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Environmental aspects of water supply to the Kyrgyz-Turkish "Manas" University campus and their assessment in the condition of the "Greenmetric" system criteria

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ABSTRACT

The paper considers the environmental aspects of water supply in the campus of Kyrgyz-Turkish "Manas" University, and evaluates them in the context of the indicators of the "UI GreenMetric World University Ranking – 2024" system: SI-infrastructure (70.33%); EC-energy and climate (37.62%); WR-water (70%); WS-waste (66.67%); TR-transport (77.78%); ED-education and research projects (66.67%). It was noted that within the campus, there is a centralized city water supply system, and in addition, four wells have been drilled, fed from the groundwater of the Chui Valley. The main consumers of water are educational, industrial, household and agricultural campus facilities. Part of the water from the springs is used for drinking purposes. Taking these circumstances into account, the chemical composition of the model water was established. Thermodynamic modeling of an aqueous solution was carried out at a minimum Gibbs energy and the concentration distribution of elements, cations and anions in the liquid phase was established. It has been shown that the pH value of water ranges from 7.3 to 7.62, and the redox potential is positive. Accordingly, the properties of water are restorative in nature and are quite suitable for drinking purposes, which means solving an important practical problem.

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1 Introduction

Currently, the global educational environment presents various models of university campuses and their sustainable development designs [1]. Accordingly, assessing the energy and environmental performance of educational campuses and comparing their sustainability ratings is a relevant task. In this regard, the University of Indonesia has developed criteria for assessing the sustainability of educational campuses (UI GreenMetric, Jakarta), taking into account: the state of energy resources and climate change, storage of organic and hazardous waste, reducing the carbon footprint, rational use of water, as well as the use of renewable energy sources and the development of smart buildings, facilities and zero emission transport [2]. At the same time, the strategy of providing clean water, organizing compact campuses and integrating them into urban infrastructure can be traced in many educational environments in the USA, Italy and other European countries. For example, the University of Texas (Dallas) is known for the development of systems for optimizing energy resources in the processes of heating - cooling air and lighting of buildings [3]. The structure of the University of Copenhagen has installed solar panels for the generation and accumulation of electrical energy [4]. The University of Canterbury in New Zealand offered special land plots in order to obtain organic products, and the University of Oslo in Norway introduced electric vehicles for students on a sustainable basis for their movement [3, 5]. It is noted that in the UI GreenMetric system, the use of water in a cyclic mode (WR2) is considered an important task, since it provides for an increase in the volume of use of recycled water, as well as rainwater and treated wastewater, and all this is provided for at the design stage of university campuses [2]. At the same time, the water assessment criteria (WR) take into account not the total part of water use, but the active share of recycled water, taking into account its legal and environmental aspects [6]. In practice, there are examples of providing campuses with demineralized water (SEWA), as well as the use of purified recycled water for irrigation purposes (Sharjah Municipality and City University) [7]. In recent years, individual universities have begun to use efficient nozzles, smart meters and automatic equipment in water flow control processes [8]. Drip irrigation methods have been introduced [9]. Many university campuses have bottled water dispensing stations [10]. The educational program includes special courses: "Ecological health", "Environmental protection and engineering", as well as courses on sustainable development and environmental culture [7, 11]. Thus, in the above context, long-term plans (until 2050) for the development of educational campuses are proposed: attracting resources to study climate change; transition to carbon neutrality; strengthening educational activities on ecology and sustainable development of society [12, 13]. The Kyrgyz-Turkish "Manas" University (KTMU) has been participating in the international ranking for the sustainable development of educational campuses "GreenMetric" since 2016. Accordingly, every year an annual report is prepared based on 6 criteria (infrastructure, energy and climate, solid waste, water, transport, education and scientific projects) and sent to Jakarta (Indonesia) [14, 15]. In 2024, 1477 universities from 95 countries participated in the above system, and in the ranking competition, the Kyrgyz-Turkish "Manas" University took 602nd place and received an official certificate. The indicators for the six criteria were as follows [14]: SI-infrastructure (70,33%); EC-energy and climate (37.62%); WR-water (70%); WS-waste (66.67%); TR-transport (77.78%); ED-education and research projects (66.67%). The presented results of each criterion include evidence in the form of calculations, diagrams, photographs and they are useful in the processes of increasing the status of the university at the international level. Along with this, the results obtained can be a matrix in the Quacquarelli Symonds (QS) and Times Higher Education (THE) database system, especially regarding the rational use of quality water on the KT 'Manas' University campus, and this circumstance became the subject of research in this work, and the treatment and use of campus wastewater is the subject of further research.

2. Materials and methods

It is noted that water use is one of the important indicators in the UI GreenMetric system. In this regard, assessing the concentration distribution of elements, cations and anions in water makes it possible to predict the quality of drinking water used on educational campuses [16, 17]. In accordance with this, the chemical composition of the model water was first established (Dr. Fatih Ramazan Istanbullugil, KTMU, Faculty of Veterinary Medicine, 2015-2018) pH = 7.2 - 7.4; NH_4^+ less than 0.2 mg/L; NO_2^- less than 0.025 mg/L; NO_3^- = 15 mg/L; E. coli and total coliform are absent [18] and according to [17]: HCO_3^- = 152.90 mg/L; Cl^- = 24.26 mg/L; SO_4^{2-} = 81.31 mg/L; NO_3^- = 8.91 mg/L; NO_2^- = 0.39 mg/L; Na^+ = 41.24 mg/L; K^+ = 2.18 mg/L; Ca^{+2} = 42.91 mg/L; Mg^{+2} = 13.9 mg/L; NH_4^+ = 0.11 mg/L; water mineralization S = 367.34 mg/L. In calculation experiments, the elemental composition of model water is given in moles [17, 18]: Na (0.00179), Ca (0.00107), Mg (0.00055), C (0.00251), Cl (0.00068), S (0.00085), N (0.00016), K (0.00006), H (111.02), O (55.52) and the maximum permissible concentrations (MPC) of chlorides for fishery water bodies - 300 mg/L, for drinking and cultural facilities - 350 mg/L are taken into account [19]. Taking into account the chemical matrix of the model water and the parameters of formation of individual components in the solution, thermodynamic modeling was carried out at a minimum of Gibbs energy. Calculations were carried out on the basis of the "Selector" software package using strict thermodynamic databases [20, 21]. The concentration distribution of elements, cations and anions in the liquid phase was established at temperature ranges (278-300 K) and temperature dependences of the hydrogen index (pH) and the redox potential (Eh) of the solution were established. And based on the obtained data, tables 1–3 were compiled and graphical dependencies were constructed (Figures 3–4).

3. Results and discussion

In Central Asia, the Kyrgyz Republic has its own water resources (6582 glaciers with a total area of 8047.8 km^2, where water reserves amount to 760 billion m^3; 40 000 rivers 15 000 km long). At the same time, the total volume of water is distributed for the following needs: agricultural – 90 %, industrial – 6 %, household and drinking – 3 %; forestry, fisheries, energy and service systems – 1 %. The annual water consumption in the republic is 10 - 12 billion m^3. Depending on the natural terrain, 800 thousand hectares of land are irrigated on the basis of 76 % of local rivers, and 80 thousand hectares (11%) of land are from water basins, i.e. 720 thousand hectares of land are irrigated by river drains [22-30]. Привести новые литературные источники.

Kyrgyz-Turkish "Manas" University is located in the southern part of Bishkek [31]. A centralized water supply system operates on the territory of the educational campus, but four wells have been drilled taking into account the seasonal low water conditions of the year (Fig.1). The water supplied by the "Bishkekvodokanal" is used for drinking, cooking, as well as for educational, industrial and economic purposes. Water for technical needs and irrigation is taken from wells. The depth of the water wells is: well No.1 is 140 m, well No.2 is 180 m, well No.3 is 200 m, well No.4 is 200 m. A pool with a volume of 1000-1200 tons was built for irrigation. Irrigation costs amounted to 199 500 m^3 in 2023 (678.17 m^3/day), drinking water consumption in 2023 amounted to 208237 m^3 [32].

Figure 1. *General view of individual wells and reservoirs on the campus of KTMU*

It was noted that the Kyrgyz-Turkish "Manas" University participated in the rating of educational campuses in the "UI GreenMetric" system every year, including in 2024, and received a certificate with applications containing comparative data on six criteria (Fig. 2).

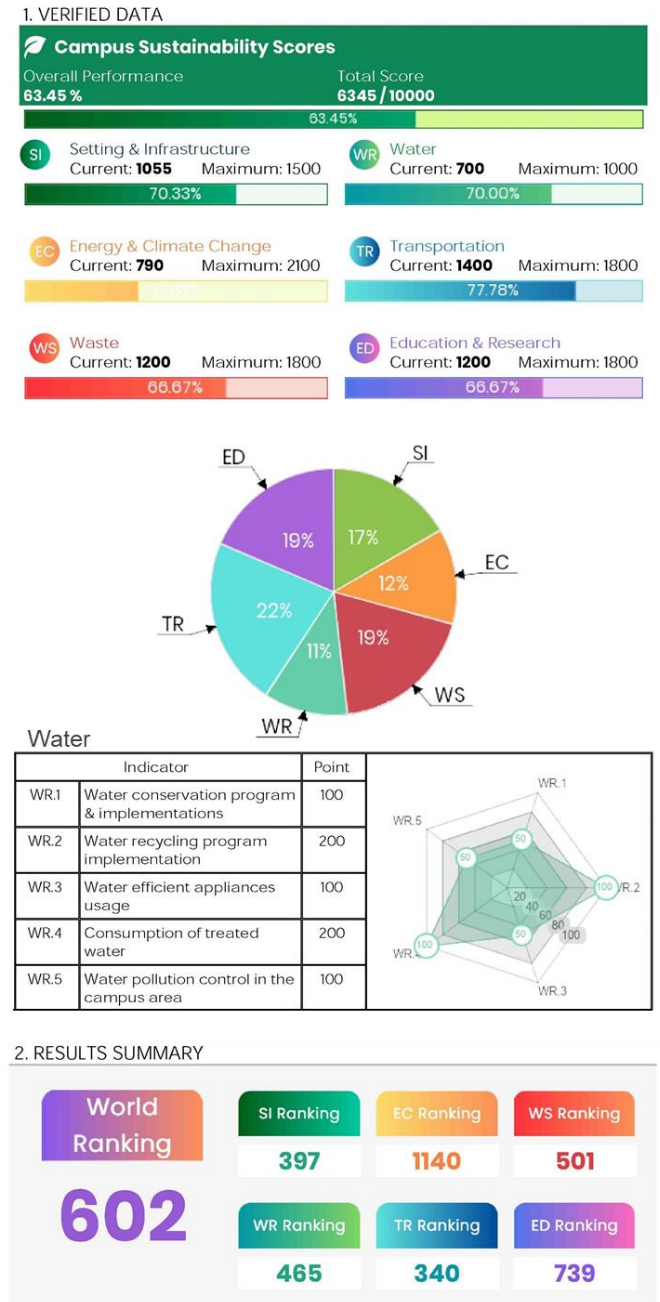

Figure 2. *Comparative ranking of KTMU campus data for 2023: infrastructure, energy and climate, solid waste, water, transport, education and scientific projects*

An assessment of the concentration distribution of elements, cations and anions in water over a wide range of temperature changes (278-300 K) made it possible to predict the quality of drinking water used on an educational campus. Table 1 shows the physico-chemical, thermodynamic characteristics of the waters of the KTMU campus and the concentration distribution of elements, cations and anions in the solution at average annual water temperatures.

Table 1. *Physico-chemical, thermodynamic characteristics of waters on the KTMU campus and the concentration distribution of elements, cations and anions in solution at a temperature of 288 K*

Temperature, K	Pressure, MPa	Volume, m³	Mass, kg	Density, kg/m³	G, MJ	H, MJ
288	0.1	0.001	1	999.4	-13.13	-15.91
S, kJ/K	U, MJ	Cp, kJ	Eh, B	pH	Ion strength	TDS, mg/kg
3.74	-15.71	4.18	0.41	7.46	0.01	346.6

Phase parameters:

name phase	volume, m³	mole quantity	mass, kg	density, kg/m³	weight %
Aq. Sol.	1.0	$5.5\cdot10^{1}$	1.0	$9.9\cdot10^{2}$	$1.0\cdot10^{2}$
Ord-Dol	$5.5\cdot10^{-6}$	$8.6\cdot10^{-5}$	$1.6\cdot10^{-5}$	$2.8\cdot10^{3}$	$1.6\cdot10^{-3}$

Element distribution

Elements	chemical composition	disparity balance mass	molality	mg/kg sol	dual solution	chemical potential	log molality
Ca	$1.0\cdot10^{-3}$	$2.6\cdot10^{-9}$	$9.8\cdot10^{-4}$	$3.9\cdot10^{1}$	-271.1	-155247	-3.0
Cl	$6.8\cdot10^{-4}$	$3.4\cdot10^{-9}$	$6.8\cdot10^{-4}$	$2.4\cdot10^{1}$	-45.4	-26047	-3.1
S	$8.4\cdot10^{-4}$	$3.0\cdot10^{-9}$	$8.4\cdot10^{-4}$	$2.7\cdot10^{1}$	-159.2	-91182	-3.0
C	$2.5\cdot10^{-3}$	$3.4\cdot10^{-9}$	$2.3\cdot10^{-3}$	$2.8\cdot10^{1}$	-106.3	-60873	-2.6
K	$5.5\cdot10^{-5}$	$5.4\cdot10^{-9}$	$5.5\cdot10^{-5}$	2.1	-143.8	-82341	-4.2
Mg	$5.7\cdot10^{-4}$	$5.7\cdot10^{-9}$	$4.8\cdot10^{-4}$	$1.1\cdot10^{1}$	-230.9	-132230	-3.3
Na	$1.7\cdot10^{-3}$	$5.3\cdot10^{-9}$	$1.7\cdot10^{-3}$	$4.1\cdot10^{1}$	-131.9	-75536	-2.7
N	$2.5\cdot10^{-4}$	$3.6\cdot10^{-9}$	$2.5\cdot10^{-4}$	3.5	56.6	32414	-3.6
H	$1.1\cdot10^{2}$	$-6.2\cdot10^{-9}$	$2.1\cdot10^{-3}$	2.1	-33.6	-19243	-2.6
O	$5.5\cdot10^{1}$	$3.9\cdot10^{-8}$	$1.0\cdot10^{-2}$	$1.7\cdot10^{2}$	-31.4	-18029	-1.9

Distribution of cations and anions

particles	gT, J/mole	molality	mole quantity	mg/kg sol. or wt, %	log mole	coeff. activity	log cf. activ.	ln activity
Aqueous Sol.								
CO_2^*	-0.4	$1.7\cdot10^{-4}$	$1.7\cdot10^{-4}$	7.7	-3.7	1.0	0.001	-12.6
CO_3^{-2}	-0.5	2.90	$2.9\cdot10^{-6}$	$1.7\cdot10^{-1}$	-5.5	0.7	-0.1	-17.1
$Ca(HCO_3)^+$	-1.1	$1.6\cdot10^{-5}$	$1.6\cdot10^{-5}$	1.6	-4.7	0.9	-0.04	-15.1
Ca^{+2}	-0.5	$9.6\cdot10^{-4}$	$9.6\cdot10^{-4}$	$3.8\cdot10^{1}$	-3.0	0.7	-0.1	-11.3
$CaCl^+$	-0.7	$2.2\cdot10^{-7}$	$2.2\cdot10^{-7}$	$1.6\cdot10^{-2}$	-6.6	0.9	-0.04	-19.4
$CaCl_2^*$	-0.8	$6.9\cdot10^{-11}$	$6.9\cdot10^{-11}$	$7.6\cdot10^{-6}$	-10	1.0	0.001	-27.4
$CaOH^+$	-0.7	$1.0\cdot10^{-9}$	$1.0\cdot10^{-9}$	$6.0\cdot10^{-5}$	-8.9	0.9	-0.04	-24.7
Cl^-	-0.1	$6.8\cdot10^{-4}$	$6.8\cdot10^{-4}$	$2.4\cdot10^{1}$	-3.1	0.9	-0.03	-11.3
HCO_3^-	-0.6	$2.1\cdot10^{-3}$	$2.1\cdot10^{-3}$	$1.3\cdot10^{2}$	-2.6	0.9	-0.04	-10.2
HSO_4^-	-0.8	$1.6\cdot10^{-9}$	$1.6\cdot10^{-9}$	$1.6\cdot10^{-4}$	-8.7	0.9	-0.04	-24.3
K^+	-0.3	$5.5\cdot10^{-5}$	$5.5\cdot10^{-5}$	2.1	-4.2	0.9	-0.04	-13.9
KCl^*	-0.4	$7.0\cdot10^{-11}$	$7.0\cdot10^{-11}$	$5.2\cdot10^{-6}$	-10	1.0	0.001	-27.3
$KHSO_4^*$	-1.1	$1.9\cdot10^{-17}$	$1.9\cdot10^{-17}$	$2.7\cdot10^{-12}$	-16	1.0	0.001	-42.4
KOH^*	-0.5	$2.1\cdot10^{-12}$	$2.1\cdot10^{-12}$	$1.2\cdot10^{-7}$	-11	1.0	0.001	-30.8
KSO_4^-	-1.07	$2.4\cdot10^{-7}$	$2.4\cdot10^{-7}$	$3.3\cdot10^{-2}$	-6.6	0.9	-0.04	-19.3
$Mg(HCO_3)^+$	-1.0	$7.7\cdot10^{-6}$	$7.7\cdot10^{-6}$	$6.6\cdot10^{-1}$	-5.1	0.9	-0.04	-15.8
Mg^{+2}	-0.4	$4.7\cdot10^{-4}$	$4.7\cdot10^{-4}$	$1.1\cdot10^{1}$	-3.3	0.7	-0.1	-12.0
$MgCl^+$	-0.6	$1.7\cdot10^{-7}$	$1.7\cdot10^{-7}$	$1.0\cdot10^{-2}$	-6.7	0.9	-0.04	-19.6
$MgOH^+$	-0.6	$9.1\cdot10^{-9}$	$9.1\cdot10^{-9}$	$3.7\cdot10^{-4}$	-8.0	0.9	-0.04	-22.6
NH_4^+	-0.1	$3.8\cdot10^{-13}$	$3.8\cdot10^{-13}$	$6.9\cdot10^{-9}$	-12	0.9	-0.04	-32.6
NO_2^-	-0.05	$5.5\cdot10^{-5}$	$5.5\cdot10^{-5}$	2.5	-4.2	0.9	-0.04	-13.8
NO_3^-	-0.1	$1.9\cdot10^{-4}$	$1.9\cdot10^{-4}$	$1.2\cdot10^{1}$	-3.7	0.9	-0.04	-12.6
Na^+	-0.2	$1.7\cdot10^{-3}$	$1.7\cdot10^{-3}$	$4.1\cdot10^{1}$	-2.7	0.9	-0.04	-10.4
$NaCl^*$	-0.4	$1.6\cdot10^{-7}$	$1.6\cdot10^{-7}$	$9.4\cdot10^{-3}$	-6.7	1.0	0.001	-19.6
$NaOH^*$	-0.4	$1.3\cdot10^{-10}$	$1.3\cdot10^{-10}$	$5.3\cdot10^{-6}$	-9.8	1.0	0.001	-26.7
$NaSO_4^-$	-1.0	$5.1\cdot10^{-6}$	$5.1\cdot10^{-6}$	$6.0\cdot10^{-1}$	-5.2	0.9	-0.04	-16.2
SO_4^{-2}	-0.7	$8.4\cdot10^{-4}$	$8.4\cdot10^{-4}$	$8.0\cdot10^{1}$	-3.0	0.7	-0.1	-11.4
OH^-	-0.2	$1.4\cdot10^{-7}$	$1.4\cdot10^{-7}$	$2.4\cdot10^{-3}$	-6.8	0.9	-0.03	-19.8
H^+	-0.04	$3.8\cdot10^{-8}$	$3.8\cdot10^{-8}$	$3.8\cdot10^{-5}$	-7.4	0.9	-0.04	-21.1
H_2O	-0.2	$5.5\cdot10^{1}$	$5.5\cdot10^{1}$	1.0	1.7	1	0	0
Solid phase								
$CaMg(CO_3)_2$	-2	$8\cdot10^{-5}$	$1.0\cdot10^{2}$	-4.0	1.0	0	0	0

Gases parameters:

gas phase	fugacity	log fugacity	partial pressure	log partial pressure	log coeff. fugacity	coeff. fugacity
CO_2	$3.8\cdot10^{-3}$	-2.4	$3.8\cdot10^{-3}$	-2.4	0	1
O_2	$1.9\cdot10^{-28}$	-27	$1.9\cdot10^{-28}$	-27	0	1
H_2O	$1.4\cdot10^{-2}$	-1.8	$1.4\cdot10^{-2}$	-1.8	0	1

The dependences of the hydrogen index of water (pH) and the redox potential (Eh) on the solution temperature were compiled (Table 2-3, Fig. 3-4). It has been shown that the pH value of water ranges from 7.3 to 7.62, and the redox potential is positive. Accordingly, the properties of water are restorative in nature and are quite suitable for drinking purposes.

Table 2. *Dependences of the hydrogen index (pH) and redox potential (Eh) on the temperature of the aqueous solution*

t_{H_2O}, °C	Eh, B	pH	Ion strength	TDS, mg/kg sol	ρ, kg/m³
5	0.410	7.62	0.007	349.8	1000.2
10	0.408	7.53	0.007	348.4	1000.0
15	0.407	7.45	0.007	346.6	999.4
20	0.405	7.38	0	344.5	998.5
25	0.404	7.30	0.007	341.9	997.3

Table 3. *Dependence of thermodynamic parameters on the temperature of the aqueous solution*

t_{H_2O}, °C	G, MJ	H, MJ	S, kJ/K	U, MJ	C_p, kJ
5	-13.09	-15.95	3.59	-15.75	4.19
10	-13.11	-15.93	3.67	-15.73	4.18
15	-13.13	-15.91	3.74	-15.71	4.18
20	-13.15	-15.89	3.81	-15.68	4.18
25	-13.17	-15.87	3.88	-15.66	4.18

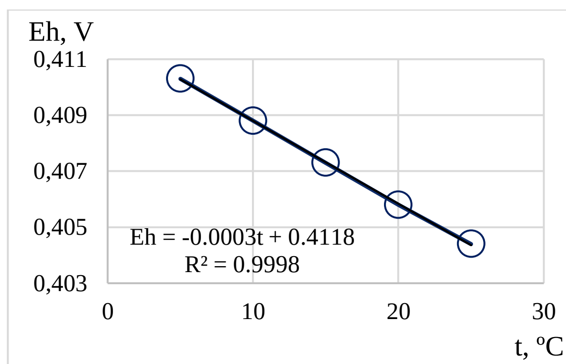

Figure 3. *Dependence of the redox potential on the temperature of an aqueous solution*

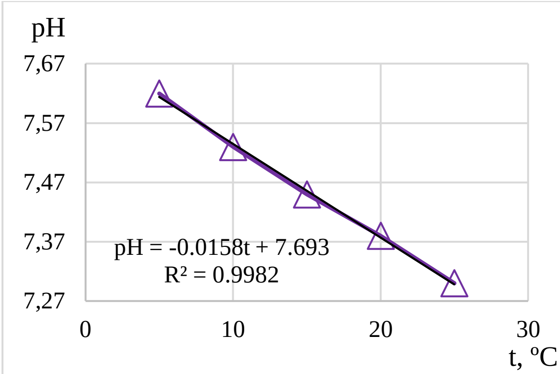

Figure 4. *Dependence of the redox potential on the temperature of an aqueous solution*

Based on Table 1-3, Fig. 3 and 4, calculation formulas for express water analysis were obtained: $Eh = -0.0003t + 0.4118$; $pH = -0.0158t + 7.693$, i.e. for express analysis of water, and thus the use of labor-intensive instrumental measurements is excluded, especially for determining the oxidation-reduction potential (Eh) of an aqueous solution.

4. Conclusion

The environmental aspects of water supply on the KTMU campus were considered and assessed in terms of indicators of the UI GreenMetric-2024 system. It was noted that the campus is provided with a central water supply from the city of Bishkek, and taking into account the seasonal low water supply, water is drawn from four drilled wells on the campus. The chemical composition of the campus model water was established and thermodynamic modeling was carried out at a minimum Gibbs energy. The concentration distribution of elements, cations and anions in water has been established and calculation formulas for express water analysis have been obtained. It has been shown that the pH value of water ranges from 7.3 to 7.62, and the redox potential is positive. Accordingly, the properties of water are restorative in nature and are quite suitable for drinking purposes.

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