

Holistic health: How ceramics and glass contribute to our physical and mental wellbeing

By Margareth Gagliardi

The relaxing sound of a fountain. A blue marine pool. Freshly made yogurt. The silky softness of a body cream. An enticing citrus scent. Holistic health relies on the five senses to provide a broad approach to physical, mental, and spiritual wellbeing.

Since ancient times, ceramics and glass have contributed to holistic health. For example, from the functional side, analysis of artifacts from 20,000 years ago confirmed that human beings have for millennia used clay containers of different shapes and sizes, such as vases, bowls, and dishes, to safely store, mix, cook, and serve foods and beverages.¹ They also used clay vessels to store beauty products, such as the miniature ceramic bottles that archeologists discovered from 5000 B.C.E. containing traces of cerussite and beeswax, two components of early cosmetics.²

Table 1. The global health and wellness market, 2022–2028 (\$ in billions)*

Segment	2022	2023	2028	CAGR% 2023–2028	Source
Sport, fitness, and recreational activities	1,443.8	1,900.7	2,279.3	3.7	Ref. 5
Traditional, complementary, preventive, and personalized medicine	1,309.1	1,490.1	2,869.1	14.0	Ref. 6
Wellness tourism	814.6	923.6	1,658.4	12.4	Ref. 7
Nutrition and weight management	623.3	668.5	985.5	8.1	Ref. 8,9
Beauty and personal care	518.6	557.4	807.7	7.7	Ref. 10
Wellness real estate	343.3	417.8	1,119.2	21.8	Ref. 11
Mental wellness	148.4	160.3	232.3	7.7	Ref. 12
Workplace wellness	56.6	60.1	79.6	5.8	Ref. 13
Total	5,257.7	6,178.5	10,031.1	10.2	Refs. 3,4

*Report data was independently verified by specialty market research firm AMG NewTech (Charlottesville, Va.)

Additionally, ancient people used ceramics and glass to communicate historical and religious ideas and to express emotions. For instance, decorative ceramic and glass mosaic tiles can be found in the homes, temples, mosques, and palaces of the Roman and Byzantine Empires and Umayyad Caliphate.

In current times, ceramics and glass have gained increasing importance in the wellness sector due to their unique aesthetic and functional properties. During the last century, technological advancements, engineered materials, and innovative processes enabled new techniques aimed at enhancing aesthetics and rejuvenating health.

Recently, the wellness industry has shifted away from being a domain for the most privileged by introducing a variety of options to reach out to broader and more diverse demographics. For example, companies are marketing affordable materials and devices that can be used at home, in addition to offering customized plans that meet the needs of a given individual.

The health and wellness industry was hit hard during the COVID-19 pandemic, but that hardship ultimately generated an even stronger consumer interest in aesthetics, nutrition, health, sports and fitness, mental wellbeing, and rest and relaxation.

People are pursuing a better lifestyle by giving priority to regular physical exams, improved personal care, better diets, exercise, and outdoor activities. As a result, the global health and wellness market reached nearly \$5.3 trillion

in 2022 (Table 1), and it is projected to grow at a 10.2% compound annual growth rate (CAGR) to reach \$10.0 trillion in 2028.^{3,4}

This article reviews the main applications of ceramics and glass in the health and wellness industry (Figure 1), and it describes how ceramics and glass help fulfill the current needs of this sector.

FACTORS DRIVING DEMAND IN THE HEALTH AND WELLNESS INDUSTRY

According to the United Nations, seniors aged 65 and over are the fastest growing demographic group worldwide.¹⁴ This segment accounted for 9% of the global population in 2019 but is expected to rise to 16% by 2050.

As people grow older, there is not only an increased need for products that prevent and treat physical and mental disorders and diseases, but there is also greater demand for cosmetics, anti-aging cream, personal care products, and procedures that help rejuvenate the body.

Men, too, are becoming larger consumers of cosmetics and personal care products in markets around the world. The Connecting the Dots 2022 report from insights firm GWI states that since 2018, beauty and cosmetic products have represented the “fastest-growing interest” among male consumers, increasing by 21% between 2018 and 2021.¹⁵

As a result of the COVID-19 pandemic, more people are aware of the need for products and activities that help support mental health. At the same time, many consumers of all ages are increasingly seeking out foods that are not only

grown with fewer chemicals and through more sustainable methods, but foods that are cooked or processed to maintain their nutritional properties.

Other trends that shape today’s health and wellness industry include

- Greater utilization of electronics and smart devices,
- Introduction of virtual and augmented reality,
- Diffusion of e-commerce for direct sales to consumers,
- Redesigning the home to incorporate health and wellness areas,
- Wider selection of amenities and services offered in spa resorts and wellness clubs to attract new customers,
- Focus on providing long-lasting experiences at these facilities,
- Reconnecting with nature through natural and sustainable products, and
- Discovering wellness practices from different cultures.

The following sections provide an overview of the various sectors of the health and wellness industry that are evolving and adapting to meet these demands. Table 2 presents a small sampling of the many companies offering products used in this industry.

SPORT, FITNESS, AND RECREATIONAL ACTIVITIES

With estimated revenues of \$1.9 trillion in 2023, sport, fitness, and recreational activities currently represent the largest segment of the global health and wellness industry with 30.8%.⁵

The ACerS Bulletin dedicated its December 2021 issue to this large sector



Figure 1. Glass and ceramic materials have many applications in the health and wellness industry.

- a) Sport, fitness, and recreational activities:** wear-resistant and lightweight components, platforms for augmented and virtual reality.
- b) Nutrition and weight management:** cookware and tableware, countertops and backsplashes.
- c) Beauty and personal care:** cosmetic ingredients and containers, massage tools.
- d) Traditional, complementary, preventive, and personalized medicine:** bioactive and biocompatible implants, displays, vials.
- e) Mental and workplace wellness:** sound therapy, aromatherapy, art therapy, games, religious objects.
- f) Wellness tourism and real estate:** mosaics and antibacterial tiling, glass panes, heater components, biohacking.

to recognize the importance of sports in society and explain how ceramic and glass materials contribute to enhanced performance and provide safety in sports. Two major highlights from that article include

1. Sports equipment and apparel benefit primarily from the addition of carbon fibers and fiberglass to produce composite materials, and
2. Ceramic coatings are used to confer specific functionalities to sports textiles.

Currently, a main application of ceramic components in sports is as wearable sensors. Other emerging applications of ceramics in sports are for production of wear-resistant and lightweight components. For example, CeramicSpeed (Holtstebro, Denmark) manufactures silicon nitride ball bearings designed to replace traditional steel ball bearings and reduce the weight of bikes, especially those used for racing. Corrosion-resistance, durability, and performance are other distinctive qualities.

"Longevity of a well-built, high-quality ceramic bearing, in many cases, can be up to 10 times longer than commonly used stock bearings," explains Martin Banke, executive vice president at CeramicSpeed, in a *road.cc* article.¹⁶ "The second

advantage of ceramic bearings over stock steel bearings is their performance under load in reducing drag. Performance cyclists are performance driven, and all data shows that the best performing bearings for reducing drag are ceramic bearings."

MTX Braking (Salt Lake City, Utah) produces ceramic brake pads for mountain and road bikes that are more durable, quiet, and heat-resistant than conventional metallic pads (Figure 2). Meanwhile, Kogel (El Paso, Texas) manufactures other ceramic bike parts, such as brackets and derailleur cages.

Not only bikes use ceramics. Piezoelectric ceramic components, for instance, incorporated into smart skis convert ski vibrations into electrical energy, helping to keep the skis in contact with the snow.

Glass is gaining increased importance in home fitness, specifically in the building of low-budget home gyms.¹⁷ Floor-to-ceiling and wall-to-wall glass panes are used to create workout spaces within larger areas, such as basements, and act as noise barriers while enabling light transmission from and to surrounding rooms.¹⁸

HILO Smart Mirror (Montreal, Canada) has introduced two very compact smart mirrors (round and square) that can be easily mounted on every wall throughout the house. The smart



Credit: Fanatik, YouTube

Figure 2. Close-up of the MTX Braking gold label heavy-duty ceramic brake pad. A blend of Kevlar and copper fibers are embedded in the ceramic.

mirrors are made from diamond-coated glass to protect against fingerprints, dust, scratches, and water.

HILO's smart mirrors can be used as gym mirrors to check the body during a workout, amplify natural lights, and create the illusion of space. They also incorporate a display that allows the user to upload fitness apps and shows workout sessions the user can take, such as cardio and yoga classes. The smart mirror is interactive and features augmented reality and artificial intelligence software to virtually try cosmetic and hair products and purchase them electronically.

Glass and ceramic components have also become an integral part of virtual reality (VR) fitness gadgets and equipment aimed at making exercise more fun and appealing. According to the Virtual Reality Institute, a research organization studying the health impact of virtual and augmented reality,¹⁹ "VR is not just fun exercise. It is the first generation of exercise equipment capable of meaningful live biofeedback," the organization says.

VR fitness sessions can be attended on a variety of electronic devices, including head-mounted displays, smartphones, tablets, laptops, and smart TVs. Although more in-depth studies are needed to fully assess the effects of VR, a preliminary review performed by the University of Minnesota in 2020 suggested that "VR exercise has the potential to exert a positive impact on individual's physiological, psychological, and rehabilitative outcomes compared with traditional exercise."²⁰

The market for VR fitness is estimated to reach \$17.4 billion in 2023, and it is forecast to have very rapid growth through 2032 with a CAGR of 31.2%,²¹ as more people prefer to exercise at home and look for personalized fitness sessions.

Scratch-resistant glass, such as the Gorilla Glass made by Corning (Corning, N.Y.), is used for fabrication of smartwatches and other wearable devices designed to monitor various physical parameters, such as heart rate, blood pressure, stress level, energy expenditure, and sleep patterns.

Garmin (Olathe, Kan.) sells a complete series of smartwatches with durable glass specifically designed for sports and fitness. These wearable devices meet the needs of both amateurs and professionals and are also capable of displaying training metrics, e.g., training readiness, morning report, recovery, training tips, daily suggested workouts, and training status.

PICKLEBALL SCORES WITH THE HELP OF CERAMIC PADDLES

By Laurel Sheppard

Pickleball is a paddle sport that combines elements of tennis, badminton, and ping-pong. It is played either indoors or outdoors on a badminton-sized court using a slightly modified tennis net.

Pickleball traces its origin to 1965, when Washington state congressman Joel Prichard and businessman Bill Bell improvised the game using assorted sports equipment to entertain their bored families. But the popularity of the sport has exploded in recent years, with a report by the Association of Pickleball Professionals estimating that more than 36.5 million people played the sport in 2022.^a

With this increased interest in pickleball, what was once a simple wooden paddle has morphed into paddles that feature numerous high-tech designs and materials, including ceramics.

For example, the face material on a pickleball paddle determines how heavy the paddle is and what type of player should use them. Ceramic materials are often used in pickleball paddle faces, such as

- **Composite-faced paddles**, typically fiberglass reinforced, are one of the most common paddle face types. They are suitable for all levels, including power and spin players.

- **Graphite-faced paddles**, which incorporate a thin layer of graphite on the paddle's core, are lightweight and best for control players.

- **Carbon-fiber-faced paddles** are a recent addition to the game, resulting in extremely durable paddles. Thus, they are suitable for power players and those who "abuse" their paddles.

- **Hybrid-faced paddles** combine several materials, including all those previously discussed, and are suitable for all-around players.

Most pickleball paddles range in price from \$60 to \$230. Aluminum-faced paddles are some of the least expensive and so are a good



Credit: Michael & Sherry Martin, Flickr (CC BY-NC-ND 2.0)

choice for beginners or recreational players looking for an inexpensive option. Once a player decides to invest in the game, however, they may want to choose one of the other, ceramic-based options.

References

^aJ. Golden, "Pickleball popularity exploded last year, with more than 36 million playing the sport," *CNBC*. Published 5 Jan. 2023. Accessed 19 Oct. 2023. <https://www.cnbc.com/2023/01/05/pickleball-popularity-explodes-with-more-than-36-million-playing.html>

Table 2. Select companies involved in the health and wellness industry.*

Company (Location)	Annual revenue (millions)*	Website	Role in value chain
SPORT, FITNESS, AND RECREATIONAL ACTIVITIES			
CeramicSpeed (Holtstebro, Denmark)	\$5.6	www.ceramicspeed.com	Manufacturer of ceramic bearings for bikes
Corning (Corning, N.Y.)	\$14,189	www.corning.com	Manufacturer of scratch-resistant and strengthened glasses for smartphones, smartwatches, and other applications
Fitbit (San Francisco, Calif.)	\$1,210	www.fitbit.com	Producer of smartwatches and trackers for sport and fitness
Fossil Group (Richardson, Texas)	\$1,682	www.fossil.com	Manufacturer of wellness smartwatches
Garmin (Olathe, Kan.)	\$4,860	www.garmin.com	Producer of smartwatches and other gadgets for sport and fitness
HILO Smart Mirror (Montreal, Canada)	\$1	www.hilosmartmirror.com	Producer of smart mirrors
Kogel (El Paso, Texas)	\$2.1	www.kogel.cc	Manufacturer of ceramic bearing, brackets, and other components for bikes
MTX Braking (Salt Lake City, Utah)	<\$1	www.mtxbraking.com	Manufacturer of ceramic brake pads
TRADITIONAL, COMPLEMENTARY, PREVENTIVE AND PERSONALIZED MEDICINE			
Apple (Cupertino, Calif.)	\$394,328	www.apple.com	Manufacturer of augmented reality head mounted displays for the healthcare sector
Corning (Corning, N.Y.)	\$14,189	www.corning.com	Manufacturer of container glass for the healthcare sector
Gerresheimer (Dusseldorf, Germany)	\$1,915	www.gerresheimer.com	Producer of specialty glass for the healthcare sector
Lithoz (Vienna, Austria)	\$7.9	www.lithoz.com	Producer of 3D printing equipment for ceramics for the healthcare sector
Microsoft (Redmond, Wash.)	\$211,915	www.microsoft.com	Manufacturer of augmented reality head-mounted displays for the healthcare sector
Stephanie Imports (Brookline, NY)	\$7	www.stephanieimports.com	Supplier of ceramic pill boxes
Vuzix (West Henrietta, N.Y.)	\$11.8	www.vuzix.com	Manufacturer of augmented reality wearable displays for the healthcare sector
WELLNESS TOURISM			
Amerec (Cokato, Minn.)	\$4.4	www.amerec.com	Manufacturer of commercial glass-based saunas
Atlas Concorde (Spezzano di Fiorano, Italy)	\$632.4	www.atlasconcorde.com	Producer of porcelain tiles for spas and wellness centers
Daltile (Dallas, Texas)	\$1,700	www.daltile.com	Producer of ceramic tiles for commercial spas and pools
KLAFS (Baden-Wuerttemberg, Germany)	\$142.3	www.klafs.com	Producer of commercial and residential spas, baths, saunas, and pools
SaunaRay (Collingwood, Canada)	\$1.5	www.saunaray.com	Producer of commercial saunas with ceramic heaters and glass fixtures
Sommerhuber (Steyr, Austria)	\$6.6	www.sommerhuber.com	Manufacturer of ceramic loungers, massage tables, and other ceramic components for commercial spas
NUTRITION AND WEIGHT MANAGEMENT			
Bormioli Rocco (Parma, Italy)	\$271.6	www.bormiolirocco.com	Manufacturer of glass for tableware
Caraway (New York, N.Y.)	\$10	www.carawayhome.com	Producer of ceramic-coated nonstick cookware and ovenware
Florim (Fiorano Modenese, Italy)	\$605.5	www.florim.com	Manufacturer of kitchen porcelain slabs and tiles
Iris Ceramica Group (Fiorano Modenese, Italy)	\$580	www.irisceramicagroup.com	Manufacturer of kitchen porcelain slabs and tiles
Kyocera (Kyoto, Japan)	\$12,443	www.global.kyocera.com	Producer of ceramic knives, nonstick coated cookware, and other kitchen tools
Schott (Mainz, Germany)	\$2,951	www.schott.com	Producer of glass-ceramic cooktops
The Cookware Company (Irvington, N.Y.)	\$35	www.cookware-co.com	Producer of ceramic-coated nonstick cookware and ovenware
Xtrema (Hagerstown, Md.)	\$9.5	www.xtrema.com	Manufacturer of pure ceramic cookware

*Financial data obtained from most recent annual reports for public companies or estimated based on google.com for private firms.

Holistic health: How ceramics and glass contribute to our physical and . . .

Table 2 (continued). Select companies involved in the health and wellness industry.*

Company (Location)	Annual revenue (millions)*	Website	Role in value chain
BEAUTY AND PERSONAL CARE			
X3M (St. Paul, Minn.)	\$34,229	www.3m.com	Producer of glass microspheres for cosmetics
BioMin Technologies (Stoke-on-Trent, U.K.)	\$2.5	www.biomin.co.uk	Producer of bioactive-glass-based toothpaste
Groupe Pochet (Paris, France)	\$512	www.groupe-pochet.fr	Manufacturer of container glass for cosmetics and personal care
Heinz-Glas (Kleintettau, Germany)	\$35.1	www.heinz-glas.com	Manufacturer of container glass for cosmetics and personal care
Lavien (Pine Brook, N.J.)	\$1.4	www.laviencosmetics.com	Producer of ceramic sculpting tools for Chinese medicine practice gua sha
Potters Industries (Malverne, Pa.)	\$37.3	www.pottersindustries.com	Producer of glass microspheres for cosmetics
Prizmalite Industries (New York, N.Y.)	\$2.5	www.prizmalite.com	Producer of glass microspheres for cosmetics
Schott (Mainz, Germany)	\$2,951	www.schott.com	Manufacturer of bioactive glass
Verescence (Puteaux, France)	\$432	www.verescence.com	Manufacturer of container glass for cosmetics and personal care
Vidraria Anchieta (São Paulo, Brazil)	\$6.2	www.vidrariaanchieta.com.br	Manufacturer of container glass for cosmetics and personal care
WELLNESS REAL ESTATE			
TheraSauna (Bettendorf, Iowa)	\$2.5	www.therasauna.com	Producer of ceramic heaters for saunas
Bardelli Group (Vittuone, Italy)	\$29.2	www.gruppobardelli.com	Manufacturer of mosaic tiles for wellness areas, kitchen, bathrooms, and swimming pools
Country Floors (New York, N.Y.)	\$11.6	www.countryfloors.com	Manufacturer of ceramic tiles for wellness and comfort
Gruppo Geromin (San Stino di Livenza, Italy)	\$15.8	www.gruppogeromin.com	Manufacturer of home spas and saunas with glass and ceramic components
Sunray Saunas (Richmond, Va.)	\$2.5	www.sunraysaunas.com	Producer of home saunas with ceramic heaters and tempered glass
MENTAL WELLNESS			
Adam Frezza & Terri Chiao (Brooklyn, N.Y.)	\$3	www.etsnitystew.com	Producer of ceramic puzzles
ALEA Mosaik (Munich, Germany)	\$3	www.alea-mosaic.com	Producer of ceramic mosaic tiles for artwork
Alpine (Commerce, Calif.)	\$33.5	www.alpine4u.com	Manufacturer of indoor ceramic fountains
Lamps Plus (Los Angeles, Calif.)	\$422.2	www.lampsplus.com	Manufacturer of indoor ceramic fountains
MumGaya Ceramics (Port St. Lucie, Fla.)	\$2.5	www.mumgaya.com	Producer of ceramic games
Sunnydaze Décor (Eau Claire, Wis.)	\$4.4	www.sunnydazedecor.com	Supplier of ceramic wellness fountains
WORKPLACE WELLNESS			
Dezine (Mississauga, Canada)	\$6.2	www.dezinecorp.com	Supplier of corporate wellness gifts made from ceramics and glass
Knack (Seattle, Wash.)	\$16.4	www.knackshops.com	Supplier of corporate wellness gifts made from ceramics and glass
Loved and Found (Addison, Texas)	\$0.5	www.lovedandfoundbox.com	Supplier of corporate wellness gifts made from ceramics and glass
Merchery (Brussels, Belgium)	\$1.7	www.merchery.co	Supplier of corporate personalized ceramic mugs
Metron Branding (Troy, Mich.)	\$2.5	www.metronbranding.com	Supplier of corporate wellness gifts made from ceramics and glass

*Financial data obtained from most recent annual reports for public companies or estimated based on google.com for private firms.

TRADITIONAL, COMPLEMENTARY, PREVENTIVE, AND PERSONALIZED MEDICINE

The market for products and services aimed at improving wellness by combining traditional, complementary, preventive, and personalized medicine is another large segment of the total health and wellness industry, with revenues estimated at nearly \$1.5 trillion in 2023, corresponding to a market share of 24.1%.⁶

Industrialization, economic development of disadvantaged regions, and a growing elderly population are causing an increase in healthcare spending to treat a variety of diseases, such as cardiovascular disorders, mental illness, diabetes, and cancer, and prevent the occurrence of new medical conditions. These factors will drive the market for wellness products and service used in traditional, complementary, preventive, and personalized medicine to expand at a very rapid 14% CAGR during the next five years.⁶

Ceramics and glass occupy a very important place in traditional medicine as they have become fairly popular in the manufacturing of implantable devices, as detailed in the December 2020 *ACerS Bulletin*. In fact, as of 2023, these materials account for approximately 20% of the \$178 billion biomaterials market.²²

Unlike metals, ceramics and glass can be formulated to be inert, resorbable, or bioactive, and they have better wear resistance and biocompatibility than polymers. These properties are often needed to ensure fast patient recovery and are particularly desirable to improve the quality of life of older patients.

The advent of ceramic 3D printing, which allows for the quick fabrication of complex ceramic shapes that mimic body organs and tissues, is expected to contribute to a very strong growth of the medical ceramic market.²³ According to MarketsandMarkets, global sales of 3D-printed medical devices are projected to exceed \$3 billion in 2023 and to expand at a very rapid CAGR of 17.1% during the next five years.²⁴

To benefit from this growth, Lithoz (Vienna, Austria) has introduced a lithography-based ceramic manufacturing system optimized for medical applications that achieves the high precision

needed to fabricate custom implants and patient-specific solutions. The system is suitable for processing ceramic materials such as alumina, zirconia, hydroxyapatite, tricalcium phosphate, and silicon nitride.

"You can now actually manufacture implants with 3D printing and generate those open, porous, interconnected networks that allow the ingrowth of the bulk of the blood vessels and the removal of metabolic products, which is important for the healing process," Daniel Bomze, director of medical solutions at Lithoz, explains in an interview with *TCT Magazine Europe*.²⁵ "There are other ways to shave these materials, but only additive manufacturing allows you to create the geometry of the pore and the connection between the pores."

Furthermore, ceramics and glass are gaining growing relevance in complementary, preventive, and personalized medicine. These fields are evolving toward a greater utilization of wearable devices, sensors, portable instruments, and equipment for telemedicine, and ceramics and glass can be found as integral components of all these devices.

For example, point-of-care testing (i.e., diagnostic testing that can be done at home without the need for a lab) uses microfluidic devices based on glass²⁶ or low-temperature cofired ceramics,²⁷ while piezoelectric ceramics are used for energy harvesting in wearable medical devices.²⁸

State-of-the-art glass display technologies are enabling the incorporation of augmented reality in telemedicine. The combination of advanced display technology and augmented reality with other capabilities provided by artificial intelligence and 5G wireless communication is expected to bring enormous benefits in the field of remote healthcare. These technologies will ameliorate home medical care, reduce healthcare costs, improve emergency services, facilitate training of practitioners, and foster preventive medicine. For instance, Vuzix (West Henrietta, N.Y.) sells smart glasses that enable doctors to share images and communicate in real-time with other medical experts around the world.

Also noteworthy is the use of ceramics and glass for products that are less

technologically advanced, such as containers for vitamins, health supplements, and prescription pills. Ceramic pill cases have been around for centuries, and, even after the advent of plastic, they continue to have their appeal as they prevent product contamination, keep pills organized, protect them from moisture, and isolate them from extreme temperatures. Pill boxes are available in a multitude of colors, handcrafted designs, shapes, and sizes.

WELLNESS TOURISM

Wellness tourism refers to travelling activities aimed at promoting individual wellbeing and preventing physical and mental disorders and diseases. Wellness

EPINEPHRINE AUTO-INJECTORS: THE GLASSY HEART INSIDE THIS LIVE-SAVING TECHNOLOGY

By Eileen De Guire



Credit: Anun Vashisthaya, Saxon Glass Technologies

For people who suffer from food or bee sting allergies, access to the drug epinephrine can be lifesaving. According to ClinCalc.com,^a in 2020, 1.2 million patients received an estimated 1.7 million epinephrine prescriptions in the U.S. alone.

Because epinephrine must be administered within minutes of the onset of anaphylaxis symptoms, many patients carry epinephrine auto-injectors, which feature a borosilicate glass cartridge that contains the drug.

Saxon Glass Technologies, Inc. (Alfred, N.Y.) developed an ion-exchange glass strengthening process for the borosilicate glass cartridge. This strengthening process ensures that the auto-injectors can be filled, assembled, shipped, and carried by patients without breaking—so it will be ready to save a life.

References

^a"Epinephrine: Drug usage statistics, United States, 2013–2020," *ClinCalc.com*. Accessed 31 Oct. 2023. <https://clincalc.com/DrugStats/Drugs/Epinephrine>

Holistic health: How ceramics and glass contribute to our physical and . . .

tourism is different from medical tourism in that the first targets prevention and general wellness, while the second focuses on medical care and treatments.

Valued at \$924 billion in 2023, wellness tourism currently represents 14.9% of the total health and wellness industry market, with revenues estimated to rise at a 12.4% CAGR from 2023 to 2028.⁷

“We’ve heard that wellness is now at the forefront of everybody’s mind, and self-care rituals are really important to everybody—and they’re taking that with them when they travel,” says Kenneth Ryan, vice president of global wellness and spa & fitness operations at Marriott International, in a *Hotel Business* article.²⁹ “This has had a profound shift in what’s going on and driving powerful growth. We’re seeing high demand in our spas and the best revenues ever—well over 2019—and really strong rates.”

Wellness tourism can be done by staying in resorts and retreats or cruise trips that offer a broad range of activities, including yoga, meditation, weight loss and detox programs, body massages, Ayurveda therapies, spas, saunas, hot springs, Turkish baths, and thermal waterparks.

The most popular routines take place in spas and baths inspired by other cultures, mainly the ancient Romans or the Ottoman Empire. These routines typically start with a warm temperature treatment.

A tepidarium, for example, is a low-to-medium-humidity room with walls, benches, and ergonomic loungers heated to provide temperatures ranging between 35°C and 40°C (i.e., at or just a little above normal body temperature). The tepidarium allows the body to pleasantly relax, relieve stress, and regenerate, and it is generally recommended for people affected by blood circulation issues or frequent colds.

In contrast to a tepidarium, in a caldarium, the temperature of walls, floors, and benches can be regulated so that the air can reach up to 60°C while humidity can go up to 100%. These warmer and humid conditions help with muscle relaxation, make the skin softer, and soothe and detoxify the body.

The laconicum (or laconium) is similar to the caldarium but has much lower humidity, between 15% and 20%. A variant is the herbal laconicum, which features herbs warmed on stones to enhance relaxation by the addition of aromatherapy.

In contrast to these humidity-based spa rooms, saunas use dry air at very high temperatures, normally between 80°C and 100°C, to reduce stress and boost the immune system. Finnish saunas are well-known for reaching even higher temperatures, as high as 120°C.

Steam rooms combine the same high humidity as a caldarium but at the same high temperatures as a sauna. This combination of high humidity and temperature helps achieve body hydration and better blood circulation while relieving stress. Relaxation can be further boosted using aromatic oils.

KLAFS (Baden-Wuerttemberg, Germany) sells and installs a broad range of the different heat-treatment rooms described above, with many incorporating ceramic mosaics and glass.

A Turkish bath, or hammam, is composed of two sections, one that emphasizes sweating and cleansing, and the other dedicated to mental repose and tranquility. The warm or hot

treatment can be followed by bathing in the cold water (12°C to 20°C) of a frigidarium to bring pores and blood vessels back to their normal size and increase blood flow.

In addition to these traditional spa setups, many routines and facilities in wellness resorts are now being designed to conform to the new trend of biohacking.

“Biohacking is the targeted autoregulation and regeneration of the body,” explains Karl-Ludwig Resch of the German Institute of Health Research on KLAFS’ website.³⁰ “Stimulating environments with heat, cold, light, movement, or current pulses create stimuli that positively influence the body in a targeted and finely dosed manner.”

An example of ceramics and glass used in biohacking are the LED bulbs for red and blue light therapy. This therapeutic technique uses wavelengths of red and blue light to help treat skin conditions, such as scarring and loss of elasticity (red light) and enlarged pores and breakouts (blue light).

NUTRITION AND WEIGHT MANAGEMENT

With a global market valued at \$685.5 billion in 2023, nutrition and weight management account for a substantial share of the health and wellness industry, at 10.8% of the total. This segment is also forecast to have healthy growth during the next five years with an 8.1% CAGR.^{8,9}

Since ancient times, ceramics and glass have contributed to the preparation of healthy, natural, and nutritious foods and have also played a very important role in their conservation and safety. Cookware made from earthenware, stoneware, porcelain, and flameware can be found in virtually every kitchen (Table 3).³¹

Earthenware is the oldest type of pottery and is made from common clay. Sintered at low temperatures (between 950°C and 1,100°C), it is porous as well as lightweight and fragile. It is suitable for cooking at low or medium heat and can be used for slow cooking of delicate foods (e.g., gravy and sauces) or to sauté or stew vegetables and meats.

Earthenware holds an important role in many ethnic cuisines. Mediterranean fish soups, Balkan ghivetch (vegetable stew), Chinese clay pot rice (a mix of rice, meat, seafood, and vegetables), and Japanese shabu-shabu (thinly sliced meat with vegetables) are just a few examples of dishes that get their qualities from clay pot cooking. Traditional Dahi, or Indian yogurt, is prepared in a clay pot. Thanks to the capability of the porous earthenware to absorb water, the cultured milk transforms into a thick, creamy, and delicious curd.

Stoneware (Figure 4a), unlike earthenware, is manufactured from fire and ball clays (i.e., kaolinitic clays) and sintered at higher temperatures (between 1,180°C and 1,250°C). Thus, it is less porous, has a low absorbency rate (i.e., does not absorb its contents), and cooks evenly.

Porcelain (Figure 4b) is made primarily from kaolin, quartz, and feldspar and is sintered between 1,200°C and 1,450°C, obtaining a ceramic that is white, translucent, very hard, and highly dense. It has a natural nonstick surface, and these impressive properties makes porcelain more expensive than earthenware and stoneware.

Table 3. Where ceramic cookware can be used.³¹

	Microwave	Oven	Stovetop	Dishwasher
Stoneware	Yes	Yes	No	Yes
Porcelain	Yes	Yes	No	Yes
Glazed earthenware	No	Yes	Maybe	Maybe
Unglazed earthenware	No	Yes	Maybe	No
Flameware	Yes	Yes	Yes	Yes

Flameware is a relatively modern ceramic cookware product that is specially formulated to withstand the thermal shock of heating directly on a stovetop. Because of the diligent testing required to ensure safety, only a few clay manufacturers make flameware products, for example, Xtrema (Hagerstown, Md.), which specializes in pots that are 100% flameware, including the handles.

As explained by Erik Bergstrom, digital media manager at Xtrema, in an Xtrema blog post, Xtrema nonstick surfaces are more durable than traditional coated nonstick pans because the flameware is made of one solid ceramic piece. As such, there is no risk of the coating wearing away and exposing an underlying metal surface.³²

“Many cookware materials contain harsh chemicals such as heavy metals, which can pose a risk to your family’s health. For example, unlined copper pans can react with acidic foods like tomatoes or leach copper into your food,” he says. “Pure ceramic is nonreactive and nontoxic, so it’s completely safe for handling food. Without a metal core, there’s no risk of metals leaching into your dishes.”

The company’s products are microwave and dishwasher safe, and they can be used on glass, electric, or gas stoves, as well as in regular ovens, toaster ovens, grills, and also in campfires and open fires.

Safety cannot be neglected when preparing food. Materials selection must be aimed at preventing transfer or leaching of chemicals from the pot to the meal. For this reason, more attention is being paid to eliminating potentially toxic compounds from ceramic glazes, such as lead and cadmium.

Also in recent years, nonstick cookware based on ceramic coatings has grown as a popular alternative to the traditional nonstick pans coated with per- and polyfluoroalkyl (PFAS) chemicals, which are known to cause serious health issues if inhaled or consumed following degradation of the coating. Advanced nonstick ceramic coatings have been enabled by the introduction of nanomaterials, such as silica and titania nanoparticles and nanoclays.

Ceramic tableware is evolving toward becoming not only more functional but also serving as a way to bring art to food. Potters are coordinating with chefs to create bowls, dishes, and other utensils that enhance food appearance while being in harmony with the atmosphere of the dining area and its ethnic or cultural setting.³³



Credit: a) Public domain image, in the collection at Germanisches Nationalmuseum



Credit: b) Public domain image, in the collection at Cleveland Museum of Art

Figure 4. Examples of stoneware and porcelain. a) Böttger stoneware teapot, b) Meissen porcelain teapot.

Besides cookware and tableware, ceramics are present in the kitchen in other forms. Kyocera (Kyoto, Japan), for example, is well-known for producing ceramic kitchen knives (Figure 5).

Ceramic tiles find application not only as flooring material but also for walls, countertops, and backsplashes. Porcelain slab countertops are being used to replace granite and engineered stone and represent the fastest growing segment of the U.S. countertop market.³⁴

Florim (Fiorano Modenese, Italy), for instance, produces porcelain tiles and slabs as large as 63 inches by 125 inches, with thickness up to 2 cm. These tiles and slabs come in different textural effects (e.g., marble, stone, wood, and metal), colors, and styles (e.g., classic, retro, and futuristic).³⁵

In addition to ceramics, glass is very common in the kitchen, and not just as drinking glasses and bottles made from soda-lime-silica formulations. For example, though much of today’s glass bakeware is thermally strengthened soda-lime-silica glass, some manufacturers, mostly from outside the U.S., still manufacture borosilicate glass bakeware. Borosilicate glass is a material characterized by a low coefficient of thermal expansion, good chemical resistance, and higher melting point than soda-lime-silica glass.

Holistic health: How ceramics and glass contribute to our physical and . . .



Figure 5. A sampling of the ceramic kitchen knives produced by Kyocera.

Corning pioneered glass-ceramic bakeware with the CorningWare product line following S. Donald Stookey's discovery of recrystallization in the lithium silicate glass system in the 1950s. Today, glass-ceramics also find use as flat cooktops, which are used to transfer heat from radiant or induction burners. Glass-ceramic cooktops are gaining increasing market share as more consumers convert from gas stoves to avoid relying on fossil fuels. Schott (Mainz, Germany) is a major player in this area (Figure 6).

Induction cooktops are gaining in popularity because they are more energy efficient than other types of stoves, heat faster, and their response time to temperature adjustments is shorter. They consist of an electric coil placed below the cooktop that creates an electromagnetic field, which interacts with the magnetic cookware to generate heat.

The main drawback of induction cooktops is that cookware used on it must be magnetic, which means that only some types of cookware are suitable for this type of burner, such as cast iron (with and without enamel) and stainless steel with low nickel content. Aluminum, copper, glass, and ceramic cookware cannot be used with induction cooktops.

At the present time, induction cooktops have a share of only 8% of the total cooktop and range market,³⁶ with global revenues estimated to reach \$24.1 billion in 2023. But their sales are forecast to rise at a healthy CAGR of 8.3% through 2028.³⁷ To take advantage of this market growth, some producers of porcelain slabs, such as SapienStone, a subsidiary of Iris Ceramica Group (Fiorano Modenese, Italy), are integrating induction cooktops into their slabs.

Ceramic materials are also used as additives in food. For example, titanium dioxide is used to enhance the white color or opacity of food products. Silicon dioxide is added to serve as an anticaking agent (avoid clumping).

BEAUTY AND PERSONAL CARE

Beauty and personal care currently represent 9.0% of the health and wellness industry, with global revenues estimated to reach \$557.2 billion in 2023 and growing at a 7.7% CAGR through 2030.¹⁰

Both glass and ceramics find use in this sector for their unique functional and aesthetic properties (see the article



Figure 6. The Schott CERAN brand of glass-ceramic cooktops has been named Brand of the Century four times by the ZEIT publishing group, in 2013, 2016, 2019, and 2022.

"Ceramic materials in cosmetic and toiletry products" on page 10 of this issue). For example, borosilicate glass has long been used as a bulking agent in the form of flakes, either uncoated, silicone-coated, or combined with various pigments.

Another common glass form is represented by microspheres, that is, microscopic rounded particles with diameter ranging from 1 micron to 1,000 microns. They are added to creams, lipsticks, skin care lotions, foundations, and eye shadows to improve their rheology and create a soft and silky texture. In addition, they blend well with other ingredients, contributing to a natural look, and have a slight abrasiveness suitable for exfoliation and scrubbing. Plus, they scatter light, making small skin imperfections and wrinkles less visible. Hollow microspheres are less transparent than the solid ones, but they are preferred when there is also a need to enhance emulsification of oil or fat-based formulations.

A common method for producing glass microspheres is by ejecting very fine glass powder through a gas flame; as the viscosity of the glass decreases, surface tension causes the particles to become rounded. Hollow microspheres are obtained with a similar process, but a blowing agent such as sodium sulfate or sodium silicate is added to the glass powder.

Glass microspheres for cosmetics and personal care can be manufactured from different types of glass, including soda-lime-silica formulations, borosilicate, and bioactive glass. Prizmalite Industries (New York, N.Y.), for example, produces highly transparent soda-lime-silica microspheres with an average diameter of between 3 microns and 6 microns and very tight particle distribution. They are very effective for disguising wrinkles and skin imperfections and for reducing gloss in foundations and eye shadows.

"Most materials are composed of particles of irregular or uneven forms [crystalline structures]. These uneven 'surfaces' reflect light as diffuse reflection, where the reflected light bounces off randomly and in all directions," the Prizmalite website states.³⁸ In contrast, glass has a smooth surface, so

light only transmits or reflects in a consistent direction and angle. Thus, it “fools” the eye and “disguises any underlying wrinkles, discoloration, or uneven pigmentation,” according to the Prizmalite website.

By comparison, 3M (St. Paul, Minn.) sells solid microspheres made from amorphous magnesium silicate with an average diameter of 5 microns. These white microspheres are ideal for producing creams as they create low friction, are easily dispersible, allow for high solid loading, and can be surface treated. Another example is Potters Industries (Malverne, Pa.), which supplies calcium aluminum borosilicate microspheres with mean diameters of 11 microns and high chemical resistance with low alkali leaching.

The microsphere market is projected to reach \$7.3 billion in 2023 and grow at a CAGR of 9.1%.³⁹ The cosmetics industry will be one of the most significant segments driving industry growth in the U.S. because this country is the largest beauty market worldwide, with the presence of many major cosmetic brands.

Bioactive glass also finds application in many cosmetics and personal care products, including anti-aging creams, antibacterial soaps, make-up, deodorants, skin care products, sunscreens, and nail polishes. Bioactive glass can be used for various functions, such as antimicrobial agents, anti-oxidative components, skin-soothing ingredients, anti-wrinkle aids, anti-odor additives, protective materials against high temperatures and ultraviolet radiation, and nail strengthener.

Schott (Mainz, Germany), a world leader in specialty glass, offers calcium sodium phosphosilicated bioactive glass powder produced in dedicated glass melting tanks and grinding facilities to ensure the high purity requested for cosmetic applications. The company also offers a mica-based version formulated to improve dispersion and enhance aesthetics.

Bioactive glass is also an ingredient in some toothpaste brands. In 2021, BioMin Technologies (Stoke-on-Trent, U.K.) received FDA clearance to sell its bioactive glass toothpaste in the U.S., although it had been available in other countries for more than a decade.

During brushing, BioMin’s bioactive-glass-based toothpaste dissolves in saliva



Credit: Fraîcheur Ice Globes, YouTube

Figure 7. Fraîcheur Ice Globes, an example of a borosilicate glass face-massaging tool.

and forms fluoroapatite, an acid-resistant mineral layer that coats the tooth surface, strengthening the enamel and reducing tooth sensitivity. The company also sells an alternate version in which chlorine replaces fluorine. This product generates a hydroxyapatite layer very quickly, but the film is less resistant to acids.

Spherical face-massaging tools made from borosilicate glass are becoming quite popular (Figure 7). Borosilicate ensures resistance to a wide range of temperatures, which allows the tools to be cooled in the refrigerator or immersed in hot water. Thanks to their perfectly rounded shape, these tools can be easily rolled on the skin. They are marketed as being able to improve blood circulation; remove fine lines, eye bags, and dark circles; soothe the skin; shrink pores; and repair sunburns.

Glass cups are also sometimes used in cupping therapy, though durable silicone or plastic cups are more common because they can more easily be moved in stroking sweeps across the body.

Glass is one of the most important materials for packaging of cosmetics and personal care products. In fact, the glass cosmetic packaging market was valued at \$5.2 billion in 2022,⁴⁰ of which \$3.5 billion is accounted for by glass bottles (67.3% of the total),⁴¹ and this market is projected to grow at a 4.4% CAGR through 2032.

With its inertness, lack of porosity, and impermeability, glass ensures formulation

stability. It can be manufactured in gloss or matte finish and in clear, blue, green, amber, and other colors. Additionally, it can be easily molded in a variety of shapes and sizes, such as perfume bottles, jars for creams, nail polish bottles, and painted containers. Containers offer many options in terms of lids and closures (plastic, wood, cork, ceramic, and metal) allowing for the creation of articles that range from being relatively inexpensive to high-end luxury products.

Ceramics also have some relevant applications in the beauty and personal care industry, such as serving as packaging material. One of the most captivating features of ceramics is that they can be made with different compositions (porcelain, earthenware, composites), formed into very complex shapes, and painted or glazed to achieve a multitude of colors. After they are emptied from their content, ceramic containers can be recycled as art or decorative objects or for other uses (e.g., office supply organizers, candle holders, pots for plants, candy boxes).

In addition to their aesthetic qualities, ceramics have a number of functional properties that come in handy in a range of applications, such as: bowls and spatulas for preparing beauty recipes (e.g., facial masks and skin creams); cleaning tools for make-up brushes; anti-slip soap dishes; make-up organizers; dispensers and closures for bottles and jars; stylish nail files for manicures and

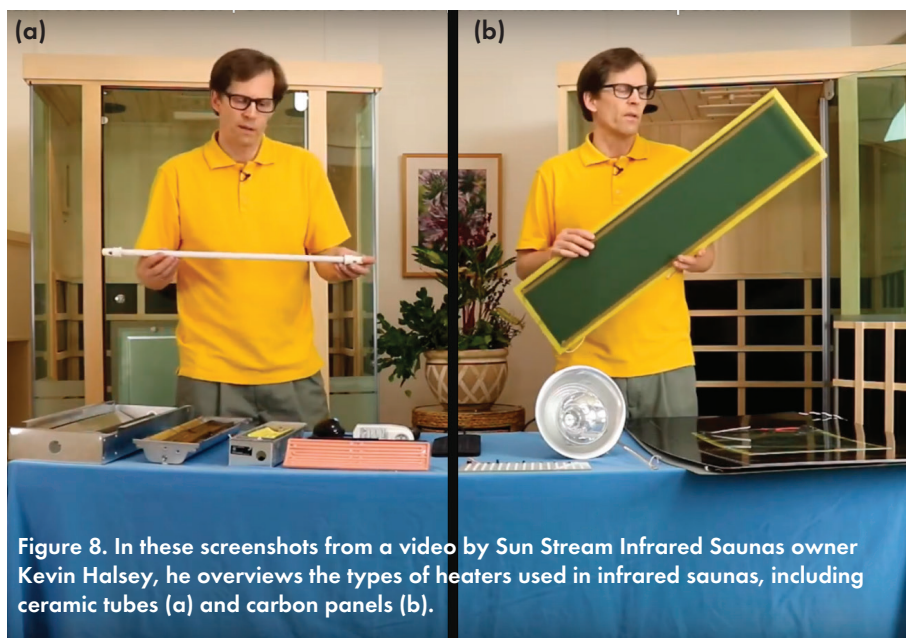


Figure 8. In these screenshots from a video by Sun Stream Infrared Saunas owner Kevin Halsey, he overviews the types of heaters used in infrared saunas, including ceramic tubes (a) and carbon panels (b).

pedicures; foot files for softening rough and dry skin; wear-resistant nail drill bits for shaping natural and acrylic nail tops; porcelain heating elements for hair straightening irons; and heated round hair brushes to reduce static electricity.

Ceramics also find application in some ethnic cosmetic practices. Gua sha, for example, is a Chinese traditional healing technique that uses ceramic sculpting tools to massage and slightly scrape the skin with the purpose of improving blood flow and lymphatic drainage. Gua sha can be applied to a person's face to remove surface impurities and wrinkles and achieve a better skin complexion, or to other parts of the body to relieve pain and stiffness.

Clay facial masks are also a popular product in the cosmetic and personal care industry, with silica, alumina, potassium oxide, and calcium oxide being common components in these masks.⁴²

WELLNESS REAL ESTATE

Wellness real estate refers to structures designed and built to ensure holistic wellbeing for their residents. This sector is projected to generate global revenues of \$417.8 billion in 2023, corresponding to 6.8% of the total health and wellness industry, and is the fastest growing segment with a CAGR of 21.8% through 2028.¹¹

In the near future, more new homes and communities are expected to incorporate wellness elements such as gyms,

saunas, spas, and pools. As discussed earlier, ceramics and glass are fundamental for the construction of these amenities and to achieve a better performance.

For example, ceramics can be found in lamps for infrared saunas. Infrared saunas use heaters to emit radiation in the near or far infrared spectrum, which are needed to evaporate water from the human body. By comparison, traditional saunas use hot air and steam to heat the body by convection and conduction. As such, infrared saunas are more effective in transforming heat into body energy, providing health benefits such as improved blood circulation, faster muscle recovery, joint pain relief, and stress reduction.

The heaters used in infrared saunas are typically made from either ceramics or nanostructured carbon fibers (Figure 8). Ceramic heaters are less expensive than carbon heaters, but carbon heaters are generally considered more efficient and durable, with heat penetrating deeper into the skin.

Some manufacturers have introduced high-performance ceramic heaters to eliminate some of these drawbacks. For example, TheraSauna (Bettendorf, Iowa) produces a solid ceramic heater rather than a conventional tubular ceramic. The heater is characterized by a 96% conversion efficiency and can be regulated to reach any temperature between 50°C and 230°C. By comparison, carbon fiber heaters do not have a temperature controller and typically operate only at 110°C.

Many homes constructed with wellness in mind incorporate glazed ceramic tiles to enhance hygiene. Ceramic tiles are easy to clean, help keep bacteria away, and do not release volatile organic compounds. In addition, they are available in a large selection of shapes, colors, and patterns, and can be used to create the desired atmosphere in every room, thus increasing the sense of comfort.

Tiny mosaic tiles are particularly well-suited to provide special effects. Appiani, a subsidiary of Bardelli Group (Vittuone, Italy), manufactures ceramic mosaics using the single press kiln firing technique, which consists of dry pressing together enamel and clay powders before sintering. This approach allows the company to obtain tiles with unique aesthetic appeal as well as high resistance to various environmental conditions, including wear and abrasion, impact, winds, and frost.⁴³

Additionally, Appiani has introduced a patented antibacterial mosaic technology that removes 99.9% of bacteria from treated surfaces.

Mosaics are also popular for hydrotherapy pools. These pools combine warm water with hydro massages to provide relief from physical and mental conditions, such as muscular stiffness, back pain, arthritis, and anxiety.

MENTAL AND SPIRITUAL WELLBEING

With global revenues estimated to reach \$160.3 billion in 2023, mental wellness represents a relatively smaller share of the total health and wellness industry with 2.6%. This segment is forecast to have fairly good growth through 2028 with a CAGR of 7.7%.¹²

Several holistic practices can be employed to achieve mental and spiritual wellbeing. Recently, sound healing has been rediscovered to promote relaxation and improve mental strength. Sound can be in the form of music or atypical tones, such as those produced by chimes or fountains. Small ceramic fountains that feature a gentle water cascade have become fairly common to provide a calming and soothing effect.

Aromatherapy is another technique that helps relaxation and sleeping. Ultrasonic ceramic diffusers are popular for producing mists containing scented

oils. For those consumers who prefer more traditional alternatives, there is a broad range of artistic ceramic candle holders or incense burners available on the market.

Alternative methods to pursue mental wellbeing are through art therapy and lighthearted entertainment. Ceramic mosaics have been used for thousands of years to create artwork. Ceramic puzzles are fun to play with and, once completed, become a form of art. Additionally, ceramics and glass can be manufactured in the shape of dominos, marbles, tic tac toe, backgammon, and chess pieces, among other games.

Spiritual wellbeing can also be attained through religious faith or by other means that help to find a sense of purpose in life, such as meditation. Ayurveda is an ancient Indian alternative medical practice that combines meditation, herbal medicine, special diets, and yoga to achieve holistic wellbeing. All products used in the Ayurveda discipline are based on very pure ingredients. For example, traditional neti pots for nasal cleaning are manufactured from lead-free ceramics made from natural clay.

WORKPLACE WELLNESS

Workplace wellness includes all those activities and programs implemented at the corporate level with the aim of helping employees feel better physically, mentally, and spiritually. Examples are stress management, weight loss, fitness, and medical screening programs.

This sector is currently worth \$60.1 billion, corresponding to less than 1% of the global health and wellness industry, and is projected to grow at a 5.8% CAGR during the next five years.¹³ Large and small companies are offering these programs to their employees primarily with the purpose of increasing productivity, reducing health-related absenteeism, and as a means to attract new talents.

Presently, ceramics and glass find no direct application in these programs, but they still have a significant role in general workplace wellness because they are commonly used in corporate presents given to employees to boost motivation, morale, relaxation, and self care. Indeed, most corporate wellness gifts include items such as

candle holders, ceramic essential oil diffusers, aromatherapy mist bottles, tea carafes, mugs, fitness trackers, and sunlight lamps.

CONCLUSIONS

There are numerous ways ceramics and glass contribute to the \$6.2 trillion health and wellness industry. Since their origins many thousands of years ago, people have adapted these materials to the changing times. Rooted in solid foundations, yet not afraid to experiment with innovative technologies and products, manufacturers of ceramics and glass will continue to take on new challenges to help the health and wellness industry flourish.

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