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Elimination of Iodine Deficiency Disorders through Iodized NaCl

Summary

The prevalence of iodine deficiency disorders (IDDs) has been a serious issue affecting the health of children and pregnant women in developing countries. Over 2 billion people are affected by IDDs; they suffer from problems like permanent brain damage that affect productivity and, therefore, retard the development of third-world countries. Common problems among pregnant women with IDDs include cretinism, stillbirth, miscarriage, and infant mortality. 38 million children born every year are at risk of IDDs. The physical symptom associated with IDDs is the presence of a goiter, i.e. enlargement of the thyroid gland.

Elimination of IDDs is both simple and affordable, costing only $0.10 per person per year. Through universal salt iodization (USI), a project initiated by the United Nations Children's Fund (UNICEF), the World Health Organization (WHO), and the International Council for Control of Iodine Deficiency Disorders (ICCIDD), excellent progress has been made in increasing consumption of iodized salt in countries around the world. Additionally, effective measures are now in progress, including international collaboration, government-enforced policies, strict monitoring, and public health awareness.

USI policy is based on five guiding principles for sustained success: secure political commitment, form partnerships and coalitions, ensure availability of adequately iodized salt, strengthen monitoring systems, and maintain education and communication. As a result of these principles, iodized salt consumption for the world's population has increased from 20% in 1990 to 70% in 2000. 34 countries have achieved elimination of IDDs through USI.

Introduction

Iodine is one of the most important supplements for both children and pregnant women. Consumption of iodine can be achieved through iodized salt or iodized oil. Iodized salt is essentially refined rock salt sprayed with an iodine additive, usually potassium iodide. Iodine stimulates hormone production in the thyroid, in cellular metabolism, early growth and development of most organs, especially synaptic development and myelination of the brain tissue [1]. Iodine deficiency at an early age causes hypothyroidism that results in low metabolic activities, stunted growth, and mental retardation. These illnesses leads to poor school performance, reduced intellectual ability, and impaired work capacity [2,3,4]. Figure 1 shows the distribution of the annual 38 million infants born unprotected against IDDs. Almost half of the infants are from South Asia, that is, Pakistan, Afghanistan, India, and Bangladesh.

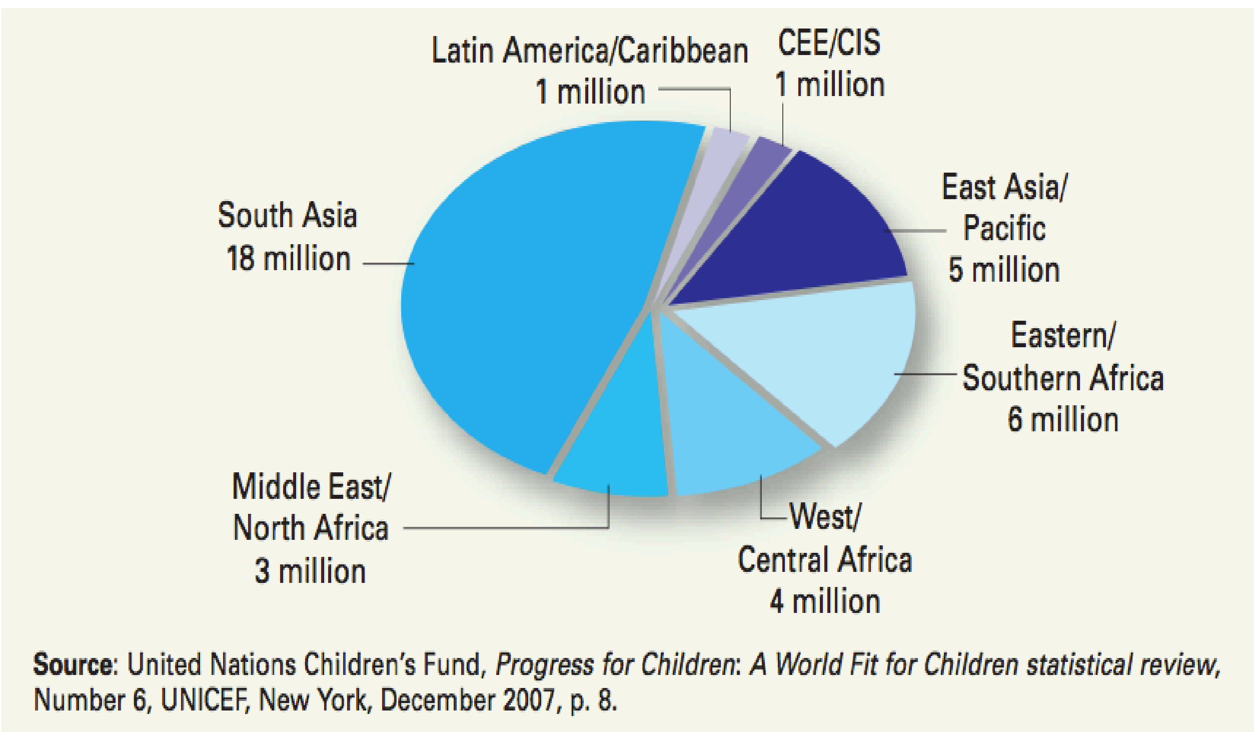


Figure 1: Distribution of the 38 million infants per year born unprotected against IDDs in developing countries.

Having too much iodine in the system can also be hazardous and lead to hyperthyroidism and to symptoms that include a swollen thyroid or small growths in the thyroid called nodules. To this day, the recommended dosage of iodine for children 0-59 months is 90 micrograms per day (µg/day), 120 µg/day for school children, 150 µg/day for adults including women of reproductive age (15-49 years), and 250 µg/day for pregnant and lactating women [5]. For testing iodine in patients, spectrophotometry of urine samples can accurately determine iodine level in the system. To determine if iodine is present in the processed salt, a simple color test using sulfuric acid can test positive for iodine.

Background

In the 1950s, Yugoslavia, Bulgaria, and Romania were the first countries to receive voluntary iodization of household salt; however, in the 1960s, surveys showed only a small decrease in goiter cases. As a result, iodization of salt in the food industry became a mandatory measure; drastic decreases in goiter cases became prevalent a decade later. In 1956, an ordinance was issued by the Ministry of Health to govern the iodization of salt in the Soviet Union. Common salt that is not iodized and contains more impurities became very scarce as the production of iodized salt in the Soviet Union increased from around 100,000 tons in 1950 to 1 million tons by 1965. This completely eliminated the endemic of goiter and cretinism in the USSR; the Ministry of Health decided to abandon monitoring and maintenance procedures. Unfortunately, the downfall of the soviet economy in the 1980s affected iodized salt production and, by the 1990s, the increase of IDDs became prevalent throughout the Soviet Union. In November 1991, UNICEF, WHO, and the International Council for Control of Iodine Deficiency Disorders (ICCIDD) gathered at Tashkent, Uzbekistan to discuss the issues regarding the reintroduction of IDDs. In 1994, rapid assessments confirmed the comeback of IDDs and resulted in immediate action, the goal for Universal Salt Iodization (USI).

Salt Production

Depending on location, there are three ways of capturing salt: solar salt (sea salt), rock salt (halite), and evaporated salt (refined salt). Figure 2 shows the preferred methods of salt extraction in countries of central Eastern Europe (CEE) and of the commonwealth of independent states (CIS). The CIS was created in 1991 such that participating countries declared their interaction on the basis of sovereignty. As of now, Azerbaijan, Armenia, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Uzbekistan and Ukraine are part of the CIS.

Country	Producer	Source of salt	Total salt supply estimate (1,000 MT/y)	Food-grade salt estimate (1,000 MT/y)	Iodized salt estimate (1,000 MT/y)
Armenia	Avan	Rock salt and solution mining	40	15	15
Belarus	Mozyrsol	Solution mining	350	280	100
Bosnia and Herzegovina	Hemijski Kombinat «Sodaso»	Rock salt mining	50	50	45
Bulgaria	Tchernomorski Solnitzy	Sea salt evaporation	75	20	20
Kazakhstan	Araltuz	Lake salt evaporation	350	90	70
Romania	Salrom	Rock salt & solution mining	2,200	200	120
Russia	Bassol	Lake salt evaporation	1,250	450	125
Russia	Silvinit	By product of kali mining	900	90	30
Russia	Iletskol	Rock salt mining	350	250	120
Russia	Tyretskii solerudnik	Rock salt mining	300	90	40
Tajikistan	Koni Namak	Solution mining	45	30	20
Tajikistan	Namaki Yovon	Solution mining	15	15	10
Turkmenistan	Guwlyduz	Lake salt evaporation	80	35	35
Ukraine	Artemsol	Rock salt mining	950	450	170
Uzbekistan	Khojiakontuz	Surface mining	240	160	70

Figure 2: Salt production in Central Eastern Europe (CEE) and Commonwealth Independent States (CIS). Source: UNICEF global databases.

Solar salt (sea salt)

Sea salt is evaporated from seawater in large concentration ponds called condensers. Climate is the important factor in this process because the sun and wind evaporate the water and eventually crystallize the salt. In the process of evaporation, calcium carbonate is the first chemical to crystallize. The layer of calcium carbonate is removed as the brine travels through a series of smaller ponds. After removing calcium carbonate, the concentrated brine is sent to a crystallizing pond where the purity of the crystallized salt ranges from 72-75%. The resulting brine is exposed to the sun until the purity of the crystallized salt reaches 99.7% or more. Once the salt reaches this purity, the remaining brine, highly concentrated with magnesium, is then drained, via pump, and is either tested for further processing or discharged.

Rock salt (halite)

Rock salt is mined in depths up to 2000 feet below the Earth's surface and is often procured through blasting using small detonation devices. Usually a shaft, around 20 feet in diameter and lined with concrete, is created to reach these depths of salt deposit.

Salt deposit mining has two different forms of configuration: horizontal sedimentary and vertical salt deposit. For a bedded or layered salt deposit, the room-and-pillar mining method is used. Each horizontal room, about 10-25 feet high and 50 feet in length, is connected by a small opening, or cross-cuts, as 45-65% (350-900 tons) of the salt is blasted and procured. Figure 3 presents a display of the floor layout for rock salt mining. The rest of the salt is left to form pillars for structural support, hence the name room-and-pillar mining method. For vertical salt deposit mining, the floors of the horizontal rooms are blasted using large diesel-powered equipment and hoisted by a conveyer belt. In large salt mines, up to 900 tons of salt can be produced per hour.

Evaporated salt (refined salt)

Usually solar salt and rock salt are not pure sodium chloride. They can attain pure salt grade (>99%) through a process where the brine is boiled and then cooled to crystallize. As a result, evaporated salt is produced for the table salt we use on our foods. This process can be done through a series of steps: solution mining followed by cooling the brine solution to obtain recrystallized salt.

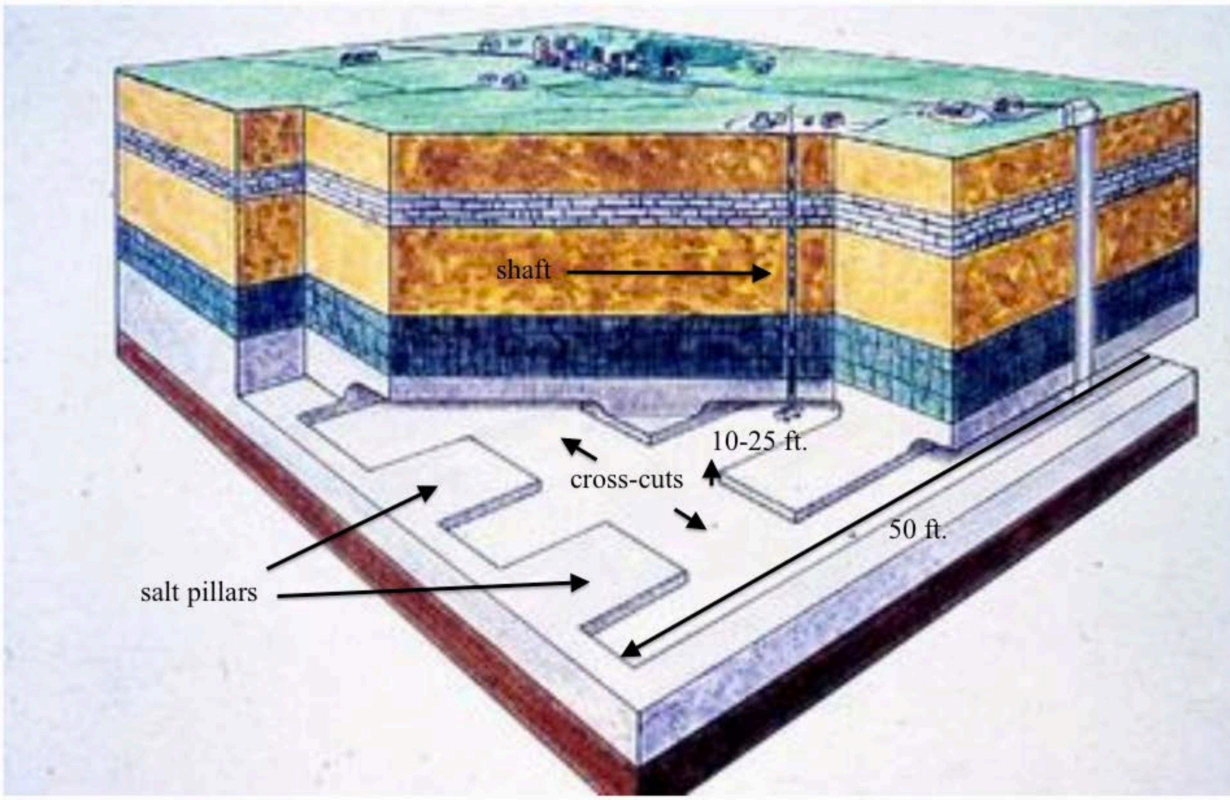


Figure 3: Floor layout for a bedded or layered salt deposit.

Solution mining

In this mining process we inject recycled water, from wastewater reclamation plants, into the well containing the salt deposit. Precise drilling and operating techniques are required for complete control over the salt cavern. Salt domes for solution mining can range from 500-5000 feet below the surface. Figure 4 shows a side-view of a salt dome as the pipeline delivers recycled water into the salt dome caverns. Once the water becomes saturated with sodium chloride, the brine is then pumped to the surface for further processing by sedimentation to remove impurities such as anhydrite (calcium sulfate) that deposit at the bottom. Further processing reduces the levels of calcium, magnesium, and sulfate present in the brine.

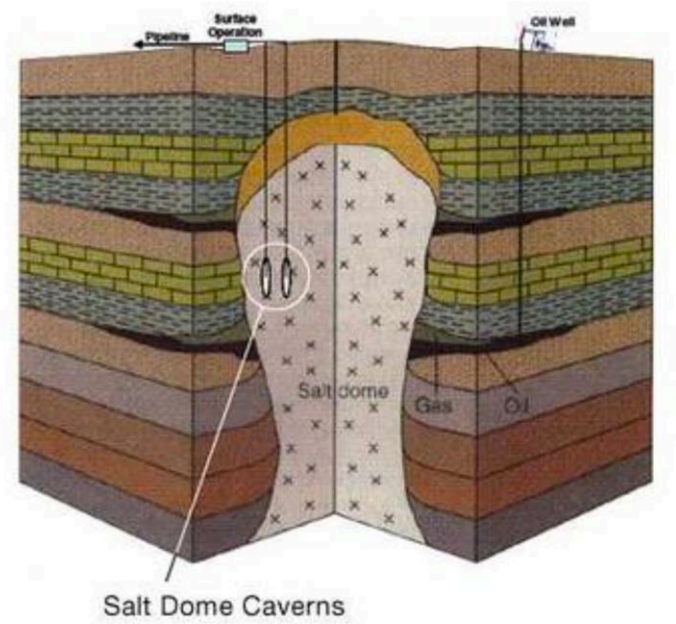


Figure 4: Side view of a salt dome in which salt is extracted through solution mining.

Vacuum pan refining

Vacuum pan refining is the technique used in Europe, Australia, East Asia, and the United States to produce "table salt". The process is described in the Salt Institute website:

"Water is evaporated from brine using steam-powered multiple-effect or electric-powered vapor recompression evaporators. Multiple-effect systems typically contain three or four forced-circulation evaporating vessels connected together in series. The evaporators operate under a vacuum to reduce the energy requirements. Steam from boilers is recycled/fed from one evaporator to the next to increase energy efficiency in the multiple-effect system. Vapor recompression forced-circulation evaporators consist of a crystallizer, a compressor, and a vapor scrubber. Feed brine enters the crystallizer vessel, where salt is precipitated. Vapor is withdrawn, scrubbed, and compressed for reuse in the heater. The crystallized salt is removed in a slurry, dewatered using a centrifuge, dried in a rotary kiln or fluidized bed dryer, treated with any additives (e.g. potassium iodide or iodate making iodized salt) and packaged."

Iodization Process

Figure 5: The process line of iodizing salt.

Potassium iodide or potassium iodate is used to iodize the salt. Only in the U.S. potassium iodide is FDA approved.

In this simple process, a huge bag of salt is poured in a basket that is transported up by an elevator to an extruder. The basket then pours the salt into the extruder that contains magnets to remove unwanted metals from the sodium chloride. At the bottom of the extruder, the aqueous potassium iodide solution is sprayed at a level of 30-170 ppm and then sent to a mixer. Potassium iodide can be purchased at chemical manufacturing facilities at an inexpensive price, such that the cost of providing the recommended amount of iodized salt to one person per year is $0.10. Finally, sodium thiosulfate or dextrose is added to the mixer to stabilize the potassium iodide in the sodium chloride and prevent it from oxidizing to iodine and eventually be lost by volatilization. This process is all done in one machine shown in Figure 5. For animal feeds, the iodized salt is fortified with sodium carbonate or sodium bicarbonate to increase alkalinity.

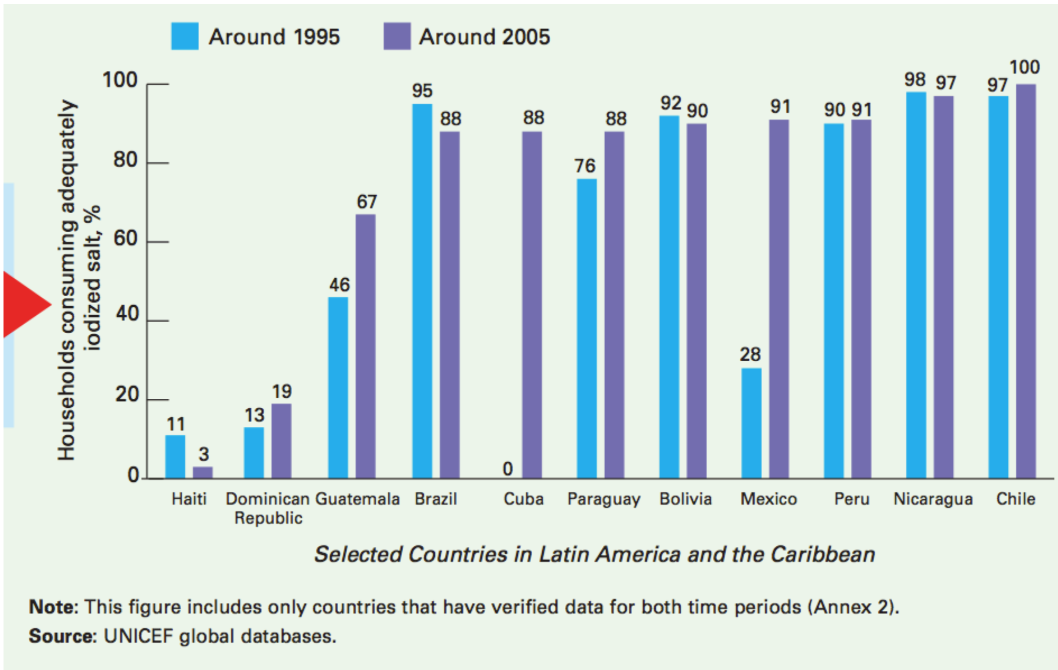
Usually the composition of iodized salt is >99% NaCl, traces of Mg, Ca, SO_4, and 0.002-0.004% iodine; however, in the U.S. the levels are higher (0.0046-0.0077% iodine).

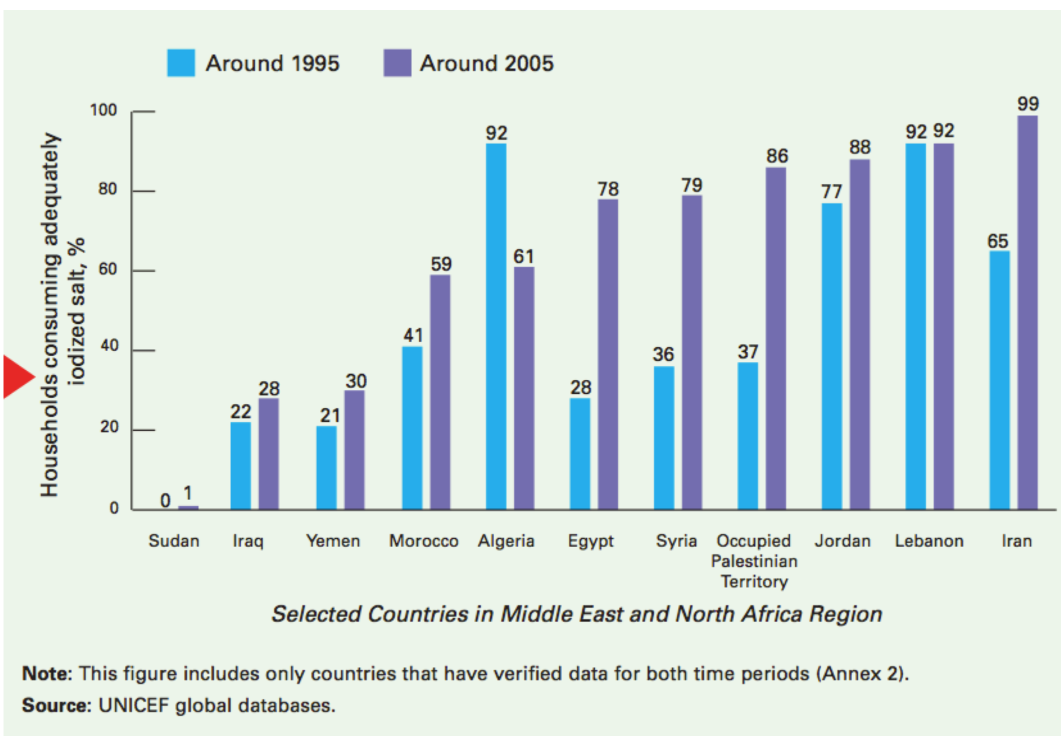
Results and Analysis

Figures 6-13 show the percentage of households consuming adequately iodized salt in 1995 and 2005 for developing countries separated by region. In Latin America and the Caribbean (Figure 6), iodized salt consumption in Cuba and Mexico improved significantly from 0-88% and 28-91%, respectively. Unfortunately for Haiti, the decrease in iodized salt consumption is dangerous perhaps due to the lack of awareness and government collaboration concerning the importance of iodine for health. In the Middle East and North Africa region (Figure 7), Sudan is in desperate need for salt iodization campaigns (0-1%). The sharp decrease for Algeria may be due to abandoning the maintenance and monitoring methods required to achieve USI. The percentage of households consuming iodized salt in Sierra Leone of the Western and Central Africa region has decreased greatly (Figure 8), due to constant turmoil within borders and civil battles between several resistance groups.

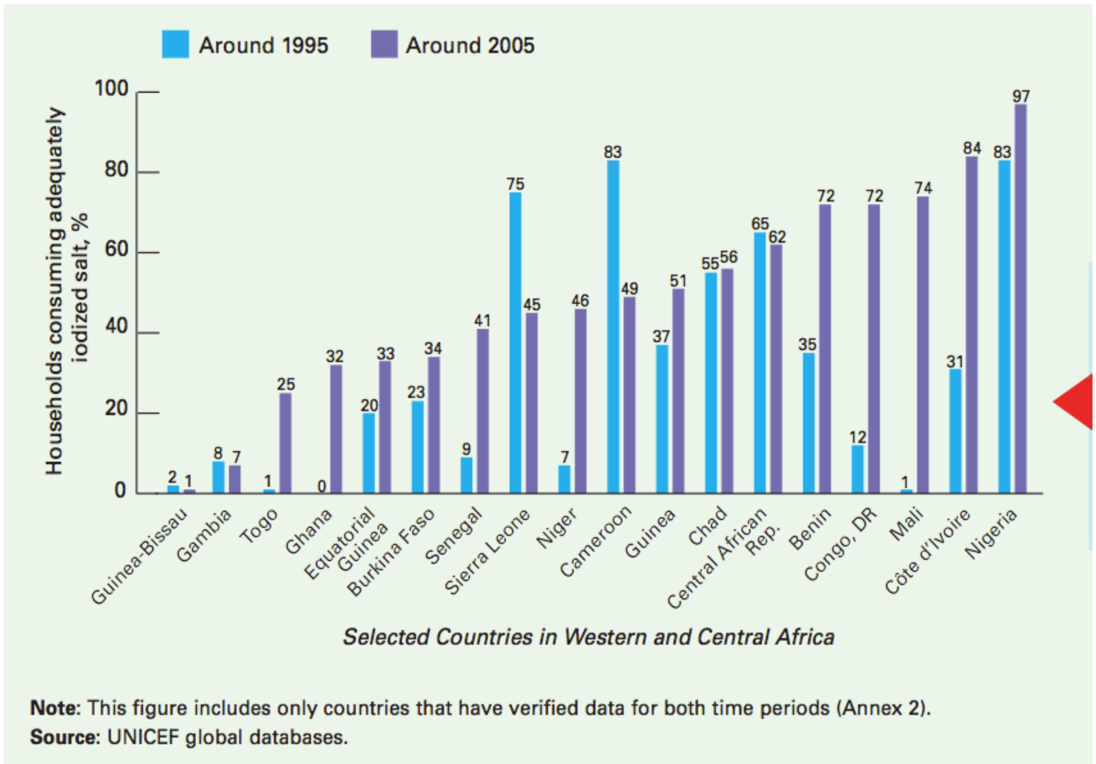
As for Ethiopia and Madagascar in Figure 9, iodized salt consumption increased significantly within the 10-year period. All the selected countries in CEE, the CIS, East Asia, and the Pacific region (Figures 10 and 11) except Bosnia and Herzegovina have improved percentages. Finally, Bangladesh, Sri Lanka, and Afghanistan of the South Asia Region have improved significantly from 19-84%, 7-94%, 2-28%, respectively (Figure 12).

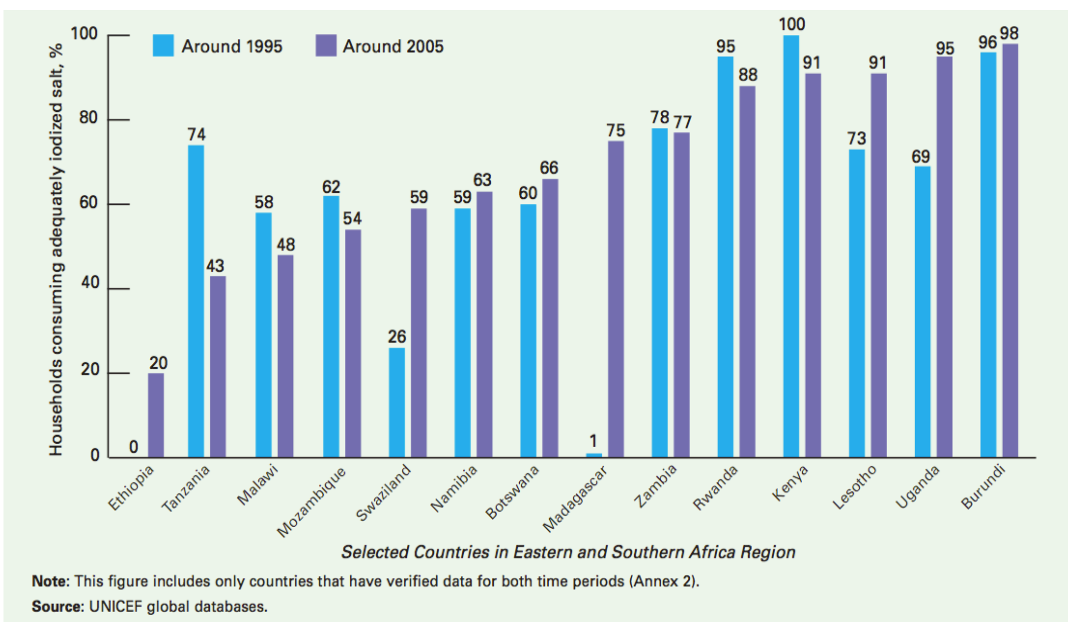
The goal for universal salt iodization is to have all countries in the world reach at least 90% of households consuming adequately iodized salt. In just a matter of 10 years, the overall percentages in each region increased. Based on Figure 13, the important fact to notice is that the percentage of households consuming iodized salt in the developing countries is almost reaching 70%. For East Asia and Pacific and Latin America and the Caribbean, USI is just 5-6% away.



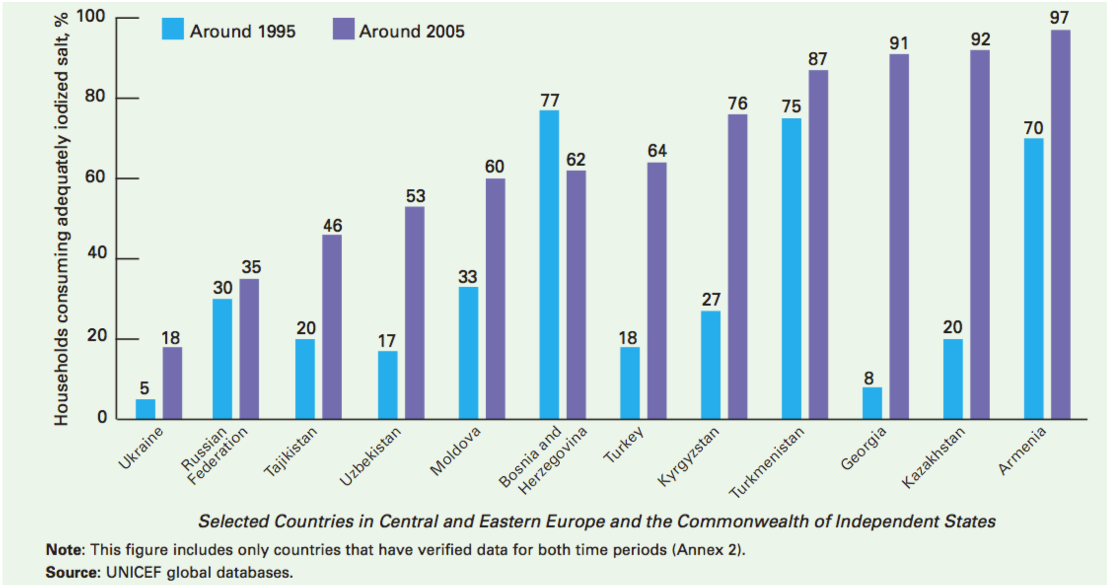


Percentage of households consuming adequately iodized salt in countries of Latin America and the Caribbean (Figure 6, top) and in the Middle East and North Africa Region (Figure 7, bottom).

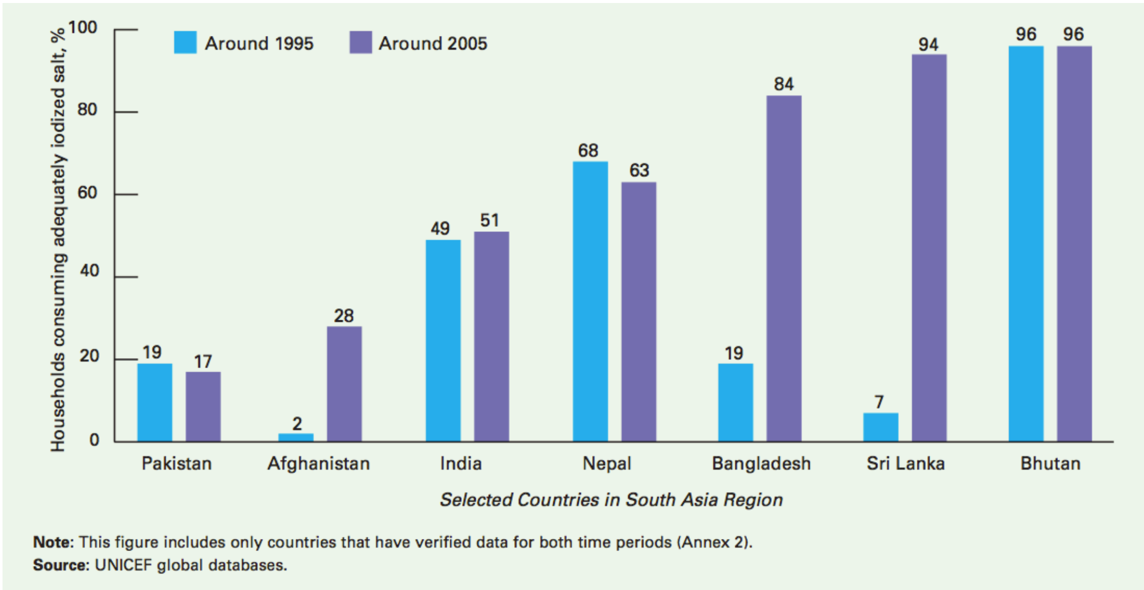




Percentage of households consuming adequately iodized salt in countries of Western and Central Africa (Figure 8, top) and of Eastern and Southern Africa (Figure 9, bottom).



Percentage of households consuming adequately iodized salt in countries of Central Eastern Europe and the Commonwealth of Independent States (Figure 10, top) and of East Asia and Pacific Region (Figure 11, bottom).



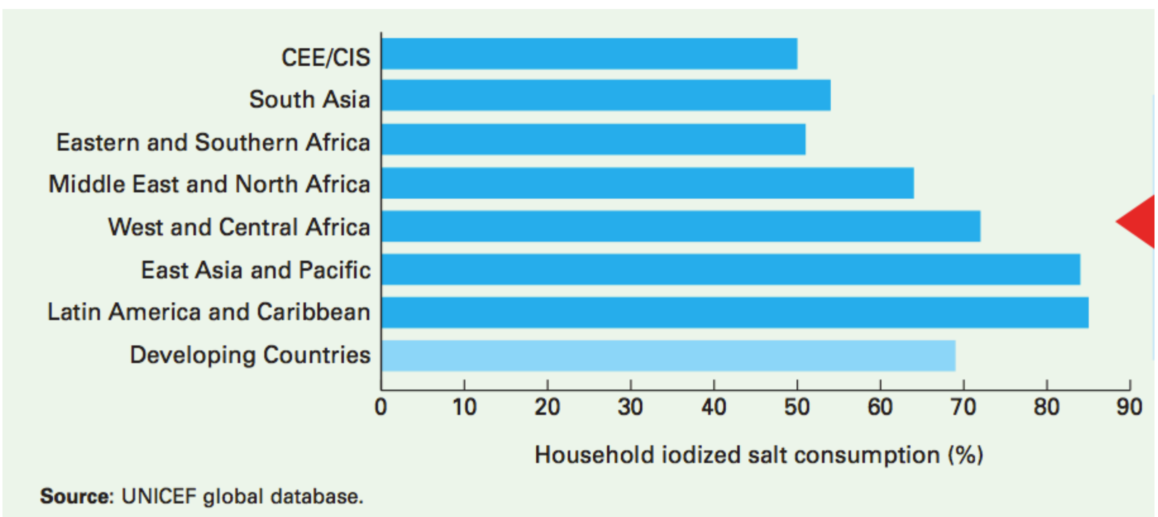


Figure 12 (top): Percentage of households consuming adequately iodized salt in countries of the South Asia Region. Figure 13 (bottom): Bar graph of overall percentages of iodized salt consumption in each region.

Conclusion

Although the extraction, manufacture, process, and production of converting raw salt to NaCl is complex, the iodization process provides an additive that has made drastic improvements in health in developing countries around the world. With the help of UNICEF and WHO, household consumption of iodized salt in East Asian countries like China, Vietnam, Cambodia, Philippines, and Myanmar have increased by staggering numbers: 39, 60, 66, 41, and 53%, respectively, from 1995 to 2005. The prevention of mental impairment due to the consumption of iodized salt has greatly improved children's ability to perform better in school. Unfortunately, not all developing countries have improved iodized-salt consumption during the 10-year period. In 2006, UNICEF identified 16 'make-or-break' countries that have made little or no progress in iodized-salt consumption. Among these 16 countries, Sudan, Ukraine, and Pakistan are still in dire need of iodized salt as the percentages of households consuming adequately iodized salt are at a mere 1, 18, and 17%, respectively. The goal to reach universal salt iodization has proven to be challenging; however, significant improvements have been made within the 10-year period (1995-2005).

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