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Water Minerals Associated in Health Risks: A Review

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ABSTRACT

Now a day drinking water has a significant role in the public health. Water is the essential part of life and also is the necessity of life. Water played an important role in the survival as well as in the transmission of disease causing agents. The microorganisms can easily grow and transmit through water resources and cause several health hazards. The residual of industries and urbanization provide unnecessary minerals to the source of drinking water sources. Minerals like Ca, Mg, Se, Mo, Cr, F, I, Zn, Na, K, Cd, Si, Cu, P and other may be present in drinking water, although not commonly realized drinking water provides some of these elements. Minerals in water have a significant etiological factor that triggering various diseases for instance, cardiovascular problems, kidney problems, cancer, reproductive failure, neural diseases, and renal dysfunction. The review highlights the risk of health hazards caused by the contaminated water and additional minerals present in the water.

INTRODUCTION

Most of the Earth's surface and the human body are filled with water. Ninety seven percent of water is found in sea and oceans which are contained salt in it. Only 3% of water is available for drinking in ground and surface [1]. Minerals like Ca, Mg, Se, Mo, Cr, F, I, Zn, Na, K, Cd, Si, Cu, P and other may be present in drinking water although not commonly realized drinking water provides some of these elements [2]. Water is crucial to sustain every living organism, including human beings. Drinking water has high impact on human health. Nearly 17% of the total population of the globe uses drinking water from unprotected and remote sources, 32% protected and 51% from pipe [3]. Minerals found in soil had dissolved in water, so water minerals depend on the location of water sources or affected by the geographical situations.

Minerals in water have a significant etiological factor that triggering various diseases for instance, cardiovascular problems, kidney problems, cancer, reproductive failure, neural diseases, and renal dysfunction and so on [3]. Different studies show that disease caused by water is related to its concentration of minerals and the microbial agents found in it. Fluoride was found in improved DW and it is non-carcinogenic when the concentration is less than 1, however non- carcinogenic risks of fluoride in specific areas, such as Inner Mongolia, Tianjin, and Sichuan has a high risk of health due to its geographic situation, even if, the concentration level of minerals in water are the same in different location, the consumption of drinking water matters the most in individuals [4]. Kidney stone had positively correlated with the concentration of calcium and magnesium in drinking water; especially peoples who drink groundwater have a high probability of developing kidney stone [5]. Important minerals recruited in DW as per standards may have a substantial protective part in health. Researchers indicate that Hard Water that encompasses a high level of Mg and Ca have a protective role in Cardiovascular Diseases.

The standard mineral concentration level was stated differently from one country to another, also continent to continent. The World Health Organization has set a guideline on drinking water mineral concentration, but most countries, including China, India, United States of America and several European countries have set their own standard DW based on WHO guidelines. This is appreciated by WHO guideline stated that water mineral concentration has to be related to according to the geographical/ environmental, economic and social circumstances of the country. For example, fluoride concentration is 1.5 g/l in the guideline; however, the intake of DW is increased in warm weather that may increase the consumption of fluoride [6]. The aim of this review is to assess the relationship between mineral composition in drinking water and its health impact in different publications.

In 2004, WHO recommended the minimum and maximum level of any desired minerals standard in drinking water? The optimum amount of Mg in drinking water is 20-30 mg/l and minimum are 10 mg/l, and for Calcium 50 mg/l is the optimum level of concentration in DW, however less than 20 mg/l is not acceptable for health. The total dissolved salt concentration (TDS) should be in between, of 2 up to 4 mmol/l [7]. In some countries where less amount of groundwater was used desalinated water from the sea or rain. A study in Israel indicates that over 75% of tap water source were desalinated water which has less amount of minerals in it, even this water removes above 60% of mineral from food when used for cooking. The survey shows a significant level of serum Mg was decreased in cases that used desalinated water for cooking and drinking [8].

METHOD

The This review explored the association of drinking water and risk of a health-related effect on peoples who are drinking water from surface water, spring, tap water, ponds or tube wells and rainwater in different places. Selected drinking water mineral was discussed in this review due to their clinical importance and widely available data in different journals.

The articles reviewed from databases included: PubMed, Web of Science, and Google Scholar, WHO web site, EBSCO host, Science Direct, Google Search, and the articles selected to this review with their convenience. Different associations, National and State department of health websites were also searched for relevant publications.

About 166 journals and health websites that related to drinking water were reviewed. The papers were categorized under sources of drinking water (tap water, spring, well, bottled water and ponds) consumed as drinking water, and minerals dissolved in the drinking water. Perhaps, there were lots of journal and other documents reviewed for this review, but only selected journals related to specific minerals and type of drinking were used for this review **(Table 1)**.

Table 1: Type of Water Sources, and Reviewed Journals and Sites

s.no.	Minerals	Tap water	wells	Bottled	Spring	Pond	Total
	Calcium	3	3	3	5	4	18
	Sodium	6	4	5	4	3	22
	Magnesium	3	3	3	2	2	13
	Phosphate	3	4	5	6	3	21
	Chlorine	4	5	5	3	3	20
	Copper	4	4	5	4	5	22
	Iron	3	5	4	5	3	20
	Zinc	3	2	4	2	3	14
	Fluoride	3	3	5	3	2	16
Total		32	33	39	34	28	166

INORGANIC ELEMENTS IN DRINKING WATER AND RISK IN HEALTH

Magnesium and its health risk

In intracellular cation Magnesium (Mg) is the next most ample minerals (next to potassium) and the fourth most abundant cation in the body. Prolonged exposure in a low level of Mg in DW may elevate the chance of risk for hypertension, dyslipidemia and type two DM [9]. Scientifically known that Mg has a significant role in the control of cardiac excitability, neuromuscular transmission, vasomotor tone, and blood pressure, among other functions. It is a co-factor for more than 300 cellular enzymes involved in cellular energy production and membrane functions [10]. Different studies show that there is significant proof in the inverse association of Mg level in drinking water and cardiovascular mortality [11,12]. When there is an extensive body exercise and high intake of protein may increase the acid load that leads to decreased Mg reabsorption and causes lower homeostasis in Mg. A study in Sweden indicates that there is no evidence to justify that only the Mg addition to drinking water used for the preventive purpose in CVD [13]. Different epidemiological studies indicated that the odds of death from an acute Myocardial infarction in the groups of drinking water Mg level were inversely associated [14,15].

A case-control study in Taiwan shows that there was a significant protective effect of magnesium intake from drinking water on the risk of hypertension [16]. Long-term magnesium deficiency in experimental animals potentiates responses to vasoconstrictor agents, attenuates responses to vasodilator agents, increases vascular tone and elevates blood pressure. A study in Gujarat, India on the level of Mg and Ca concentration in serum from filtered and non-filtered water sources shows that Hypomagnesaemia correlates with lower magnesium concentrations in drinking water (both rural tube-well and urban municipal waters), which can be attributed to the use of water purifiers [17]. As shown in studies there was an association between the Mg concentration and the impact of health due to the level of Mg minerals in serum.

A randomized cross-sectional study in Serbia indicates that the people who intake high Mg level of drinking water (42 mg L) have lowest diastolic blood pressure than from those who intake less Mg level DW (11 mg L^{-1}). Reduced Mg level in serum has an impact on serum lipid level due to Mg on triglyceride levels and positive correlation between Mg and serum cholesterol. The study adjusted confounders like Age, gender, and BMI. The serum Mg level is an independent predictor of triglycerides [9]. Demineralized

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water, which lost its Mg minerals that used for drinking water for a long time can increase morbidity and mortality from cardiovascular diseases, risks of motor neuronal disease, pregnancy disorder [7].

A case-control study in Taiwan indicates that there is no statistically significant association between people who consume low magnesium level drinking water and kidney cancer development. The study considered that there are confounding factors like consumption of food, amount of water intake, BMI that might affect the result [18].

Calcium in DW and its health risk

It is the main components of teeth and bone development, also used for vascular contraction, nerve transmission, and blood clotting system in our body. The most known disease with deficiency of calcium mineral is osteoporosis. Some literature shows that the deficiency of calcium might cause hypertension [7]. In terms of concentration of calcium is registered in relation to cardiovascular disease [13]. A systematic review of observational studies, 2009 revealed that there was no evidence was found on the association of cardiovascular disease and Calcium mineral in drinking water [11].

A study in Serbia shows that calcium in drinking water has a negative correlation to Ischemic heart disease. Low intake of calcium mineral was associated with independent of significant impact on the elevation of total cholesterol, triglyceride, and LDL-cholesterol levels, and systolic and diastolic blood pressure, which indirectly increases the risk of IHD in the study population [15].

A cross-sectional study undergone on Norwegians population in, 2015 shows that there was an inverse association of Calcium minerals in Drinking water and Bone fracture in the male. 15% of men who intake low level of calcium in DW has had a lower hip fracture, but no significant association in older female populations. The association elevated by the minerals copper in drinking water [19].

A matched case-control study in Taiwan indicates that an individual who died with kidney cancer cases that had a high calcium concentration in their drinking water was attributed higher death than compared to the lower concentration of calcium in their DW [18]. The calcium concentration in the body is determined by different factors like physical exercise, BMI, gender, age, smoking and alcohol consumption are known to affect the intake of Mg.

Sodium and its health risk.

Sodium and its health risk

Source of Sodium minerals for our body is dietary sodium chloride and above three fourth of sodium gained from processed foods. Drinking water is one of the sources of sodium minerals. Sodium carries electrolytes that facilitate muscles contraction and nerve cell transmissions, also used for maintain fluid balance and blood volume. Daily maximum sodium concentration in our body should reach 2,300 milligrams for adults to age 50 and 1500 milligrams for those 51 or older based on the Dietary Guidelines for Americans in 2010. The guidelines also recommend a maximum intake of 1500 milligrams for people of any age who are African-American or who have hypertension, diabetes or chronic kidney disease [20].

The Imbalance ratio of sodium and potassium concentration in our body has an effect on health. When sodium becomes too high and K too low, it causes hypertension. To balance the sodium and potassium concentration in the blood required mineral called magnesium. This means the concentration of magnesium has an effect on the level of blood pressure [10,21]. The concentration of Na that gained from drinking water is not more that 10% of total Na intake. So how this 10% of Na concentration that intake from drinking water affects the human health will be the major question to be answered.

The contribution of sodium mineral from drinking water is less than other dietary sources of total dietary sodium. Since there are a lot of confounding factors was there between the association of diseases that related to sodium in water and other dietary sources. Still, there are no firm conclusions can therefore be drawn at present as to the importance of sodium in drinking- water and its possible association with disease. A review from 1960 to 2015 from PubMed, Scopus, and Web of Science indicates there were association between drinking water sodium concentration and blood pressure, however, the association between water sodium and human diastolic blood pressure is not determined yet in the reason of insufficient number of studies (largely in young populations) and the cross-sectional design and methodological drawbacks. Now a day the way of people living standard, climate change and changes the context of people's concerns of drinking water, minerals and its sources in a higher manner [22]. Further research is urgently warranted to investigate and guide intervention in this increasingly widespread problem.

Fluoride and health risk

Fluoride helps in normal development and growth of children. Drinking water is the largest contributor to the daily fluoride intake for our body [23]. Mostly found in ground water and oceans naturally, however it requires fluoridation, which is the adjustment of fluoride to a recommended level for preventing tooth decay. “The World Health Organization acknowledges that fluoride is used to combat dental caries (tooth decay), particularly in areas of high sugar intake. It recommends that the optimal fluoridation of water ranges from 0.5 to 1.0 milligrams- per-liter.” According to CDC due to tooth decay an estimated 51 million school hours and 164 million work hours are lost each year due to dental-related illness.

Studies show the association of high fluoride concentration in drinking water and dental fluorosis is strong. Fluoride above the WHO requirement of 1.50 ppm causes dental fluorosis, which was indicated by the Ghanaian studies in children [24]. Most studies indicated that the prevalence of dental fluorosis is related to high concentration of fluoride and Based on their evidence, de-fluoridation of drinking water was recommended in places where high fluoride concentrations in drinking water than WHO recommendations [25-27].

In India, more than 60 million people drink water, which contain >1.5 mg/l concentration of fluoride and suffers with fluorosis [28]. It is difficult to treat dental fluorosis easily because the procedure is complex and hard to cover for people living at developing countries especially in rural areas [23]. There is no specific treatment for skeletal fluorosis, so it is better to use prevention mechanisms in those areas to control the prevalence **(Table 2)**.

Table 2: Drinking Water Standards for Fluoride Prescribed by Various Authorities [23]

S. No	Authorities	Permissible limit of Fluoride concentration (mg/l)
1	WHO (International Standard for drinking water)	0.5
2	US Public Health Standard	0.7-1.2
3	BIS (IS 10500)	1.0-1.5
4	Indian Council of Medical Research	1.0-2.0
5	CPHEEO	1.0-1.5

Phosphate and its health risk

Phosphorous is one of important minerals that used for body growth of animals and plants. Exists in three forms: Orthophosphate, Meta-phosphosulfate and organically bound phosphate. Each compound contains phosphorus in a different chemical formula ortho form is produced by natural processes [29,30]. It appears as a phosphate compound in water. Condensed phosphate is used in to prevent corrosion, during in treatment of drinking water.

Phosphate has an important role in key stages of the Krebs cycle, also in the synthesis of ATP, DNA, RNA which are the backbone of any organisms. Phosphate in drinking water is not harmful to human beings, however, when it appears in high amount causes digestive problems [30]. The concentration of phosphorous in dissolved orthophosphate form in drinking water is ranged from mg/L 1.8 to 2.88 ppm [31].

Absence of phosphorous causes bone mass loss, muscle weakness, malaise, and pain. There were limited studies focused on the relationship between phosphorous in drinking water and its risk of health. There was not sufficient data in hand to address those matters, due to this concern it is difficult to conclude about the effect of phosphorous minerals in drinking water and its health implications.

Chlorine and health risk

Chlorine is used disinfectant and oxidant in drinking-water treatment. The reaction of chlorine in water forms hypochlorite and hypochlorous acid. Present in most disinfected drinking- water at concentrations of 0.2–1 mg/l [32]. The recommended daily intake of chlorine concentration for health in 2 liters of drinking water for an average of 70 kg adults is for 0.4-1.5 g municipal water and0.3-9 g for wells [2]. The primary purpose of having chlorine in the water is to destroy the bacteria and viruses that can enter a water system in many different ways. The American Environmental Protection Agency (EPA) requires treated tap water to have a detectable level of chlorine to help prevent contamination. The allowable chlorine levels in drinking water (up to 4 parts per million) pose "no known or expected health risk [including] an adequate margin of safety".

For a long time, chlorine is not considered as a very harmful effect on human health from drinking water. However, effects of chlorinated drinking water have just recently been recognized. From the report of the U.S. Council of Environmental Quality, "Cancer risk among people drinking chlorinated water is 93% higher than among those whose water does not contain chlorine [33].

Epidemiological studies show that chlorination of drinking water causes possible adverse health risks such as a small increased incidence of cancers in males and developmental effects on infants, due to the formation of chlorinated disinfection by-products (DBPs) in drinking water [34,35]. When Chlorine is added to the water, it combines with other natural compounds to form Trihalomethanes (chlorination by-products) or THMs. These chlorine byproducts trigger the production of free radicals in the body causing cell damage, and are highly carcinogenic. Although concentrations of these carcinogens (THMs) are low, it is precisely these low levels that cancer scientists believe are responsible for the majority of human cancers in the United States.

A review of 40 epidemiological studies in 2016 shows the effect of chlorination of drinking water and its health risks. However, studies insufficiently addressed the numerous challenges to DBP risk assessment, failing to evaluate the evidence for a causal relationship, not appropriately addressing the complex nature of DBP occurrence as a mixture of chemicals, not adequately characterizing exposure in space and time, not defining specific health outcomes, not accounting for characteristics of target populations, and not balancing potential risks of DBPs against the health benefits related with drinking water disinfection [36].

Zinc and Iron health risk

In 1996, the WHO guideline recommends the standard limit of zinc in drinking water is 3.0 mg/l and Iron 0.3 mg/l [37]. Zinc

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is an essential nutrient for body growth and development. In natural surface waters, the concentration of zinc is usually below 10 µg/liter, and in ground waters, 10–40 µg/liter. According to Central Pollution Control Board (CPCB), it is 15 mg/L beyond these limits water becomes unsafe for drinking purpose [30]. It might be elevated in piping higher as a result of the leaching of zinc [38,39]. Previously zinc is known as an essential element for humans, and most health issues are focused on a deficiency of zinc rather than an excess, but now a day's studies show that the elevation of zinc in drinking water beyond permissible limits has an adverse effect on human health [40]. The exceeding amount of zinc enters the food chain through drinking water and cause toxicity.

An adult person daily intake of zinc can take up to 10-15 mg, but more than this, it becomes hazardous. A higher dosage of zinc also causes bio-accumulation of zinc in different body organs such as liver, kidneys, and gonads. Although kidney helps to remove excess zinc through homeostasis large amounts are difficult to remove from the body. Consuming large amounts of zinc causes nausea, vomiting, abdominal cramps, and anemia in humans [41].

Zinc is a public health problem when it exceeded the recommended limits in drinking water, however, there are no data was found in lesser Zn concentration in drinking water associated to risk to human health. The possibility of Zn mix with drinking water is increased due to expanding of industrialization increases Zn production from various sources such as corrosive pipelines, the release of industrial effluents, and metal leaching. Every water source will be exposed to zinc, so still needs to determine the level Zn in drinking water and assesses the effect in industrialized cities.

Iron is most commonly found in nature in the form of its oxides. Rarely found in nature, as the iron ions Fe^{2+} and Fe^{3+} readily combine with oxygen- and sulfur-containing. In drinking- water supplies, iron (II) salts are unstable and are precipitated as insoluble iron (III) hydroxide which settles out as a rust-colored silt. Iron concentrations of 1-3 mg/liter can be acceptable for people drinking anaerobic well-water [42].

Copper and health risk

Copper is an essential element for living organisms, most organisms require in a small amount for their diet. If the amount of copper is higher than there commended threshold, it causes an adverse effect on human health like nausea, diarrhea, stomach cramps and also leads to liver damage and kidney disease.

The concentrations of copper may have elevated in treated water, regularly increase during distribution. Mostly an acid pH or high-carbonate and in an alkaline pH water are the reason for the elevation of copper. Copper concentrations in drinking-water vary widely, with the primary source most often being the corrosion of interior copper plumbing. Levels in running or fully flushed water tend to be low, whereas those in standing or partially flushed water samples are more variable and can be substantially higher (frequently above 1 mg/l) [32]. One acidic well water gave 250% of Cu (from pipes) **(Table 3)** [43].

Table 3: A standard Concentration of Copper in Drinking Water Different Level [32,44]

S. No	Authorities	Acceptable limits
1	WHO	5 mg/l (5000 µg/l)
2	American	4 mg/L or 4 ppm
3	Indian	250-1000 mg/l; o.2 -1.0 for free chlorine ion

Inappropriate intake of copper has an effect on body metabolism and leads to diseases. An experimental study shows prolonged exposure to high causes redox-active metal concentration in drinking water has been implicated in different neurological disorders such as Wilson's, Menkes', Alzheimer's, and Parkinson's diseases. Peoples extensively uses Cu tubing in the plumbing system, thus dissolving of Cu in water corrosion causes the metal to leach into the drinking water. The experiments in mouse show that the effect of Cu on AP-1 is unique and may involve direct modulation of DNA binding [45]. Another experimental study indicates that there is a positive relationship between Cu in drinking water and Alzheimer disease that increased by copper plumbing use in developed countries parallels the growing prevalence of Alzheimer's disease [46-48].

The concentration of copper increased through pollution or corrosion of water tubes. According to experimental studies, chronic intake of this high concentration of Cu in drinking water causes cerebral ischemic injury in mice. Copper contamination of drinking water also leads to impairment of EPCs and consequent reduction of angiogenesis in the ischemic brain which is the main risk factor for stroke and cardiovascular diseases [49-51].

The future scenario of Cu concentration in drinking water and its health risk will be even worse, due to the practice of humans in the environment that make a change in climate and atmospheric CO_2, and natural burning of fossil fuels together makes acid rain. The acidic nature of drinking water made corrosion of Cu in drinking water. Copper-containing pipes are the reason for the elevation of drinking water copper concentration in the presence of acidic PH of water [52]. Low levels of copper can be found naturally in all water sources. However, drinking water that has been left standing in household copper pipes for long periods of time is usually the main cause of higher levels of copper. Studies show reasonable correlations between copper concentration released from copper plumbing tubes due to corrosion, dissolution, precipitation and other processes in drinking water [53]. The normal adult requires approximately two to three milligrams of copper per person per day. More than 90% of the dietary need for copper is provided by food. Drinking water is usually provided less than 10% of your daily copper intake. Further study has been needed to explore the association of this 10% of Cu concentration in drinking water causes risk to human health.

COMPARISON BETWEEN TAP WATER AND BOTTLED WATER FROM THE ASPECT OF HEALTH RISK

Now a day's bottled water is widely used as a source of drinking instead of tap water, however many studies indicated that there is and will be great debate on which one is more convenient for human health.

Studies on tap water shows that Lead (Pb) can permit in service lines containing drinking water and lead-containing plumbing, predominantly in the occurrence of corrosive water, it might cause neurodevelopmental in children even at low levels of exposure [54]. In the other side it is also showed in bottled water, where packed with plastics have an impact on drinking water. Studies indicated that bottled water contain a double dose of plastic particles (>100 um) than compared to Tap water on average of (10.4 *vs.* 5.45 particles/L) **(Table 4)** [55].

Table 4: Comparison of bottled water and Tap water

Key aspects	Bottled water	Tap water
Chlorine	No	Yes
Fluoride	Mostly not	often
Cost	Cost higher than tap	Less cost
Eco friendly	Less	High
Safety and quality regulations	high	moderate
Environmental impact	High impact	Very minimal
Extra added minerals	Yes	No

Bottled water is collected from natural springs or public sources goes through a purification process and is then bottled and distributed to retail stores, however tap water is delivered through a system of pipes, pumps and purification systems to homes and buildings in the developed and developing world.

Most studies shows from the aspects of health risks in bottled water and tap water that elations the convenience of tap water and grants a more safe and better choice than bottled water. However, Tap water has its own limitations on the concern of quality, but when critically analyzed from the ecosystem, specifically environmental aspect, and also future aspects Bottled water causes much chaos for a diversified life on the earth than Tap water.

So, it is better to acquaint that a person who consume tap water have a better advantageous regarding with less health risk than bottled water. Instead of consuming tap water directly, using filter material is better to ensure safety and quality.

Generally, quality drinking water should contain important minerals set by national and international agreed standard limits. The likes of Calcium, Magnesium, and Sodium may provide clinically important portion of dietary, however Copper, zinc and arsenic should be avoided from drinking water due to its carcinogenic character that might lead to certain forms of cancer, cardiovascular disease and rare congenital malformation of central nervous system.

CONCLUSION AND RECOMMENDATION

Now a day drinking water has a significant role in the public health. There are many factors that affect the quality of drinking water that affects the social health status, especially in the current scenario; urbanization and the spread of industrialization have a major factor to inhibit the quality of drinking water and social impact as a cause for community health. The residual of industries and urbanization provide unnecessary minerals to the source of drinking water sources.

Minerals in drinking water are very helpful for the human health during growth and development; however, beyond the acceptance limit it causes diseases. The primary purpose of determining the level of drinking water minerals is to protect the public health from mineral induced diseases. Important inorganic minerals like Na, Ca, Cl, F, Cu, Fe, Zn, Mg, and P are assessed in this review.

Calcium and Magnesium have a significant role in cardiovascular disease. Both minerals play a major role in water hardness though inverse roles in ischemic heart disease, acute Myocardial infarction, and cause for hypertension. Sodium also associated with hypertension, but it needs sufficient research has been needed to conclude. Dental fluorosis and the skeletal problem are associated with elevated fluoride concentration in drinking water. This is also major public health problems in the different region of African and Asian continents. Phosphorous in drinking water and its risk of health is shown a limited association in drinking water, however, elevated phosphorous causes some disturbance of metabolism. Exceeded concentration of zinc in drinking water in drinking water causes toxicity for the body; however, the effect of reduced Zn in drinking water is not well studied in the current scenario as the best knowledge of the reviewer. Experimental study shows copper (2+) in drinking water beyond permissible limits causes Alzheimer diseases which are a major public health problem in different continents.

Finally, the drinking water minerals are essential to growth and developments of human, however, maintaining the permissible limit has to be essential to keep producing a healthy generation for this world.

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