purchased from markets) have a pungent smell. This is because of the presence of a high percentage of ammonia (Fig. 27). Drinking cow urine distillate with such a high percentage of ammonia is extremely difficult. However, the cow urine distillate prepared using a solar thermal hydrodistillation system contains the lowest levels of ammonia and nitrogen (please see Fig. 27). Consequently, the cow urine distillate prepared using solar energy has a negligible smell and is easy to drink for humans without dilution. The percentage of ammonia and nitrogen present in this distillate was 0.88% and 2.25% respectively, which was extremely small (80% smaller) as compared with the average value of ammonia and nitrogen present in the market-based cow urine distillate as shown in Fig. 25.

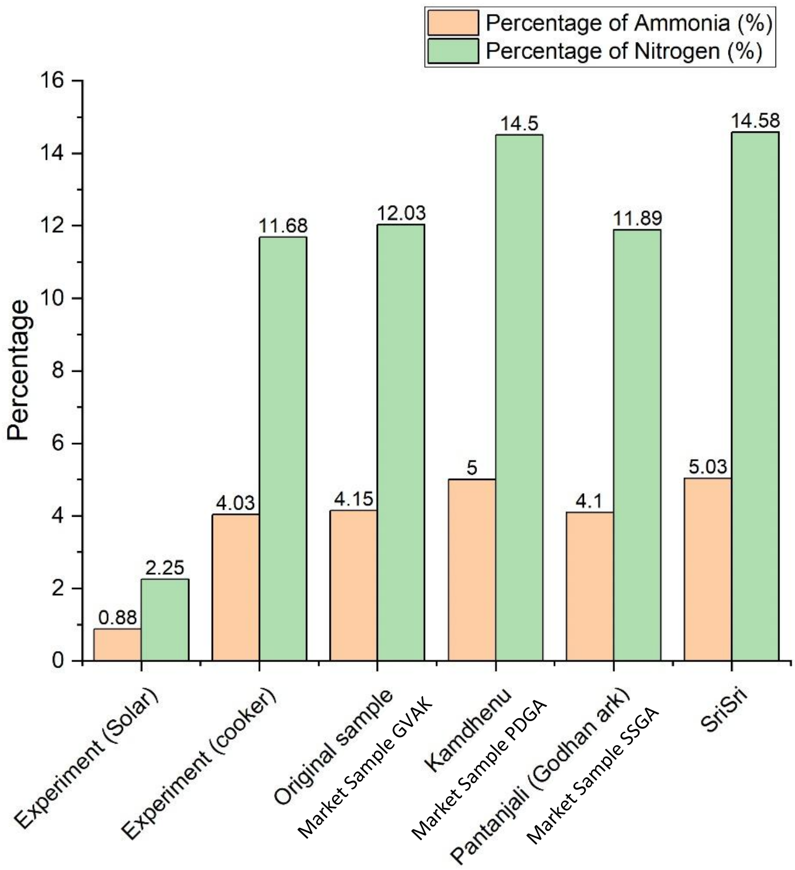


Figure 25: Percentage of ammonia and hydrogen in samples

5.5 Comparison of TDS

Total Dissolved Solids (TDS) is a measurement of the number of substances that are dissolved in water. It is often represented in units of parts per million (ppm) or milligrams per litre (mg/L). Fig. 26 shows the TDS of various samples considered for the testing. It shows that the lowest TDS was recorded for cow urine distillate prepared using a solar-thermal hydrodistillation system (1900 ppm). It was much smaller (85% smaller) than the other cow urine distillate samples purchased from the market. Low TDS indicates it is a high-quality cow urine distillate.

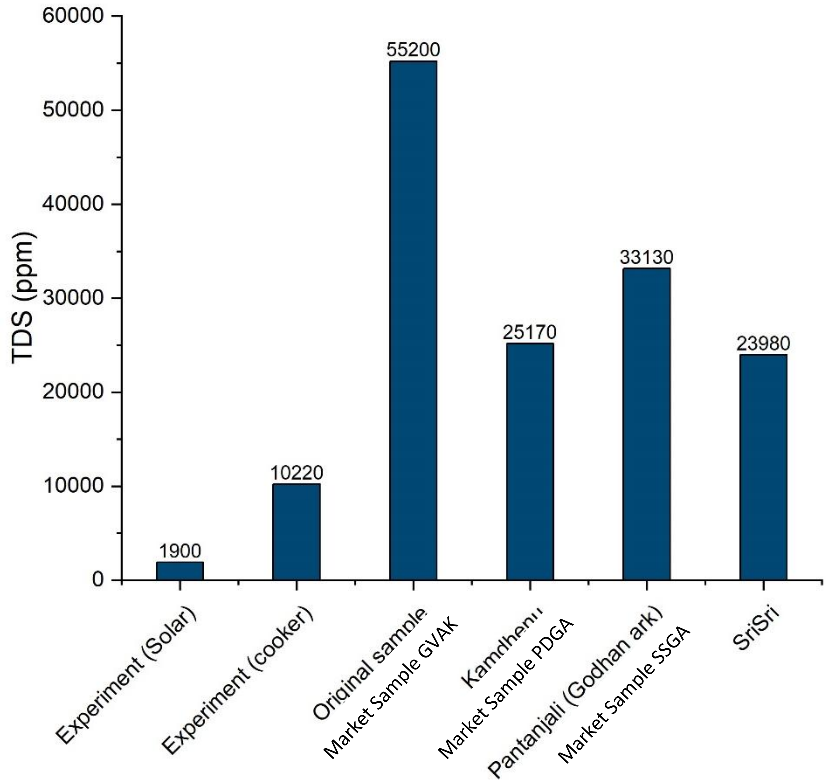


Figure 26: TDS of different samples

5.6 Dose-specific effect of cow urine distillate on anxiety in the elevated plus maze

As shown in Fig. 27, acute administration of diazepam (1.5 mg/kg, i.p.), a positive control and cow urine distillate (0.5–2 ml/kg, i.p.) showed a significant effect on percent open arm entries [F (4, 29) = 36.52, P<0.001] and time spent in open arm [F (4,29) = 21.69, P<0.001] as compared to the respective control group. Post hoc analysis showed a significant increase in open-arm entries [diazepam 1.5mg/kg (P<0.001) and cow urine distillate 1ml/kg & 2ml/kg (P<0.001)] and time spent in open-arm [diazepam 1.5mg/kg (P<0.001) and cow urine distillate 1ml/kg (P<0.01) & 2ml/kg (P<0.001)] but did not affect closed arm entries in these doses. However, the lower dose of cow urine distillate (0.5 ml/kg) was ineffective.

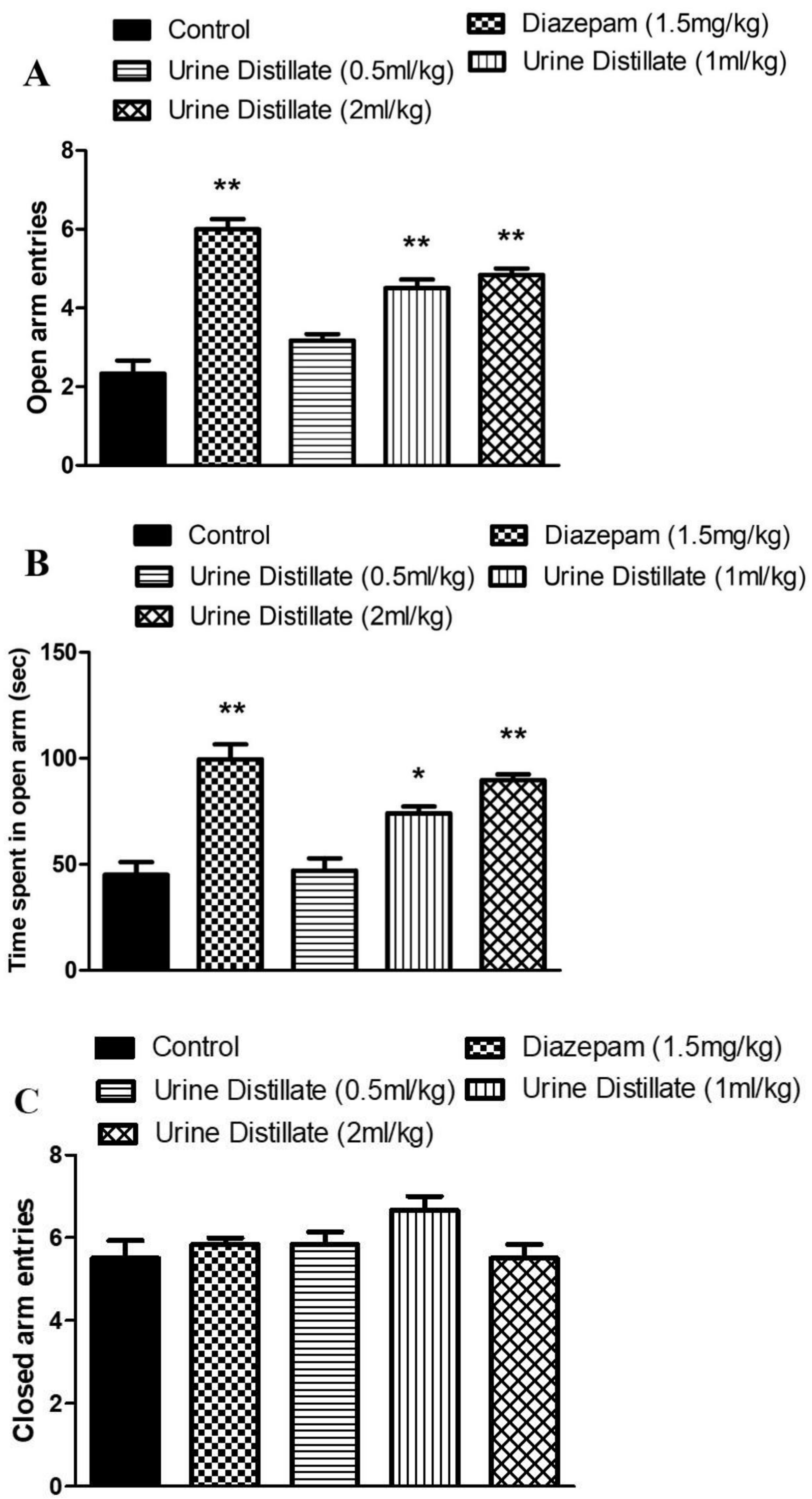


Figure 27: Effect of Urine distillate (0.5-2 ml/kg) on A) Open arm entries, B) Time spent in open arm, and C) Closed arm entries in the EPM test. Each bar represents mean± S.E.M. (n= 6) *P<0.01, **P<0.001 vs respective control (One-way repeated measure ANOVA followed by post hoc Dunnett's test).

5.7 Anti-depressant effect of cow urine distillate in the forced swim test (FST)

As shown in Fig. 28, fluoxetine (40 mg/kg, i.p.), a positive control and urine distillate (2 ml/kg, i.p.) produced a significant dose-dependent reduction in the duration of immobility in rats exposed to FST. [one-way ANOVA: F (4,29) = 40.71, P< 0.001]. However, the lower dose (0.5 & 1 ml/kg) did not significantly affect immobility duration compared to the control group.

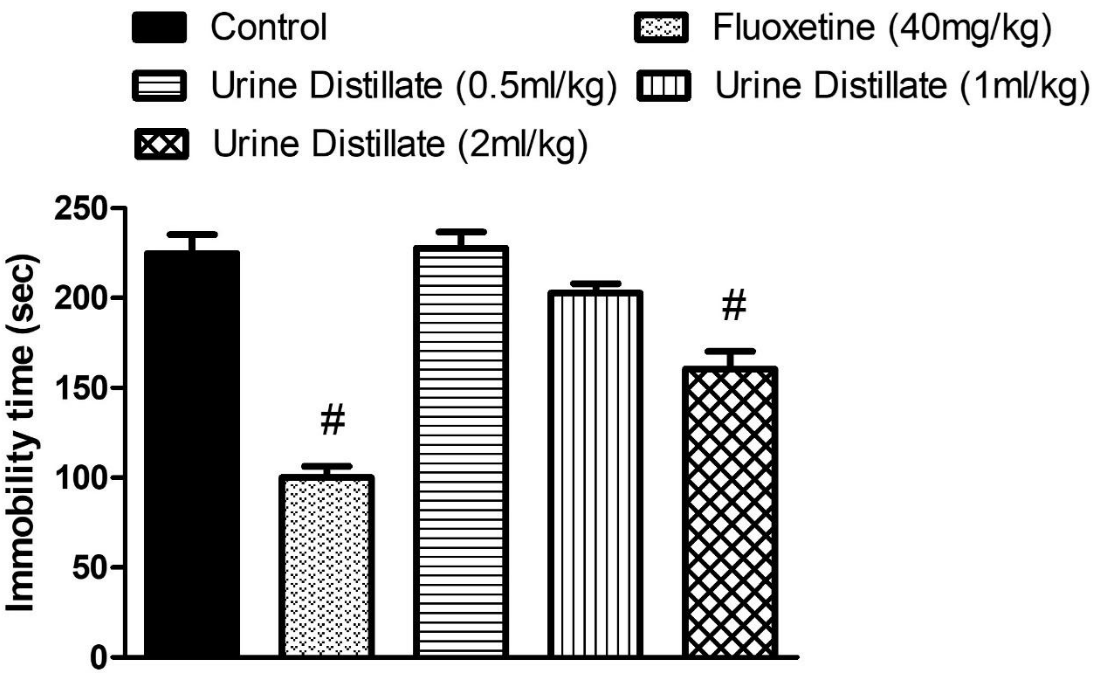


Figure 28: Effect of (A) Cow urine distillate (0.5-ml/kg, i.p.) on antidepressant-like effect. Each bar represents the mean immobility time ± SEM (n = 6), with P < 0.001 compared with the respective control group (One-way repeated-measures ANOVA followed by post hoc Dunnett's test).

5.8 Effect of urine distillate on nociception

Fig 29 shows thermal nociception in the tail-flick test, assessed as the latency to tail withdrawal when subjected to heat. When administered agmatine (40mg/kg, i.p.) as a positive control, it showed a significant increase in flick latency (antinociceptive effect), but urine distillate (0.5-2 ml/kg, i.p.) was ineffective compared with the control group. [One-way ANOVA: F (4,29) = 60.60, P<0.001].

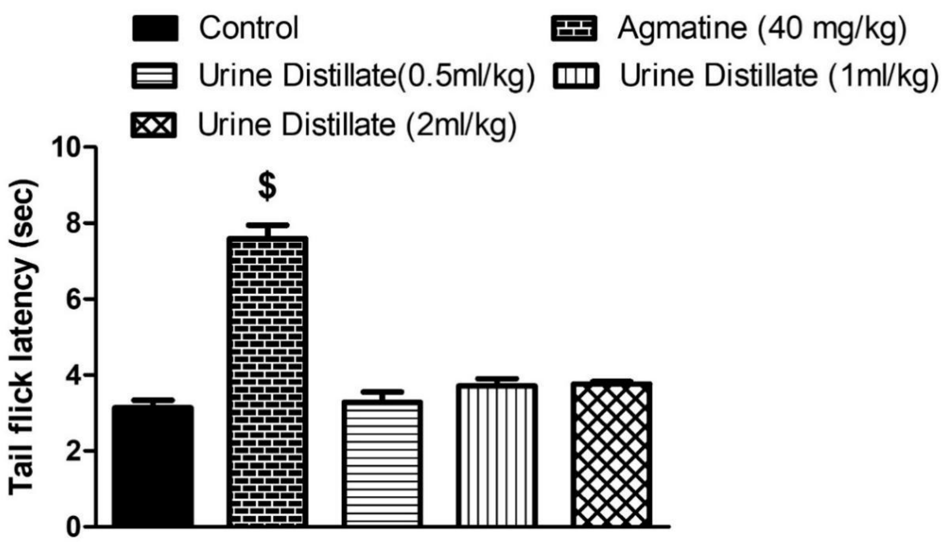


Figure 29: Effect of (A) Cow urine distillate (0.5-2 ml/kg, i.p.) on nociception. Each bar represents the ±SEM (n =6), P < 0.001 when compared with the respective control group (One-way repeated measure ANOVA followed by post hoc Dunnett's test).

5.9 Effect on locomotor activity

As shown in Fig. 30 (A-C), urine distillate (0.5-2 ml/kg, i.p.) had no significant effect on ambulations, rears, or grooming compared with the control group. OFT was used to evaluate locomotor components and explore animals in new environments. [One-way ANOVA: F (4,29) = 0.7584; rearing F (4,29) = 2.344; grooming F (4,29) = 0.0.3024].

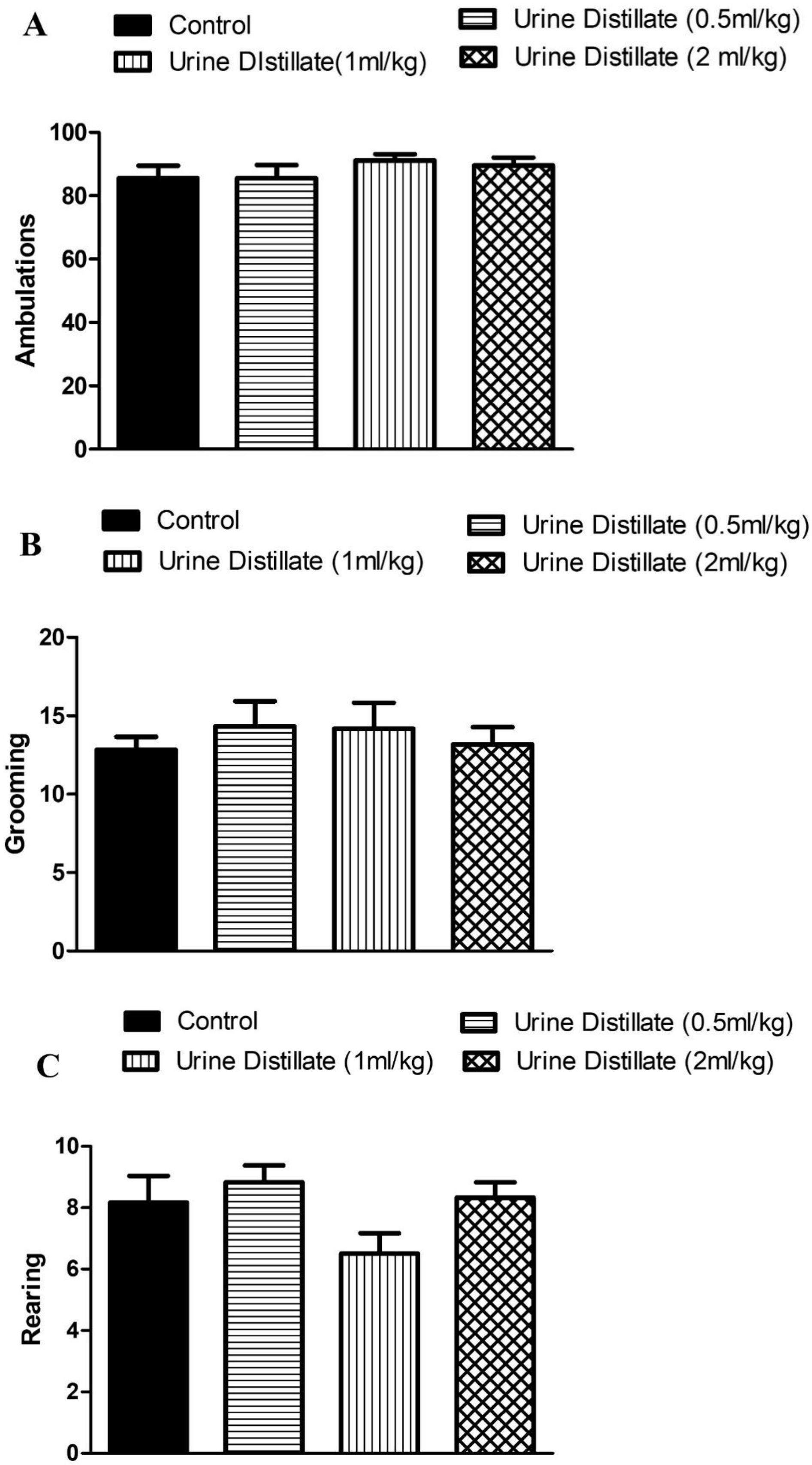


Figure 30: Effect of (A-C) urine distillate (0.5-2 ml/kg, i.p.) on locomotor activity. Each bar represents the ±SEM (n =6) (One-way repeated measure ANOVA followed by post hoc Dunnett's test).

From the above experimental results, it is evident that cow-urine distillate possesses anxiolytic and antidepressant effects. It has also shown a mild, dose-dependent increase in analgesic effect, but higher doses should be tested to confirm a significant impact. No change in the locomotor test indicates that the results obtained for anxiolytic and antidepressant effects have no locomotor (CNS stimulant or depressant) component.

5.10 Anti-diabetes activity

Diabetes is a chronic condition in which the body is unable to make or utilise insulin adequately. Diabetes is defined by high blood glucose (or blood sugar). When insufficient insulin is produced, or cells stop responding to insulin, too much blood sugar accumulates in the circulation. Over time, this may lead to significant health issues, including heart disease, eyesight loss, and renal illness. Diabetes is known by its scientific term, diabetes mellitus [76]. There are three forms of diabetes: type 1, type 2, and gestational diabetes (diabetes during pregnancy). This test used 6 mice (3 males and 3 females). In the first week, animals were given a normal pallet diet (NPD). In the second week, they used a high-fat diet (HFD) with streptozotocin (STZ) (Streptozotocin is a drug used to develop rat models of type I and type II diabetes [77]). By the third week, animals were diabetic, as shown in Fig. 33 (see blood glucose levels). From the fourth week, treatment was started to control the diabetes. Metformin (control condition) was given in addition to cow urine distillate 10%, 20%, and 40% to prevent diabetes. In the seventh week, animal diabetes was under control, as shown in Fig. 33. Similarly, other blood parameters were measured from week 1 to week 7. These test results (shown in Fig. 31 and Table 10) showed that 40% of cow urine distillate prepared using a solar thermal hydrodistiller was a valuable dose for controlling diabetes.

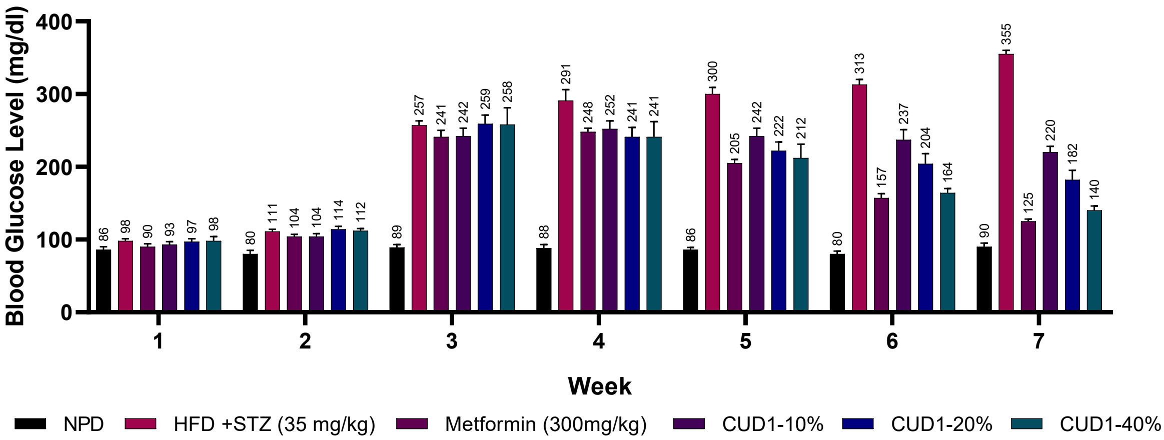


Figure 31: Blood glucose level measurement

Table 7: Blood test results showing the effect of cow urine distillate prepared by a solar thermal hydrodistillation system on controlling blood sugar or diabetes

Sn	Parameter	Value with 40% cow urine distillate	Normal value range
1.	Blood Glucose Level	140	70-150 mg/dl
2.	Blood Cholesterol Level	139	130-160 mg/dl
3.	High-Density Lipoprotein Level	20	30-80 mg/dl
4.	Low-Density Lipoprotein Level	121	130-160 mg/dl
5.	Blood Triglyceride Level	144	26-145 mg/dl
6.	Urea Level	28	14-40 mg/dl
7.	α-Amylase Level	29	Up to 114 U/L
8.	Lipase Level	25	Up to 60 U/L
9.	SGOT Level	74	Up to 75 U/L
10.	SGPT Level	90	Up to 100 U/L
11.	Creatinine Level	1	0.4-1 mg/dl
12.	IPITT	86	70-130 mg/dl
13.	IPGTT	113	Up to 140 mg/dl

5.11 Anti-cancer activity

Cancers are a category of illnesses characterised by abnormal growth of cells. Without a check, the condition may continue to develop [78]. The cancer cell line test results are listed below. Table 11 shows the proportions used to make doses to treat cancer cells in the 786-O cancer cell line. Adriamycin was used as a positive control compound. Tables 11, 12, and 13, and Fig. 32 illustrate the results of treatment for the cancer cell. Fig. 32 shows that, up to 10% cow urine distillate concentration, the growth of cancer cells was controlled; i.e., the number of cancer cells did not increase or decrease. It indicates that cow urine distillate can be used as a bioavailability enhancer for anti-cancer treatment, either directly or in combination with anti-cancer drugs. However, when the cow urine distillate percentage was greater than 10%, there was a decrease in cancer cells, as shown in Fig. 33, 34, and 35.

Table 8: Preparation of doses for cancer treatment

Sample Code	Experiment(s) Concentration(s)			
	1	2	3	4
Cow Urine Extract (%)	2	4	5	10
ADR (µg/ml)	10	20	40	80

Table 9: Test results

1.00	Human Renal Cell Carcinoma Cell Line 786-O % Control Growth Drug Concentrations (µg/ml)															
	Experiment 1				Experiment 2				Experiment 3				Average Values			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Cow Urine Extract	111.1	118.5	107.4	114.2	105.9	121.4	119.6	112.6	105.4	125.6	121.2	119.8	107.5	121.8	116.1	115.5
ADR	-71.6	-76.4	-86.7	-88.1	-67.4	-75.2	-85.8	-89.0	-70.3	-78.6	-87.2	-86.8	-69.7	-76.7	-86.6	-88.0

Table 10: Test results

Drug concentrations calculated from the graph			
786-O	LC50	TGI	GI50
Cow Urine Extract	NE	NE	>10%
ADR (µg/ml)	<10	<10	<10

LC50 = concentration of drug causing 50% cell kill
GI50 = concentration of drug causing 50% inhibition of cell growth
TGI = concentration of drug causing total inhibition of cell growth
ADR = Adriamycin, Positive control compound
NE Non-evaluable data. The experiment needs to be repeated using a different set of drug concentrations.
NA Non-analysable due to microbial contaminant
Note: Erratic data may result from the compound's lower solubility.
GI50 value of ≤ 10^{-6} molars (i.e. 1 µmolar) or ≤ 10µg/ml demonstrates activity in the case of pure compounds. For extracts, a GI50 value ≤ 20 µg/mL is considered indicative of activity.
Yellow-highlighted test values under the GI50 column indicate activity.

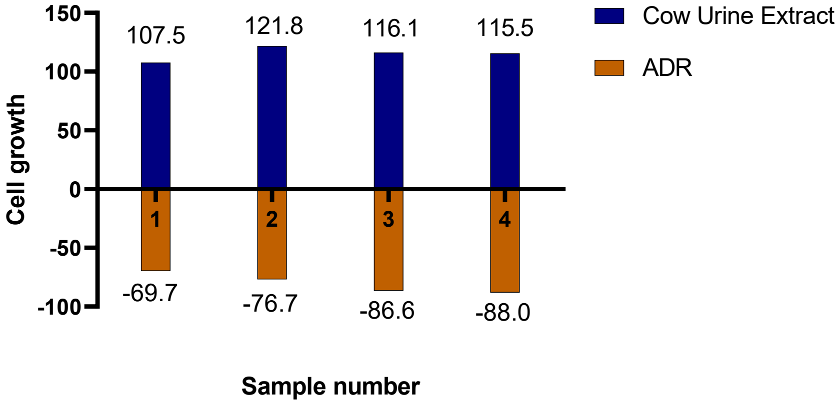


Figure 32: Effect of cow urine distillate on cancer cell growth

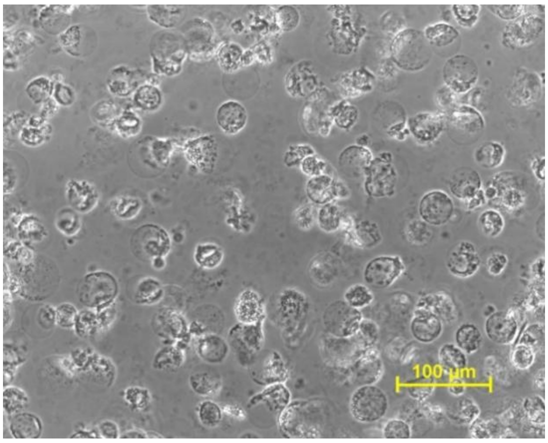


Figure 33: Cancer cells, 786-O cell line

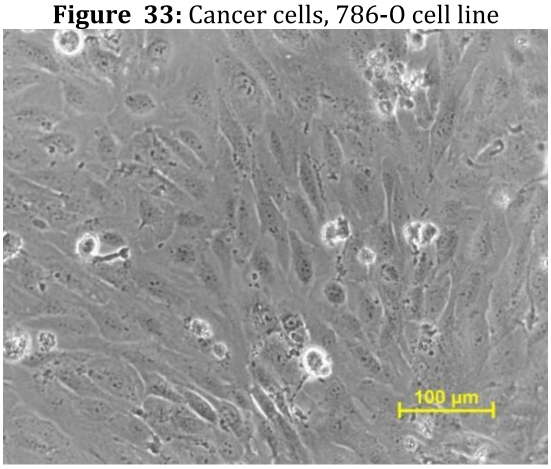


Figure 34: Cancer cells, 786-O Control condition, ADR

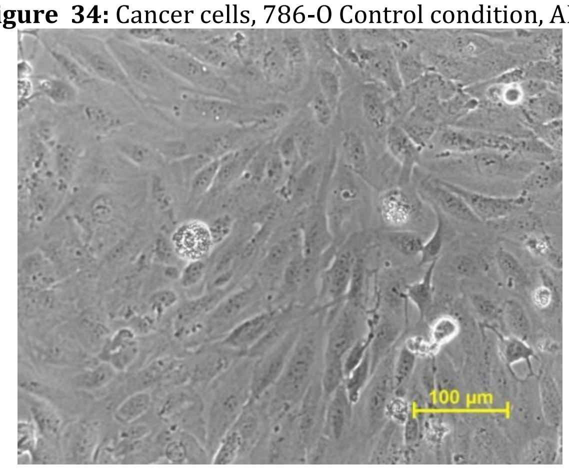


Figure 35: Cow urine, cancer cells with more than 10% cow urine distillate (cancer cells were found to be decreased with this dose administration)

6. Economic and environmental analysis

Economic analysis primarily involves assessing costs and benefits. The process begins by evaluating projects' economic feasibility to optimise resource allocation [47]. Environmental analysis consists of the use of economic concepts to examine the development and management of ecological and natural resources [79].

Table 14 illustrates the economic analysis of the developed solar thermal hydrodistillation system for cow urine distillation. This estimation shows that, over the 270 working days per year, over ten years of the distiller's life span, and at a selling price of 400 ₹/kg for the cow urine distillate, the payback period was only 29 sunny days. It shows that the developed distiller is affordable to rural people and cow shelter managers. From an environmental point of view, the developed system is also found helpful, as the carbon credits earned were ₹ 6240.09, the carbon dioxide emission during lifetime was 649.25 kWh, and the energy payback period was less than a year, as shown in Table 15.

Table 11: Estimation of economic analysis

Parameter	Notation	Value
Initial investment in solar still for 1 m^2	P (₹/m^2)	32,694
Area of solar still	A (m^2)	0.45
The daily yield of the solar still	m_{ew} (kg/day)	1.69
Daily yield of solar still per m^2 area	m_{ew} (kg/m^2 per day)	3.76
Number of working days	n (days/year)	270
Annual yield for 270 working days	mew (kg/m^2 per year)	1,014
The life of a solar still	n (years)	10
Interest rate (15%)	i	0.15
Capital recovery factor	CRF	0.20
Sinking fund factor	SFF	0.05
The salvage value (20% of the initial investment)	S	6,538.80
Annual salvage value	ASV (₹)	322.05
Annual first cost	AFC (₹)	6,514.35
Annual maintenance cost (15% of the annual first cost)	AMC (₹)	977.15
Annual cost/m^2	(₹)	7,169.45
Annual cost per kg of yield	₹/kg	7.07
Latent heat of vaporisation	hfg (kWh/kg)	0.65
Annual useful energy input	kWh	659.10
Annual cost per kWh	₹/kWh	10.88
Selling price	₹/kg	400
Cash flow per year	CF (₹/year)	4,05,600
Payback period	np (days)	29

Table 12: Estimation of environmental analysis

Parameter	Notation	Value
Embodied energy	Ein (kWh)	410.92
Annual energy output	Eout (kWh)	659.10
Carbon dioxide mitigation over the lifetime	kg of CO_2	281172.06
Net Carbon dioxide mitigation over a lifetime	tons	9.76
Carbon dioxide merchandised rate	Euro/ton	7.07
Cost of 1 Euro as of Jan. 2024	₹	90.39
Carbon credits earned	₹	6240.09
Carbon dioxide emissions during a lifetime	kWh	649.25
Energy payback period	year	0.62

7. Conclusions

This research work focuses on fabricating and testing a cost-effective solar thermal hydrodistillation system for cow urine distillation. It also examines the therapeutic applications of cow urine distillate. The following findings emerged from this exploration:

a) The study of cow urine and distillate began about 1940. Scientists have examined cow urine or its distillate in more applications since 2011. 57.1% of researchers used cow urine and distillate for agriculture, and 28.6% for electricity. And 14.3% of researchers utilise cow urine distillation therapeutically.

b) Cow urine pH averages 8.10, indicating basicity. Solutions' pH substantially affects metal behaviour. Thus, solar thermal hydrodistillation for cow urine distillation employed glass for its construction.

c) Experiments revealed that the average absorber plate and cow urine temperatures were 70^0C and 60^0C. Despite glass's poor heat conductivity, the developed system can achieve 70^0C, which is enough for solar energy-driven cow urine distillate production.

d) The yield per absorber plate square metre ranged from 3 to 4 kg/day, depending on solar radiation intensity.

e) The distillate's main component was phosphonic acid (81.13%). Market-bought cow urine distillate compounds did not include it. The possible reason is that the solar thermal hydrodistillation system slowly produces cow urine distillate at very gentle heat. This chemical destroys fungus. It is an essential antiviral treatment for cancer, HIV, and hepatitis B prodrugs. It is an antibiotic for UTIs. Many anti-nausea drugs include it. Also fights malaria. Oxidative stress reduction may alleviate anxiety.

f) All market-purchased distillates were light brown, while the solar energy-prepared distillate is transparent. This is because the solar thermal hydrodistillation device evaporates cow urine without boiling it.

g) A surprising discovery is that all samples, except the solar hydrodistiller-prepared cow urine distillate, contain p-Cresol. Corrosive cresols may burn and injure skin and eyes.

h) The solar thermal hydrodistillation technology produces cow urine distillate with the lowest levels of ammonia and nitrogen. Thus, solar-powered cow urine distillate was odourless and undiluted for drinking. This distillate had 0.88% ammonia and 2.25% nitrogen, 80% less than market-based cow urine distillate.

i) Solar thermal hydrodistillation produces cow urine distillate with the lowest TDS (1900 ppm). It was 85% smaller than commercial cow urine distillate. Low TDS means good cow urine distillation.

j) The experiments reveal that cow urine distillate was an anxiolytic and anti-depressant. And 40% of cow urine distillate manages diabetes.

k) Cancer cells did not change at concentrations up to 10% cow urine distillate. When cow urine distillate exceeded 10%, cancer cell numbers decreased.

l) Based on 270 working days per year, ten years of distiller life, and 400 ₹/kg cow urine distillate sales, the payback time was just 29 sunny days. It shows that rural families and cow shelter owners can afford distillers.

m) The system has a positive environmental impact, generating ₹6240.09 in carbon credits, emitting 649.25 kWh of CO_2, and achieving energy payback in less than a year.

Thus, from the present investigations, it can be concluded that the solar thermal hydrodistillation system for cow urine distillation is an affordable, environmentally friendly method. However, further pharmacological and biological investigations are required to confirm the findings of the present research work.

Conflict of Interest: The authors declare no potential conflict of interest concerning the contents, authorship, and/or publication of this article.

Source of Support: Nil

Funding: The authors declared that this study has received no financial support.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Ethical approval: Not applicable.

References

1. Huffman B. Cow. Encyclopedia Britannica, https://www.britannica.com/animal/cow (2024, accessed 19 February 2024).

2. Katekar VP, Rao AB, Sardeshpande VR. Review of the Contemporary Applications of Cow Urine and its Distillate in Agriculture , Medicine , and Electricity Generation for Sustainable Development. Int J Enhanc Res Sci Technol Eng 2024; 13: 102-127. https://doi.org/10.2139/ssrn.4857807

3. Katekar VP. Investigations on production of cow urine distillate using solar distillation system for cow shelter livelihoods. Clean Circ Bioeconomy 2025; 10: 100143. https://doi.org/10.1016/j.clcb.2025.100143

4. Jagran K. Indian cattle Breeds For Huge Milk Production. Krishi Jagran, https://krishijagran.com/animal-husbandry/indian-cattle-breeds-for-huge-milk-production/ (2021).

5. Kumar R, Kaushik JK, Mohanty AK, et al. Identification of bioactive components behind the antimicrobial activity of cow urine by peptide and metabolite profiling. Anim Biosci 2023; 36: 1130-1142. https://doi.org/10.5713/ab.22.0249 PMid:36634651 PMCid:PMC10330998

6. Ahirrao NK, Dharse Y V, Khokrale SS, et al. Design, Fabrication & Performance Analysis of Solar Still for Cow Urine Distillation. Int Res J Eng Technol 2023; 10: 1500-1505.

7. Nevens WB. Cows' Urine as a Fertilizer for Bluegrass Pastures. J Dairy Sci 1941; 24: 761-769. https://doi.org/10.3168/jds.S0022-0302(41)95454-1

8. Limmer AW, Steele KW. Effect of cow urine upon denitrification. Soil Biol Biochem 1983; 15: 40-43. https://doi.org/10.1016/0038-0717(83)90004-4

9. Prabhu M, Mutnuri S. Cow urine as a potential source for struvite production. Int J Recycl Org Waste Agric; 3. Epub ahead of print 2014. https://doi.org/10.1007/s40093-014-0049-z

10. Ledgard SF, Steele KW, Saunders WHM. Effects of cow urine and its major constituents on pasture properties. New Zeal J Agric Res 1982; 25: 61-68. https://doi.org/10.1080/00288233.1982.10423373

11. Jandaik S, Thakur P, Kumar V. Efficacy of Cow Urine as Plant Growth Enhancer and Antifungal Agent. Adv Agric; 2015. Epub ahead of print 2015. https://doi.org/10.1155/2015/620368

12. Hoh JM, Dhanashree B. Antifungal effect of cow's urine distillate on Candida species. J Ayurveda Integr Med 2017; 8: 233-237. https://doi.org/10.1016/j.jaim.2017.04.009 PMid:28869083 PMCid:PMC5747510

13. Sadhukhan R. Cow urine as a biofertilizer and biopesticide maintains environmental sustainability in agriculture INTEGRATED FARMING SYSTEM View project, https://www.researchgate.net/publication/330855067 (2017).

14. Tapke R, Tayade PR, Motghare KA. Zero Bugget Natural Reforming With the Help of Cow Dung and Cow Urine. Int J Adv Sci Eng Technol 2017; 5: 47-50.

15. Grange A. Experimental studies on the 'cow's urine mixture'. Ann Trop Paediatr 1981; 1: 175-179. https://doi.org/10.1080/02724936.1981.11748083 PMid:6185066

16. Jain NK, Gupta VB, Garg R, et al. Efficacy of cow urine therapy on various cancer patients in Mandsaur District, India-A survey. Int J Green Pharm 2010; 4: 29-35. https://doi.org/10.4103/0973-8258.62163

17. Suemitsu R, Fujita S ichi, Matsubara H. Studies on cow's urine. Agric Biol Chem 1965; 29: 908-911. https://doi.org/10.1271/bbb1961.29.908

18. Mohanvel SK, Rajasekharan SK, Kandhari T, et al. Cow urine distillate as a bioenhancer for antimicrobial & antiproliferative activity and redistilled cow urine distillate as an anticlastogen agent. Asian J Pharm Clin Res 2017; 10: 273-277. https://doi.org/10.22159/ajpcr.2017.v10i10.18879

19. Choudhary S, Kushwaha M, Preeti Singh S, et al. Cow Urine: A Boon for Sustainable Agriculture. Int J Curr Microbiol Appl Sci 2017; 6: 1824-1829. https://doi.org/10.20546/ijcmas.2017.602.205

20. Safitri A, Roosdiana A, Srihardyastutie A, et al. Fermentation of Cow Urine Collected from Ngabab Village, Malang: Its Potential as Liquid Fertilizer. IOP Conf Ser Earth Environ Sci 2019; 239: 3-8. https://doi.org/10.1088/1755-1315/239/1/012029

21. Shalaby MAM, Adly AM, Ahmed AF. Cow's Urine-Dung Extract Foliar Spraying as a Complementary Pest Control Method against Boll-Worm Complex on the Cotton Plant. Int J Sci Res 2018; 8: 212-219.

22. Singh SN, Maurya KK, Singh GP. Effect of cow urine (gomutra) as a source of nitrogen on growth, yield and nitrogen uptake in rice (oryza sativa l.). Int J Microbiol Res 2018; 10: 1035. https://doi.org/10.9735/0975-5276.10.3.1035-1037

23. Jhalani A, Sharma D, Soni S, et al. Feasibility assessment of a newly prepared cow-urine emulsified diesel fuel for CI engine application. Fuel 2021; 288: 119713. https://doi.org/10.1016/j.fuel.2020.119713

24. Bisen P, Choudhary R, Khule S. Cow Urine Power Generated System. Int J Adv Res Sci Eng 2015; 4: 80-85.

25. Hasan W, Ahmed H, Salim K. Generation of Electricity Using Cow Urine. Int J Innov Appl Stud 2014; 9: 1465.

26. Gidde A, Patil N, Kamble Y, et al. " Hybrid Electricity Generation Using Cow Urine and Microbial Fuel Cell (MFC) Based Buck Convertor ". 2018; 6: 142-146.

27. Biswal V, Kumar M, Kumar A, et al. Generation of hydrogen from methane. Int Res J Eng Technol 2017; 2017: 7.

28. Kiran T, Fathima TN, Lavanya B, et al. Feasibility Assessment of Cow Urine Blended With Petrol To Reduce Emissions. Int Res J Eng Technol 2023; 867-872.

29. Kume S, Sato T, Murai I, et al. Relationships between urine pH and electrolyte status in cows fed forages. Anim Sci J 2011; 82: 456-460. https://doi.org/10.1111/j.1740-0929.2010.00853.x PMid:21615840

30. Katekar VP, Rao AB, Sardeshpande VR. A hydrodistillation based essential oils extraction : A quest for the most effective and cleaner technology. Sustain Chem Pharm 2023; 36: 101270. https://doi.org/10.1016/j.scp.2023.101270

31. Katekar VP, Prayagi S V., Mahajan BR, et al. Essential Oils Extraction : A Promising Enterprise for Rural Areas ' Sustainable Development. SAMRIDDHI A J Phys Sci Eng Technol 2023; 15: 20-26. https://doi.org/10.18090/10.18090/samriddhi.v15i01.24

32. Palatkar S V, Katekar VP. An Investigation for the Best-Performing Design of Box-Type Solar Cooker for Commercialisation : A Comprehensive Review. J Sol Energy Res 2025; 10: 2275-2315.

33. Katekar V, Deshmukh S. Assessment of Socioeconomic Development of the Aspirational District in Central India : A Methodological Comparison. J Asian Afr Stud 2022; 1: 1-29.

34. Todmal AP, Mali AD, Kale SD, et al. Solar Devices:-Solar Water Heater, Solar Still, Solar Cooker and Solar Dryer: A Review. Int Res J Eng Technol 2023; 1649-1657.

35. Katekar VP, Rao AB, Sardeshpande VR. An experimental investigation to optimise pebbles-based sensible heat storage system : An exploration to improve thermal efficiency of solar devices. J Energy Storage 2023; 73: 1-28. https://doi.org/10.1016/j.est.2023.108964

36. Ramteke RJ, Dhurwey AR, Borkar HB, et al. Recent Trends in Solar Distillation. Int J Res Appl Sci Eng Technol 2016; 4: 184-192.

37. Mamulkar C, Ikhar S, Katekar V. Computational Fluid Dynamics Analysis of a Solar Dryer with Various Phase Change Materials. Int J Thermodyn 2023; xx: 1-8. https://doi.org/10.5541/ijot.1324341

38. Katekar VP, Deshmukh SS. Performance Investigation of Solar Still by Exergy Analysis -A Review. In: Advances in Mechanical & Electrical Engineering. 2019, pp. 1-9.

39. Katekar VP, Rao AB, Sardeshpande VR. The optimum nanomaterial coating for solar thermal device absorber plates: an experimental investigation. Int J Nano Biomater 2024; 10: 270-300. https://doi.org/10.1504/IJNBM.2024.143831

40. Katekar VP, Deshmukh SS. A review of the use of phase change materials on performance of solar stills. J Energy Storage 2020; 30: 1-28. https://doi.org/10.1016/j.est.2020.101398

41. Pandit RR, Deshmukh SS, Khatod KJ, et al. Efficiency, cost, and carbon footprint considerations in analysing hybrid solar thermal-photovoltaic desalination systems. Desalin Water Treat; 325. Epub ahead of print 2026. https://doi.org/10.1016/j.dwt.2025.101606

42. Katekar VP, Rao AB, Sardeshpande VR. Harnessing solar energy for bioresource valorisation: A case study on decentralised rosewater production through solar hydrodistillation. Bioresour Technol Reports 2025; 32: 102387. https://doi.org/10.1016/j.biteb.2025.102387

43. Katekar VP, Deshmukh SS. Integration of Solar Distillation in Dairy Effluent Treatment: a Step Toward Reducing Carbon Footprint. Proc ASME 2024 18th Int Conf Energy Sustain ES 2024 2024; 1-8. https://doi.org/10.1115/ES2024-132182

44. Olivkar PR, Katekar VP, Deshmukh SS, et al. Effect of sensible heat storage materials on the thermal performance of solar air heaters: State-of-the-art review. Renew Sustain Energy Rev 2022; 157: 112085. https://doi.org/10.1016/j.rser.2022.112085

45. Dhurwey AR, Katekar VP, Deshmukh SS. An Experimental Investigation of Thermal Performance of Double Basin, Double Slope, Stepped Solar Distillation System. Int J Mech Prod Eng Res Dev 2019; 9: 200-206.

46. Khatod KJ, Katekar VP, Deshmukh SS. An evaluation for the optimal sensible heat storage material for maximizing solar still productivity: A state-of-the-art review. J Energy Storage 2022; 50: 104622. https://doi.org/10.1016/j.est.2022.104622

47. Katekar VP, Deshmukh SS. Techno-economic review of solar distillation systems: A closer look at the recent developments for commercialisation. J Clean Prod 2021; 294: 126289. https://doi.org/10.1016/j.jclepro.2021.126289

48. Katekar VP, Rao AB, Sardeshpande VR. An Energy-Sustainable Approach of Ginger Rhizomes Hydrosol Extraction Using a Solar Thermal Hydrodistillation System. In: Proceedings of ASME 2024 18th International Conference on Energy Sustainability, ES 2024. 2024, pp. 1-10. https://doi.org/10.1115/ES2024-132177

49. Mamulkar C, Ikhar S, Katekar V. Computational Fluid Dynamics Analysis of a Solar Dryer with Various Phase Change Materials. Int J Thermodyn 2024; 27: 35-42. https://doi.org/10.5541/ijot.1324341

50. Mate A, Katekar V, Bhatkulkar HS. Performance Investigation of Solar Still for Batteries of Railway Engine, Indian Railways, at Ajni Loco Shed, Nagpur. In: International conference on Advances in Thermal Systems, Materials and Design Engineering (ATSMDE2017). VJTI, Mumbai, https://ssrn.com/abstract=3101269 (2017).

51. Mamulkar C, Katekar V. Performance Evaluation of Double Flow Solar Air Heater. In: National Conference on Innovative Paradigms in Engineering & Technology (NCIPET-2012). 2012, pp. 5-6.

52. Ukey AA, Katekar VP. An Experimental Investigation of Thermal Performance of an Octagonal Box Type Solar Cooker. In: Smart Technologies for Energy, Environment and Sustainable Development. Lecture Notes on Multidisciplinary Industrial Engineering. Springer, Singapore, pp. 769-777.

53. Katekar VP, Sardeshpande VR, Rao AB. Case study on the dissemination of solar hydrodistillation system for rosewater production. In: National Symposium on Green Energy Interventions to support MSME's in Technology Deprived Areas. Wardha: MGIR, Wardha, 2025, pp. 1-13.

54. Katekar VP, Deshmukh SS, Vasan A. Energy, drinking water and health nexus in India and its effects on environment and economy. J Water Clim Chang 2020; 11: 1-26.

55. Katekar VP, Rao AB, Sardeshpande VR. Review of the rose essential oil extraction by hydrodistillation : An investigation for the optimum operating condition for maximum yield. Sustain Chem Pharm 2022; 29: 100783. https://doi.org/10.1016/j.scp.2022.100783

56. Katekar VP, Rao AB, Sardeshpande VR. Evaluation and forecasting of the number of steps and dimensions for stepped solar stills to maximise distillate yield. Therm Sci Eng Prog 2025; 67: 104226. https://doi.org/10.1016/j.tsep.2025.104226

57. Katekar VP, Rao AB, Sardeshpande V. Solar energy-assisted extraction of bioactive compounds. In: Munekata PES (ed) Application of Emerging Technologies and Strategies to Extract Bioactive Compounds. Academic Press, pp. 199-255. https://doi.org/10.1016/B978-0-443-18975-3.00006-1

58. Katekar VP, Rao AB, Sardeshpande VR. Investigating the kinetic model of rosewater production using a solar energy driven hydrodistillation system. Next Chem Eng 2025; 1: 100002. https://doi.org/10.1016/j.nxcen.2025.100002

59. Katekar VP, Rao AB, Sardeshpande VR. A cutting-edge assessment of recent advancements in essential oils extraction technologies for energy and ecological sustainability: A comprehensive review. J Food Process Eng 2023; 1-35. https://doi.org/10.1111/jfpe.14414

60. Katekar VP, Rao AB, Sardeshpande VR. A cleaner and ecological rosewater production technology based on solar energy for rural livelihood. Clean Circ Bioeconomy 2022; 1: 1-42. https://doi.org/10.1016/j.clcb.2022.100022

61. Prasad A, Kothari N. Cow products: boon to human health and food security. Trop Anim Health Prod; 54. Epub ahead of print 2022. https://doi.org/10.1007/s11250-021-03014-5 PMid:34894304 PMCid:PMC8665701

62. Stocks A. Gir Cows. ST, https://stock.adobe.com/in/search/images?k=%22indian+cow%22 (2023).

63. Shukla A, Bajpai D. Cows are not a problem , but a solution . All we need to do is shift our focus. Gaon Connections, 25 February 2020, pp. 1-13.

64. Damodaran H, Agarwal S. Revealing India ' s actual farmer population. The Indian Express, 2022, pp. 1-10.

65. Board NDD. Livestock population in India by Species 2019. Livestock Census, DAHD&F, GoI, 2019, pp. 1-3.

66. Knuivers M. Dairy Global - Indian dairy: Big, but still traditional. Dairy Global, 2019, pp. 1-3.

67. Kothandaraman CPP, Subramanyan S. Heat and Mass Transfer Data Book. 8th ed. New Delhi: New Age International (P) Ltd., https://www.bnec.ac.in/assets/images/Mechdatabooks/HMT Data Book.pdf (2007).

68. Piechocka J, Wieczorek M, Głowacki R. Gas chromatography-mass spectrometry based approach for the determination of methionine-related sulfur-containing compounds in human saliva. Int J Mol Sci 2020; 21: 1-18. https://doi.org/10.3390/ijms21239252 PMid:33291575 PMCid:PMC7729597

69. Sevrain CM, Berchel M, Couthon H, et al. Phosphonic acid: Preparation and applications. Beilstein J Org Chem 2017; 13: 2186-2213. https://doi.org/10.3762/bjoc.13.219 PMid:29114326 PMCid:PMC5669239

70. A. Cengel Y, Ghajar AJ. Heat and Mass Transfer: Fundamentals and Applications. 5th ed. India: McGraw Hill Education, https://www.amazon.in/Heat-Mass-Transfer-Fundamentals-Applications/dp/9339223195 (2002).

71. Bell NA. Beryllium. In: Comprehensive Organometallic Chemistry. 1982, pp. 121-153. https://doi.org/10.1016/B978-008046518-0.00003-9 PMid:6804299

72. New Jersey Department of Health. Cresols (mixed isomers). Hazard Subst fact sheet 2007; 1: 6.

73. Budzianowski W, Koziol A. Stripping of Ammonia from Aqueous Solutions in the Presence of Carbon Dioxide. Chem Eng Res Des 2005; 83: 196-204. https://doi.org/10.1205/cherd.03289

74. Liu CW, Sung Y, Chen BC, et al. Effects of nitrogen fertilizers on the growth and nitrate content of lettuce (Lactuca sativa L.). Int J Environ Res Public Health 2014; 11: 4427-4440. https://doi.org/10.3390/ijerph110404427 PMid:24758896 PMCid:PMC4025000

75. de Vries W. Impacts of nitrogen emissions on ecosystems and human health: A mini review. Curr Opin Environ Sci Heal 2021; 21: 100249. https://doi.org/10.1016/j.coesh.2021.100249

76. Kulkarni A. Diabetes. 2016. https://doi.org/10.1093/med/9780198729426.003.0005

77. Ghasemi A, Jeddi S. Streptozotocin As a Tool for Induction of Rat Models of Diabetes: a Practical Guide. EXCLI J 2023; 22: 274-294.

78. Memorial TH. Cancer. 2018.

79. Katekar VP, Deshmukh SS. Thermoeconomic analysis of solar distillation system with stepped-corrugated absorber plate. Proc Inst Mech Eng Part C J Mech Eng Sci 2020; 0: 1-20.