Goiter and Manufacture of Iodized Salt in Developing Countries

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ABSTRACT

Special techniques have to be adopted for the manufacture of iodized salt in developing countries depending upon traditional usage of salt by the goiter affected population. The Indian experience in manufacture, transport, and distribution of iodized salt is described. Results of experiments on the keeping quality of iodized salt in storage and transport are outlined.

Goiter, the disease of the thyroid gland, occurs with varying intensity in almost every country. It is prevalent, especially in remote mountainous areas but also occurs in comparatively low-lying areas and even at sea-level. Goiter is largely attributed to iodine deficiency in the normal diet of the inhabitants of goiter affected area[1]. In some places it is due to the general presence of goitrogenic substances of fluorine and calcium in drinking water[1]. Iodine is found mainly in sea foods, and to some extent in vegetables and water, depending upon the iodine content of the soil. Iodine is characteristically concentrated in relatively high quantities in sea weeds, sponges and corals and in the thyroid gland of animals and man. The normal human body contains about 20 to 50 mg. of iodine of which 8 mg. are concentrated in the thyroid gland[2], a shield-shaped organ located in the front of the neck. The gland manufactures from the iodine of the food, a hormone known as thyroxine (3:5:3′:5′-Tetraiodothyronine). This amino-acid, containing 65% of iodine controls the growth, physical development, reproduction and other physiological functions of the human body. The deficiency of iodine in food intake manifests in impairment of growth and swelling of thyroid gland. The slopes of Himalayas, Alpine Valleys, Pyrenees, the Great Lake basin between Canada and the United States of America and the low lying areas of Netherlands are well known for high incidence of endemic goiter. The prevalence and geographical distribution of endemic goiter are described in detail by Kelly & Snedden and according to their estimate 200 million people are affected by goiter in the world[1].

The obvious method of preventing the goiter is to make good the deficiency of iodine in food and in drinking water. Marine and Kimball[3] demonstrated in 1917 how iodine prevented the disease. Since that time systematic investigation has led to universal acceptance of use of iodized salt to combat goiter on global scale[6]. It is equally effective in the case of goiter created through the action of indirect goitrogenic influences which raise the normal demand of iodine[4].

Even though the use of iodized salt is universally accepted for the prevention of goiter since 1930 and the methods of iodization of high purity vacuum salt are standardized and well known, the progress made in iodization of coarse crystalline solar salt and its supply to goiter affected population in the developing countries has been found slow by joint FAO/WHO Expert Committee on Nutrition which examined the prevention of goiter in developing countries in 1967[5]. What are the unique problems faced by a developing country in the implementation of this project? Can we draw a working plan from the study of execution of this project in a typical developing country? Indian experience in the manufacture, transport, distribution of iodized salt is described in this paper. An attempt has been made to draw a general plan from Indian experience for iodization of salt and prevention of goiter for a developing country.

Let us examine the various problems to be overcome for successful implementation of the project—i.e. addition of suitable iodine compound to coarse, crystalline solar salt and its supply to goiter affected population in the developing countries.

The problems faced by the developing country on the manufacture of iodized salt are stated below seriatum:

1. Lack of precise data on goiter affected areas and the population to whom iodized salt is to be supplied.
2. Inadequate information regarding the salt industry of the concerned country.
3. Lack of laboratory facilities; absence of quality control methods in the salt industry and want of trained personnel.
4. Wide variation in the chemical composition of solar salt manufactured from saltworks.
5. Choice of proper iodizing chemical and the level of iodization which are to be based on consumption of salt and likely loss of iodine on storage.
6. Lack of knowledge on keeping quality of coarse and crystalline iodized salt on long storage, high humidity, transport hazards etc. in the particular developing country.
7. Selection of equipments for iodization and selection of suitable location of the plant.
8. Problem of distribution of iodized salt.
9. Selection of packing material for iodized salt—gunny bags or polythene lined gunny bags or suitable material to withstand handling, transport and storage.
10. Administrative problem—legislative action and banning entry of non-iodized salt to goiter affected population and its enforcement.
11. Financial problem—who will bear the additional cost of iodization—industry or consumer or national government.
12. Creation of an agency to monitor the project and enforce quality control at the various stages of the program.
13. Periodic evaluation of the results of supply of iodized salt on the incidence of goiter.

GOITER SURVEY

A detailed survey of goiter affected regions in the country should be made to assess the population affected to whom iodized salt is to be supplied. McCarrison[6] estimated in 1917 that 5 million people are affected by goiter in India along the slopes of Himalayas. Ramalingaswami[7] confirmed it in 1956. But recent regular and systematic survey[8] conducted by the Director-General of Medical Services, Government of India with the assistance of UNICEF from 1965 to 1972 fixed the estimate at 71 million people to whom iodized salt is to be supplied. The affected areas are Himachal Pradesh, Chandigarh, Ambala, Northern districts of Punjab, Uttar Pradesh, Bihar, West Bengal, Nagaland, Manipur, Arunachal Pradesh, Tripura and North-West Frontier Agency. This revision of estimate of goiter affected population in India from 5 million to 71 million underlines the need and necessity to undertake a systematic survey of goiter affected regions in a developing country before the commencement of the program.

STUDY OF SALT INDUSTRY

A detailed study of salt industry of the country is to be made to ascertain the following:

1. Location of Saltworks.
2. The methods adopted for the manufacture.
3. The chemical analysis of various kinds of salt produced.
4. The kind of salt consumed by the local population affected by goiter and their preference.
5. To advise suitable technique for addition of KI or KIO_3 to the locally produced salt.

Salt is produced in India from seawater, from inland lake brine, from pit or sub-soil brine and from rock salt mines. The sea saltworks are mostly located along the coastal areas. Location of saltworks in India state-wise is given in Table 1. The major goiter affected areas are located along the slopes of the Himalayas, in the northern part of Indian Peninsula.

Traditionally, the goiter affected areas in Punjab, Himachel Pradesh, Utter Pradesh and Bihar are supplied with *salt* from Sambhar Lake in Rajasthan and Kharaghoda in Gujarat. The north eastern states of Assam, Mehalaya, Tirupura, Manipur etc. are supplied *sea salt* from Government Stores (Salt Golah) at Calcutta.

CHEMICAL COMPOSITION OF LOCAL SALT

The salt is generally produced in India by the solar evaporation of brine. The physical and chemical composition of salt varies depending upon the source of brine and method of salt manufacture. The average chemical composition of various varieties of salt manufactured in India is given in Table 2. Indian Standard Institution has prescribed standards for salt depending upon its use and it is given in Table 3. Since crystalline solar salt is consumed by majority of population for kitchen purposes, the standard proposed for iodized salt is the same as edible salt for human consumption.

1. Chloride content (as NaCl) (Minimum)—96.0%
2. Water insoluble matter (Maximum)—1.0%
3. Matter soluble in water other than sodium Chloride, (Maximum)—3.0%
4. Moisture—2.0%

This specification allows for wide variation in the impurities present in the salt regarding matter soluble in water

TABLE 1

Location of Salt Works in India

Location	Annual Average Production (In '000 Tons)
1. Himachal Pradesh Rock Salt—Mandi Mines	4.20
2. Rajasthan (Inland Lakes) Sambhar Lake, Didwana Pachbadra, Phalodi etc.	488.30
3. Gujarat (Inland Sources) 87 saltworks at Kharaghoda, Dhrangadhra, Kuda etc.	2,634.50
4. Gujarat (Marine Sources) 526 salt works situated at Mithapur, Jamnagar, Bhavanagar etc.	2,072.80
5. Maharashtra (Marine Source) 262 saltworks around Bombay	468.50
6. Karnataka (Marine) one saltworks at Sunikatta	12.20
7. Goa (Marine) 6 saltworks	9.20
8. Tamil Nadu (Marine) 32 salt factories situated along the coast from Tuticorin	796.20
9. Andhra Pradesh (Marine) 32 salt factories	230.90
10. Kerala (Marine) one salt factory Malipuram	0.70
11. Pondicherry (Marine) one at Karaikal	0.20
12. Orissa (Marine) 7 salt works	25.40
13. West Bengal (Marine) 8 saltworks	2.70
Average Annual Production 1970–1975	6,745.80

TABLE 2

Average Chemical Analysis of Various Varieties of Salt Produced in India (Percentage on Dry Basis)

Source	Mandi	Gujarat Inland	Gujarat and Maharastra Sea Salt	Maharastra Sea Salt	Tuticorin	Sambhar Lake Inland		
Name of Variety	Rock Salt	Baragara	Kurkutch	Kuppa	Sea Salt	Kyar	Reshta	Pan
Chemical Composition:								
NaCl	82.28	97.10	97.95	98.56	98.78	96.59	97.77	96.11
$CaSO_4$	0.62	1.36	0.56	0.17	0.32	—	—	—
$MgSO_4$	0.26	0.24	0.52	0.26	0.26	—	—	—
$MgCl_2$	0.27	0.88	0.84	0.78	0.52	—	—	—
Na_2SO_4	—	—	—	—	—	2.49	1.23	3.11
Na_2CO_3	—	—	—	—	—	0.56	0.50	0.46
Insoluble	16.57	0.42	0.13	0.23	0.12	0.36	0.50	0.32

other than NaCl. It is due to difference in the climatic conditions of the Indian Sub-continent where the saltworks are located. Further, the chemical composition brine from Inland sources varies depending upon the source.

In many of the developing countries, there is no specification for salt for human consumption. Salt is produced by many methods, in developing countries, namely by solar evaporation, boiling, leaching or collecting salt encrustations. The salt is used as such without further treatment. A detailed analysis of salt has to be carried out. Manufacturing methods have to be standardized to bring the quality within acceptable limits for iodization.

IODIZATION TECHNIQUE

The pure vacuum salt can be easily fortified by spraying it with a solution of potassium iodide in water. It is carried out while the salt is passing along a conveyor belt before the final operation of drying with hot air. Such techniques as used in developed countries are not suitable since solar salt used for iodization is coarse, crystalline and impure compared to vacuum evaporated salt. It is packed in gunny bags, transported by rail or road over 1,000 miles and stored in humid conditions. Usually, there is a time lag of 3–6 months from the time of salt iodization and its use by the

TABLE 3

Indian Standard Institution Specifications on Common Salt

Edible Common Salt (15:253–1970) (Percentage Dry Basis)	Common Salt	Table Salt	Dairy Salt
a) NaCl (minimum)	96.00	97.00	99.60
b) Ca^{++} water soluble (Max)	—	0.10	0.01
c) Mg^{++} water soluble (Max)	—	0.10	0.01
d) SO_4^{--} water soluble (Max)	—	0.50	0.20
e) Matter soluble in water other than NaCl (Max)	3.00	—	—
f) Water insoluble matter (Max)	1.00	2.20	0.03
g) Acid insoluble (Max)	—	1.50	—
h) Alkalinity (as Na_2CO_3) (Max)	—	0.20	0.10
i) Moisture (Max)	6.00	0.50	0.50
Common Salt for Animal Consumption (15:920–1958)			
a) NaCl (minimum)	—	90%	—
b) Matter insoluble in Water (Max)	—	10%	—

TABLE 4

Sieve Analysis of Pan Salt

Sieve Size	Percentage
+ 4	11.17
+ 8	27.76
+20	30.81
−40	26.13
−40	4.13

affected population. Can coarse salt be iodized? What will be the effect of chemical impurities, and moisture on keeping quality of iodized salt? Will high humidity of the atmosphere, temperature and sunlight affect the iodized salt? How much iodine will be lost? To study these factors peculiar to local conditions, a pilot plant was installed at Sambhar Lake in India. The site was selected on the basis of the following factors:

1. It is the nearest salt source to goiter affected area.
2. People living in the goiter affected area are accustomed to the use of salt from Sambhar Lake.
3. The saltworks are well equipped with control laboratory, electricity and skilled personnel.
4. The saltworks are under public sector (parastatal).

Three kinds of salt, namely kyar, reshta and pan are manufactured at Sambhar Lake. The chemical analysis of the three kinds are given in Table 2. Kyar and Reshta are manufactured from surface lake brine while Pan salt is manufactured from sub-soil brine. Pan salt has a uniform crystal size compared to Kyar and Reshta and is free from algal contamination. The sieve analysis of Pan Salt is given in Table 4. Dry-mixing process is adopted. Pan salt is conveyed from open stores after breaking the lumps manually. The salt is further passed through a sieve to eliminate big lumps. By means of a screw conveyor salt is fed to crude salt hopper. A fixed quality of salt is allowed to fall from the salt hopper by means of a bulk controller into an enclosed worm-screw conveyor. A short distance away, a precision feeder, fitted to conveyor, introduces KIO_3–$CaCO_3$ powder at the rate designed to produce the required degree of iodization and the two (salt and KIO_3) are thoroughly mixed as they pass along the worm-screw conveyor before being collected at the end. KI or KIO_3 is mixed with a carrier namely $CaCO_3$ in the ratio of 1:20 and this fine mixture is placed in chemical precision feeder. The average weight of fall of salt and that of KIO_3 mixture from chemical feeder are taken and the rate of fall is adjusted so as to produce iodized salt of required ratio. The pilot plant study on iodization, keeping quality, storage, transport and distribution was carried out from 1958 to 1962. Based upon the experience gained[8], commercial production units were installed at Sambhar Lake, Kharaghoda and Calcutta. Spray mixing process was later introduced in 1964 and found efficient. The location of iodization units in India is given in Table 5.

After careful study of the salt resources of the concerned country and taking into consideration the preference of the type of salt consumed by the goiter affected population, a suitable location has to be selected for installation of iodization plant where electricity, quality control laboratory and transport facilities are available.

TABLE 5

Location of Salt Iodization Plants in India

Location of Unit (Salt Used)	Annual Production Capacity On Basis of Two-Shifts (In Tons)
1. *Sambhar Lake (Rajasthan)* 2 Dry Mixing and 2 Spray Mixing Plants (34,000 × 2 = 68,000 38,000 × 2 = 76,000) (Pan Salt)	144,000
2. *Kharaghoda (Gujarat)* 2 Spray Mixing (38,000 × 2) (Baragara Salt)	76,000
3. *Calcutta* 5 Spray Mixing (24,000 × 5 = 120,000) 1 Pilot Plant = 12,000 (Sea Salt)	132,000
4. *Mandi* Pilot Plant	600
Total	352,600

LEVEL OF IODIZATION OF SALT

Level of iodization of salt has to be carefully fixed depending upon the daily consumption of salt by the population in the goiter affected area, the nature of salt to be iodized, loss of iodine on storage and the minimum dietary requirement of iodine to be supplemented through the supply of iodized salt. Same level of iodization cannot be recommended for all areas. Depending upon local food habits, nature of salt to be iodized, mode of packing, climatic conditions and presence of goitrogenic factors in the food and drinking water, various governments have adopted different levels of iodization. WHO study—Group on Endemic Goitre which met in London in 1953 recommended 1 part of iodide in 100,000 parts of salt, assuming daily consumption of 10 gms of pure, dry salt. The Third Conference on Nutrition Problems in Latin America held in 1953 recommended that the maximum level of iodization should be 1 part in 10,000 and minimum 1 part in 20,000. It recommended higher level of 1 in 10,000 where goitrogenic factors are shown to be important. The Ministry of Health, Government of India, considering normal food habits of goiter affected population along the slopes of Himalayas and the results of pilot plant study fixed the level of iodization[8] at 1 part of KIO_3 to 40,000 parts of salt or 1 part of KI to 50,000 parts of salt. This level is based on daily intake of 15 gms of coarse, crystalline salt, after giving due allowance for loss of iodine on storage and distribution. The level of iodization of salt adopted in different countries and iodine intake per head are given in Table 6. Based on proper appraisal of various factors mentioned above, the level of iodization has to be selected for each area and the developing country. It calls for study of food habits of affected population and keeping quality of locally produced coarse crystalline iodized salt in the concerned developing country.

TABLE 6

Level of Iodization of Salt and Iodine Intake Per Head in Different Countries

Country	Salt Intake Per Head Daily (gm)	Level of Iodization Chemical: Salt	Intake of Iodine Per Head Daily (mg)
USA	6.5	1: 10,000	0.500
Canada	6.5	1: 10,000	0.500
New Zealand	10	1: 20,000	0.380
Argentina	10	1: 30,000	0.228
Switzerland	10	1:100,000	0.076
Brazil	10	1:100,000	0.076
Panama	6.5	1: 10,000	0.500
India	15	1: 40,000 (KIO_3)	0.222
		1: 50,000 (KI)	0.238

IODIZATION CHEMICAL

The choice of iodine compound for iodization depends upon the nature of salt to be iodized. Sodium iodide, potassium iodide, potassium iodate and more recently calcium iodate are used for iodization. Potassium iodate is more stable than potassium iodide and sodium iodide and is the choice for iodization of coarse crystalline salt used in the developing countries. To prevent loss of iodine from iodized salt, stabilizers like sodium thiosulphate, calcium carbonate and magnesium carbonate are used.

LOSS OF IODINE IN IODIZED SALT

The success of the project depends upon the stability of iodine in iodized salt and that the salt carries the actual amount of iodine stipulated by medical authority. Individuals and people for whom iodized salt is intended as a goiter preventive must receive the required quantity of iodine in their daily intake of salt. Experiments were conducted at Sambhar Lake to study the keeping quality of iodized pan salt, on long storage in ordinary jute bags with and without exposure to sunlight, in polythene lined bags and subjecting them to transport hazards involved in their handling. The effect of moisture content of salt was also studied[8]. It is seen that salt iodized with KIO_3 was keeping better than the one with KI. The distribution of iodine is fairly uniform and there is no loss or migration of iodine on exposure to sunlight in the case of salt iodized with KIO_3. If moisture content of salt is more than 3.5%, it is difficult to run the plant. Salt clogs the hopper and screw conveyor and the distribution is not uniform. The plant is not run during rainy season since atmospheric humidity is high and the salt is also wet. The winter months in the north India is ideal for running iodization plant where the weather and salt are dry. Pan salt contains about 0.5% Na_2CO_3, which acts as self-stabilizer. Kyar and Reshta salt, manufactured from surface lake brine, are colored pink due to adhering algae. When freshly harvested Kyar and Reshta salt are iodized, it is found to lose iodine up to 30% to 40% on storage. If Kyar & Reshta salt are rainwashed and dried in the atmosphere, the iodization is fairly uniform and loss of iodine is negligible. Since all three salt varieties from Sambhar Lake contains Na_2CO_3, it acts as self stabilizer.

It is necessary to conduct such experiments with other varieties of salt, namely Baragara and Sea Salt which are iodized recently, to determine the extent of loss of iodine on storage etc. The above varieties contain magnesium chloride and magnesium sulphate which make the salt highly deliquescent, in high humid conditions. They do not contain sodium carbonate as Sambhar pan salt. The crystal size of baragara salt may not be conducive for uniform iodization.

Since the quality of salt to be iodized has an important bearing on the keeping quality of iodine, a detailed study has to be made on pilot plant basis to determine loss of iodine in the iodized salt in the developed country, before embarking on commercial scale production.

PROBLEM OF DISTRIBUTION OF IODIZED SALT

In many of the developing countries, the saltworks where iodization units have to be located, are far away from goiter affected areas. Since iodized salt is an important substance of daily use, steady and regular supplies have to be maintained. It is necessary to create an agency to look after this aspect of the problem. Quantity to be iodized and transported to goiter affected area have to be fixed depending upon the population and daily intake of salt. India has worked out a zonal distribution of salt linking manufacturing centers to the nearest consumption centers and distribution effected through the help of railways and local governments. The whole program of distribution of iodized salt is supervised by Salt Commissioner to the Government of India.

Since it is working satisfactorily, a similar scheme with suitable modifications to conform to local conditions may have to be worked out in a developing country.

PACKING MATERIAL

In order to prevent loss of iodine during long storage and transport iodized salt needs to be packed in suitable bags. Jute bags are normally used for packing salt in India in units of 75 kilos 100 kilos. During the rainy season when the temperature and humidity are high, the salt absorbs moisture from atmosphere and becomes deliquescent. It is admissable to pack iodized salt in polythene lined jute bags for bulk packing and for retail sales in one kilo polythene packets. A detailed study of packing material to be used for iodized salt has to be made by the developing country.

ADMINISTRATION

The success of goiter control will depend upon the goiter affected regions getting only *iodized salt*. It may be necessary by legislation to ban entry of non-iodized salt in the goiter affected regions on the grounds of public health. Such ban orders have been issued by State Governments in India in the goiter affected regions.

FINANCE

In the developing countries, the price of iodized salt should not be different from that of uniodized salt for the success of the scheme. The entire cost of iodization is borne by the Ministry of Health in India and iodized salt is sold to the public at the same price as non-iodized salt. The cost of iodization in India ranges from U.S. $2 to U.S. $3 per ton, depending upon the location of unit and the process.

AGENCY

Since it is a multidisciplinary project involving salt industry, Ministry of Health and local governments, an agency should co-ordinate the various activities of the project. A permanent Committee on goiter and supply of iodized salt, consisting of members from the following organizations, periodically meet in India to review various aspects.

1. Salt Commissioner to Government of India.
2. Representative from the Ministry of Health.
3. Representative from Ministry of Industry.

4. Representative from Director General of Health Services.
5. Representatives, from local Governments.

The functions of the committee are:

1. to select the proper iodizing agent,
2. to select the saltworks where the iodization units to be installed,
3. to determine the areas where iodized salt to be supplied,
4. to review technical, financial and administrative problems of iodization of salt and
5. to recommend to State Governments the measures to be taken for banning entry of non-iodized salt in goiter areas.

EVALUATION

To assess the progress of eradication of goiter, a periodic survey of goiter affected regions has to be carried out by the Ministry of Health. It is reported by Joint FAO/WHO Experts Committee on Nutrition in 1967 that goiter has fallen to 5% in the Himalayan Region where iodized salt is supplied from around 40 percent at the beginning of the program to about 15 percent after 5 years.

To eradicate goiter along the Himalayas and to supply 71 million people affected by goiter, it is estimated that 450,000 tons of salt have to be iodized annually. Indian experience in iodizing various varieties of coarse crystalline salt, transport and distribution may be utilized by developing countries interested in launching a goiter eradication program.

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