

# The control of endemic goitre

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World Health Organization

## THE CONTROL OF ENDEMIC GOITRE

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Further information on many aspects of WHO's work are presented in the Organization's publications.

# The control of endemic goitre

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# Preface

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*Following a recommendation of the World Food Council, endorsed by the General Assembly of the United Nations in December 1978, WHO, UNICEF, and the World Food Council have launched a worldwide campaign to control goitre within the next decade.*

*The present book explains the significance of endemic goitre as a public health problem and gives a detailed account of the means available to control it. The techniques described are simple and cheap. They do not involve sophisticated technology and can be used anywhere in the world.*

*The preparation of this book has been made possible by a generous financial contribution from UNICEF. Members of the staff of that organization have also participated in the preparation of the text, especially of chapters 2 and 4, which deal with subjects on which they have accumulated wide experience over the years. Their collaboration has been much appreciated and the authors wish to express their gratitude for it.*





# 1. Introduction

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**G**OITRE is the name given to an enlargement of the thyroid gland. One speaks of endemic goitre when this condition affects a significant number of people living in any circumscribed area. From a public health point of view, it has been suggested that endemic goitre can be defined as a prevalence of goitre of at least grade 1b (see classification on page 10) of 5% or more in pre- and peri-adolescent individuals or of 30% or more of grade 1a among adults. At this level, public health intervention seems to be called for. Goitre may affect all ages and both sexes. It is, however, more frequently observed in females and after puberty.

Endemic goitre has been reported from all over the world. It is now accepted that the most important single causal factor is an inadequate content of iodine in food and consequently an insufficient dietary intake of iodine. In most cases food is the major source of dietary iodine, providing about 90% of the total intake, the rest coming from water. The presence of goitrogenic factors in a number of foodstuffs is well known but they seldom play a major role in the causation of endemic goitre. In some parts of the world, however, the prevalence of endemic goitre in spite of adequate iodine intake appears to indicate that goitrogens are significant. Goitrogens fall into two major groups from the point of view of practical control—those that can be countered by iodine supplementation and those that continue to exert an effect in spite of such supplementation. Among the latter are sulfur-containing organic compounds of high molecular weight recently identified in the Cauca Valley in Colombia (*1*). As a general rule, however, iodine deficiency is the primary cause of endemic goitre and it occurs in areas where food is produced on soils low in iodine. In practice, this means that goitre is likely to exist and persist in communities that depend on local production for the major part of their food. As lines of communication are opened to other regions and the sources of food become diversified, the prevalence of goitre is likely to decline owing to the increased availability of foods grown on soils richer in iodine. Changes in the origin of food supplies may account for the otherwise unexplained

disappearance of endemic goitre from a number of localities during the past 50 years.

Most goitrous persons are euthyroid, which means that their enlarged thyroid gland is functioning adequately. While mild enlargement may have only aesthetic significance, severe goitre can be the cause of obstructive complications. Even more important from the public health point of view is the fact that endemic goitre is epidemiologically associated with endemic cretinism and deaf-mutism and with mental deficiency (2, 3), which varies in degree according to the severity of the iodine deficiency and how early in life it occurs, being worst when it occurs during fetal development. The prevalence and severity of goitre among women of childbearing age is therefore of particular concern. It has been shown (3) that in areas where goitre is highly prevalent intellectual impairment can be prevented by the prenatal administration of iodine. In people over 40 years of age, goitre may also lead to a progressive destruction of the secretory element of the gland, with the result that mild forms of myxoedema may appear, especially in women. The presence of cretins, deaf-mutes, and mental defectives places a heavy load on the community, and a control programme is justified on this score alone.

In prevalence surveys of endemic goitre, the most widely used classification system (4) is as follows.

Grade 0: thyroid not palpable, or, if palpable, not larger than normal.

Grade 1a: thyroid distinctly palpable but usually not visible with the head in a raised position; the indication is of a thyroid larger than normal, i.e., at least as large as the distal phalanx of the subject's thumb.

Grade 1b: thyroid easily palpable and visible with the head in a raised position; the grade also includes all patients with a discrete nodule.

Grade 2: thyroid easily visible with the head in a normal position.

Grade 3: goitre visible at a distance.

Grade 4: monstrous goitres.

The presence of cretinism or the occurrence of a mean urinary iodine excretion below 25  $\mu\text{g/g}$  of creatinine are two indices that are easy to obtain and provide good indicators of the severity of the endemia.

The prevention of endemic goitre rests primarily on increasing the iodine intake of populations in goitrous regions. Controlled studies have indicated that when the amount of iodine available to the body is increased so that it covers the estimated daily requirement (100–150  $\mu\text{g}$  per day for adults) the prevalence of goitre will decline. The preventive treatment is most effective in children and adolescents who do not have a goitre when the measures are introduced. Established goitres in adults do not usually decrease in size, although in some programmes in which iodinated oil has been administered reductions have been observed.

Four methods have been used to increase the iodine intake of populations in goitrous regions:

- (1) addition of iodide or iodate to salt,
- (2) addition of iodide or iodate to bread,
- (3) use of tablets containing potassium or sodium iodide, and
- (4) administration of iodinated oil.

The availability of iodine for supplementation purposes is not a problem since the world production of iodine is in the region of 15 000 tonnes per year. Until recent years the bulk of the world's iodine was derived from nitrate deposits in South America. Large-scale production is now undertaken in Asia and North America. The precise proportion of the world's population that requires iodine supplementation is not known. Assuming that it is about 20% (i.e., 1000 million people) and that each person would require an additional 200  $\mu\text{g}$  of iodine per day, including losses for handling and storage, about 73 tonnes of iodine would be required every year for supplementation. This is only 0.5% of the world production of iodine, and so availability would pose no problem.

The following terms are often used to identify the iodine compound used in supplementation programmes:

iodination—supplementation with any compound of iodine.

iodization—supplementation with potassium or sodium iodide.

iodation—supplementation with potassium or sodium iodate.

To avoid confusion, however, and for the sake of uniformity the term "iodination" will be used throughout this publication.

The choice of a vehicle for supplementing with iodine depends entirely on practical considerations. Water and bread have occasionally been used but are clearly not feasible in areas without extensive piped water supply or among populations that do not consume bread universally and daily. Moreover the fortification of water is unduly expensive, considering the small amount that is used for drinking or the preparation of food. The distribution of iodide tablets has not proved successful owing to difficulties of organization and lack of acceptability. In most parts of the world the iodination of salt is clearly the best method of goitre control. The mixing of an iodine compound with salt is simple and produces no adverse chemical reactions. Salt is consumed daily by everyone in fairly constant amounts and is therefore a most practical vehicle for iodine supplementation. Potassium iodate ( $\text{KIO}_3$ ) is usually chosen as the compound to be added to salt owing to its stability. The quantity of iodine supplementation ranges

from 150  $\mu\text{g}$  to 400  $\mu\text{g}$  per day (calculated as iodine) depending on the degree of goitre endemicity. The level of iodine supplementation of alimentary salt is calculated on the basis of daily salt intake and the quantity of iodine required, taking into account the additional amount of iodine required to make up for the losses between iodination and consumption. The choice of iodination process and equipment will depend on the quantity of salt involved and its physical and chemical characteristics. The possibility of using existing buildings, the logistics of salt reception and distribution, and the availability of services and manpower should be the most important considerations in selecting the location of an iodination plant. The budget for iodination of salt is based on the cost of potassium iodate, the cost of services, the depreciation of equipment, the cost of manpower, and the interest on working capital. The costs of iodination can be recovered from the public, especially if non-iodinated salt is prohibited in the area, otherwise they will have to be met from public funds.

In many countries, particularly developing countries, the organization of iodinated salt programmes has been hampered by various geographical, economic, and administrative obstacles (5, 6). The most frequent setbacks have stemmed from the inadequate and irregular distribution of salt in regions where transport is difficult. In some of these regions, salt is produced from mines or salt marshes and the heterogeneity of the commercial market makes the systematic iodination of all salt extremely difficult. In many areas salt iodination has been achieved only after being made compulsory. Laws of this kind, however, are slow to implement and require supervisory and enforcement agencies (6, 7, 8).

In areas where salt iodination is not feasible, the injection of iodinated oil has been proposed as a way of providing people with a long-lasting source of iodine. Pilot studies have proved the physiological effectiveness of this practice but very few large-scale public health programmes have been launched. Some experience has been gained, however, in Ecuador, Papua New Guinea, Peru, and Zaire.

For the health services of most developing regions, a prevention programme based on iodinated oil offers several advantages. It is well known that the establishment and reinforcement of local health services is an important priority for the governments of developing countries, and an iodinated oil programme provides an excellent opportunity to mobilize such services because it is one of those rare rural health programmes that is modest in scope and cost but can produce effects directly visible to the population concerned. The objectives of such a programme are therefore twofold—to eradicate or control a disease and to impress the population favourably with regard to the introduction of health programmes.

Important though these objectives are, however, it has to be recognized that experience in implementing iodinated oil programmes is still limited.

The choice between salt iodination and the periodic administration of iodinated oil will depend much on the operational difficulties confronting the former method. Given an adequate communication and distribution network, iodinated salt is certainly the best method and is widely used in industrialized countries. The periodic administration of iodinated oil appears to be justified only when salt iodination is not feasible because of a poor marketing infrastructure or extreme diversity of sources of production or when the goitrous areas are small and scattered. However, when the rate of cretinism is high a crash programme for administering iodinated oil may be implemented while legal, administrative, and logistic arrangements are made for salt iodination.

In conclusion, it should be recognized that the control of endemic goitre is not only a medical problem but one that is politically determined. Inexpensive methods are available but their implementation depends on a political will to improve the health status of the entire population.

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## 2. Technical aspects of salt iodination

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**C**OMMON salt is produced either by the solar evaporation of brine of oceans and salt lakes or by the exploitation of dried lake deposits, quarries, and salt mines. Salt is therefore produced on a continuous basis from oceans and brine lakes and on a progressive reduction basis from natural deposits accumulated in past ages. In general, the requirements of Europe and North America are met from accumulated deposits, only limited amounts being manufactured through solar evaporation. Africa, Asia, Australasia, and South America depend on sun-dried salt recovered mainly from coastal areas.

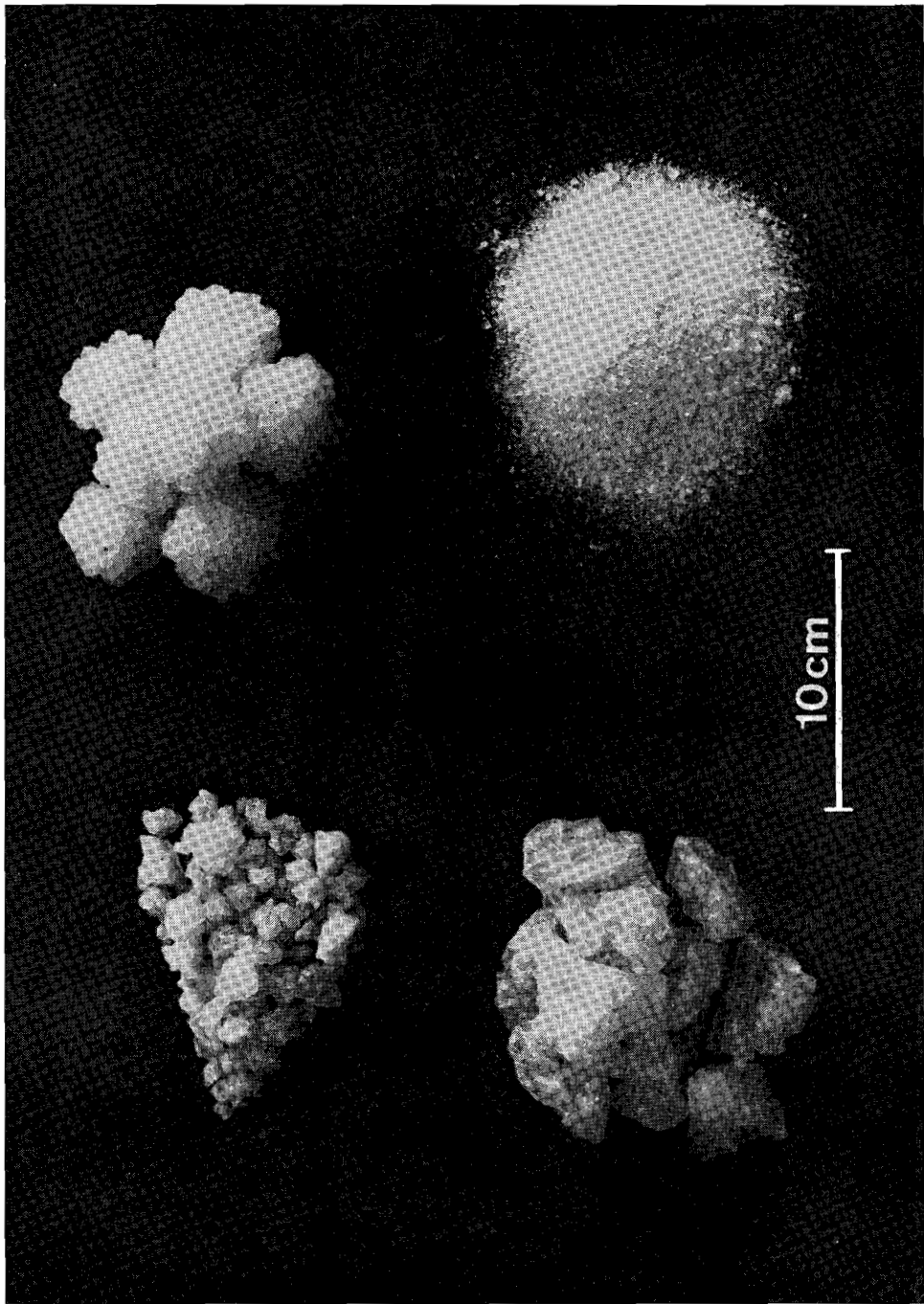
### **Marine solar crystals**

Manufacture of salt by the solar evaporation of sea-water has been practised for thousands of years. Efficient production of salt by this method requires suitable flat coastal land with the correct combination of sand and clay. Low rainfall, good sunshine, prevailing winds, and low humidity are weather conditions most suited to the rapid evaporation of water from brine. Favourable atmospheric and land conditions with facilities for drawing ocean brine and disposal of residual liquor can yield approximately 50–100 tonnes of marine salt per hectare per year.

The process of manufacture begins by collecting ocean brine in a series of collecting ponds and concentrating it from 35 g/l to approximately 150 g/l. The brine is then passed through concentration ponds where gypsum (calcium sulfate) and other relatively insoluble salts are precipitated. This precipitation would also remove about 5% of the total dissolved salts in sea-water. The concentrated brine, containing about 250 g/l soluble solids, is transferred to crystallizing beds to produce nearly pure sodium chloride (NaCl), which can be recovered by a continuous process of solar evaporation and the draining of the mother liquor, known as “bittern”, before any substantial quantities of magnesium salts can precipitate. Some magnesium salts remain as surface impurities and can be reduced by washing the salt with fresh brine or



Fig. 1. Solar salt crystals



exposing it to rain. The recovery of sodium chloride is about 75% of the total present in ocean brine.

The salinity of ocean brine is measured by hydrometer. Sea-water usually contains 35 g/l of soluble solids made up of 65% sodium chloride, 28% magnesium chloride and magnesium sulfate, 4% calcium sulfate (gypsum), and 3% potassium and other salts.

The quality of the salt produced will depend on the successful removal of deposited fractions and residual liquor. The precipitated gypsum should have minimum sodium chloride and the principal salt fraction should be low in calcium sulfate and magnesium salts. Fig. 1 shows different types of salt crystals produced in India by solar evaporation.

The residual liquor contains almost all the natural ocean content of iodine and is thus lost from the recovered sodium chloride. Since iodine is a constituent of sea-water it might be incorrectly assumed that salt made from sea-water contains sufficient iodine for nutritional purposes. The total dissolved salts in sea-water contain less than  $2\text{ }\mu\text{g}$  of iodine per gram of salts, equivalent theoretically to about  $3\text{ }\mu\text{g}$  of iodine for every gram of recovered sodium chloride. For a daily consumption of 10 g of salt, the iodine would amount to only  $30\text{ }\mu\text{g}$  per person per day, assuming it were wholly recovered. However, this small quantity of iodine is lost in the residual bittern during the process of salt production. It is therefore important to bear in mind that all calculations to establish the level of iodine supplement should ignore the possibility of iodine being initially present in the salt.

A typical crude solar salt produced in a good salt-works with efficient intakes and residue disposal would contain 85–90% NaCl, 3.5% calcium and magnesium salts and 7–10% water. As most of the magnesium salts are in the surface moisture, a well washed and drained crude salt would have 92–94% NaCl, 2–3% other salts, and 4–5% moisture.

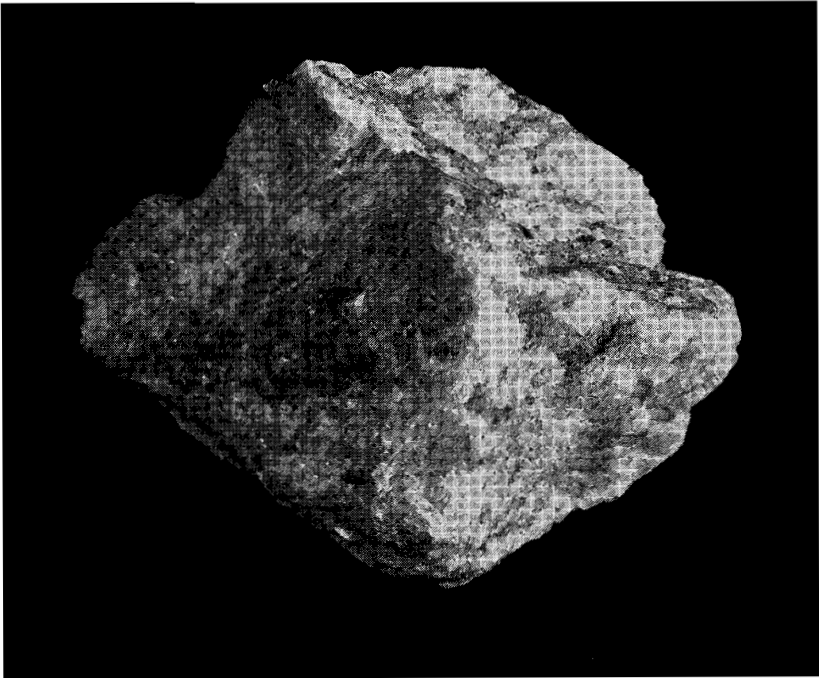
### **Rock-salt deposits**

Rock-salt can be recovered by quarrying or mining. Deposits suitable for quarrying are usually dried-up salt lakes either already exposed or only thinly covered with earth. After the process of excavation the rock-salt is reduced to the most convenient size for industrial use by crushing and grading. The salt is screened to separate four or five different sizes ranging from 5 mm crystals to fine powder.

Salt deposits beneath the surface of the earth can be recovered by sinking wells and injecting water to produce brine, from which the salt is recovered by thermal evaporation. A sample of rock-salt from Pakistan is shown in Fig. 2.

Salt deposits are often of high purity—99% NaCl—and so it is not necessary to purify it by recrystallization in order to produce com-

Fig. 2. Sample of rock-salt



mercial grade or edible salt. The moisture content of rock-salt is usually much lower than that of the sun-dried crystals, and this factor should be taken into consideration in the iodine supplementation process.

### **Use of salt**

Salt was originally manufactured solely for alimentary use, and in many countries it is still used entirely for this purpose. With the progressive spread of industrial development the need for salt as a basic chemical will increase rapidly relative to the demand for it for alimentary purposes. This is evident when some of the salt statistics are examined. North America, with a population of 300 million, annually produces about 50 million tonnes of salt, of which only 1.5 million tonnes are used for domestic retail trading and only 5 million tonnes for all human and animal feed processing. In Central and South America the salt production is less than 5 million tonnes per year for a population of 300 million. Africa, with a population of 460 million, is producing only 2-2½ million tonnes per annum. It is therefore apparent that

developing countries and regions use over 90% of their production for alimentary purposes while the industrial nations use 90% for technical and commercial purposes.

Table 1  
Salt for human consumption, projected requirements, 1980

	Population, 1980	Salt production per annum (tonnes)	Calculated alimentary salt requirement per annum (tonnes)
Africa	460 010 000	2 199 000	2 300 050
America, North and Central	371 490 000	55 694 000	1 857 450
America, South	248 970 000	4 958 000	1 244 850
Asia	2 513 810 000	31 182 000	12 569 050
Europe	754 760 000	65 409 000	3 773 800
Oceania	23 470 000	4 775 000	117 350
190 countries and areas	4 372 510 000	164 217 000	21 862 550

Table 1 shows projected populations,<sup>1</sup> total salt production, and alimentary salt requirements for various regions in 1980. The figures for salt production are based on the period 1971–74 and include a projected overall increase in production of about 5%. Domestic salt consumption ranges from 5 g to 15 g per person per day, which is equal to 1.8–5.5 kg per person per year. Salt consumption is markedly greater in some countries; in Japan it may reach 27 g per person per day. With an allowance of 50% for handling, distribution, and other losses, the average salt requirement for domestic use is 5 kg per person per year. This figure was used for calculating the values for alimentary salt in the last column of the table.

## Iodine

Iodine fortification of salt is normally carried out by using the iodides or iodates of potassium, calcium, or sodium. The characteristics of these salts are given in Table 2.

Potassium iodide, KI, is extensively used for supplementation of refined (table) salt. The high solubility of the iodide is advantageous

<sup>1</sup> Population figures are taken from the document *Single-year population estimates and projections for major areas, regions, and countries of the world 1950–2000* prepared by the United Nations Population Division (document No. ESA/P/WP.56, 6 October 1975).

**Table 2**  
**Solubility of iodine and its compounds**

	Relative molecular mass	Percentage iodine	Solubility in water (g/l)				
			0° C	20° C	30° C	40° C	60° C
Iodine, I <sub>2</sub>	254	100		0.290	0.400	0.560	
Calcium iodide, CaI <sub>2</sub>	294	86.5	646	676	690	708	740
Calcium iodate, Ca (IO <sub>3</sub> ) <sub>2</sub> (6H <sub>2</sub> O)	390	65.0	1.00		4.20	6.10	13.6
Potassium iodide, KI	166	76.5	1280	1440	1520	1600	1760
Potassium iodate, KIO <sub>3</sub>	214	59.5	47.3	81.3	117	128	185
Sodium iodide, NaI (2H <sub>2</sub> O)	150	85.0	1590	1790	1900	2050	2570
Sodium iodate, NaIO <sub>3</sub>	198	64.0	25.0	90.0		150	210

in preparation and dispersion by means of atomized sprays on very dry crystals. However, losses of iodine occur if the table salt:

- is not dry and free-running during production,
- is exposed to a humid atmosphere or excessive aeration,
- is exposed to sunlight,
- is subjected to heat,
- has an acid reaction, or
- contains impurities derived from mother-liquor.

It is extremely difficult to avoid all these adverse conditions in salt iodination programmes.

Certain impurities in table salt in the presence of moisture cause oxidation of the iodide. If packages of table salt iodinated with KI are exposed to excessive moisture or become damp, the iodide will be attracted to the areas of high moisture and thus migrate from the body of the salt to the cardboard or fabric of the container, which results in a reduction in the iodine content of the salt. These adverse effects on KI can be minimized by the addition of stabilizers and drying agents in amounts less than 1 g/kg of the carrier salt. The stabilizers are sodium thiosulfate and calcium hydroxide. Other stabilizers such as magnesium carbonate, sodium bicarbonate, sodium carbonate, or calcium carbonate can also be used.

Potassium iodate, KIO<sub>3</sub>, is an extremely stable compound that is unlikely to be affected by impurities, and its lower solubility in water gives it another important advantage over potassium iodide, because it migrates much less readily and so cannot easily be removed from iodinated salt.

Since  $\text{KIO}_3$  rapidly breaks down in the human body, large doses of the compound can be tolerated, providing a source of iodine to the thyroid gland for the synthesis of thyroid hormone. It is therefore approved and recommended by WHO as safe when used in the minute proportions required for the iodination of salt. Most of the people in goitrous areas use crude salt, which can be effectively supplemented with potassium iodate without the need to add carrier agents or stabilizers. This simplifies the procedure of salt iodination. Potassium iodate can be rapidly dissolved to prepare a solution of up to 40 g/l strength. The solution strength alters the relative density, which can be measured by a hydrometer. For measurements of relative density,  $d$ , made at 18 °C the mass concentration (g/l) is equal to:  $1134.75 (d - 0.99830)$ .

Potassium iodide is cheaper than potassium iodate and less of it is needed because of its larger iodine content. However, the overall cost of using it is higher owing to the added cost of stabilizers and extra processing and handling.

### **Fortification of salt with potassium iodate**

The size of salt crystals should not be more than 1.0–1.5 cm for effective iodination. This does not pose a problem for solar salt since the crystals are never more than 1 cm across, but rock-salt sometimes needs to be crushed and a salt crusher might have to be included as an additional item of equipment. If iodinated salt crystals are smaller than the salt crystals normally available, some effort should be put into marketing the new type of salt. Fortification of salt with potassium iodate can be done by wet or dry blending, using the correct strength and quantity of potassium iodate solution. Wet blending can be done either by the drip-feed method or by the spraying method depending upon the type of salt.

The drip-feed system is the simplest and cheapest. It is suitable for coarse salt with uniform particles up to 1.0 cm in size and a moisture content of 4–5%. The dispersion of the iodate solution is facilitated by the moisture present on the surface of the salt, but the total moisture is too low to permit free drainage or loss of iodine.

The spraying method is used for dry and very fine table salt, for which the drip-feed system is not suitable because it does not disperse the iodate solution with sufficient uniformity. The spraying method atomizes the iodate solution and sprays it as a mist over the tumbling salt crystals. The spraying method is also preferable to the simpler drip-feed system when the salt has varying particle size and moisture content, which will usually be the case if the iodinating plant receives salt from a number of sources.

The dry blending of potassium iodate powder is possible if the salt is finely ground to a uniform particle size, otherwise potassium iodate, having a finer particle size and being heavier than salt, will settle at the bottom of the container. This method is suitable for fortifying table salt but not regular coarse salt, which is more commonly used in developing countries. It has been reported that dry blending is more expensive than wet blending.

Table 3 shows the quantity of potassium iodate solution of different strengths required for an iodinating plant with an output of 5000 kg/h for different concentrations of iodine in salt.

Very little difference can be seen between normal and iodinated salt.

### **Drip-feed system**

Practical experience has shown that a capacity of 5000 kg/h is ideal for a drip-feed system, which requires only a low-pressure head to maintain the required flow rate.

The salt to which the iodate is to be added is transported in a narrow band, 10–12 cm wide and 2 cm deep, in a shallow-trough conveyor-belt about 35–40 cm wide. To achieve a capacity of 5000 kg/h the speed of the conveyor-belt should be about 0.5 m/s. The conveyor is about 5.5 m long and is set up at a slope of about 20°. The conveyor-belt should be equipped with a tensioning device.

The feed hopper has a capacity of about 300 kg and the rate of salt flow on to the conveyor is controlled by means of a slide valve. Flexible rubber curtains on three sides shape the salt into a narrow band on the conveyor-belt and prevent it from spilling over the edge.

The potassium iodate solution is contained in two 200-litre polyethylene stock tanks with discharge valves at the bottom to permit the filling of two 25-litre feed bottles mounted in such a way as to ensure a continuous supply of iodate solution at a constant head. The flow rate can be regulated by a flow meter and needle valve control. Alternatively, only one feed bottle may be used, the constant head being maintained by the continuous circulation of solution from the main tank to the feed bottle (Fig. 3).<sup>1</sup>

The iodinated salt falls into a discharge hopper from which it is collected in bags. For continuous operation the hopper should have a twin spout outlet with a diversion valve.

Since salt is a corrosive substance, all parts coming in contact with it should be made of corrosion-resistant materials such as stainless steel,<sup>2</sup> food-grade poly(vinyl chloride), or hardwood.

<sup>1</sup> Equipment specifications may be obtained from UNICEF, P.O. Box 202/JKT, Jakarta, Indonesia.

<sup>2</sup> AISI 316 grade stainless steel is recommended.

Table 3  
Salt iodination for different intakes of salt and iodine

Iodine intake per person per day (1)	Average salt intake per person per day (2)	Ratio of iodine to salt (mg/kg) (3)	Ratio of KIO <sub>3</sub> to salt <sup>a</sup> (mg/kg) (4)	KIO <sub>3</sub> in 5000 kg salt (g) (5)	KIO <sub>3</sub> solution in litres/h for 5000 kg/h iodination unit		
					10 g/l KIO <sub>3</sub> solution (6)	20 g/l KIO <sub>3</sub> solution (7)	30 g/l KIO <sub>3</sub> solution (8)
100 µg	5 g	20	33.70	168.50	16.85	8.43	5.62
	10 g	10	16.85	84.25	8.43	4.22	2.81
	15 g	6.67	11.23	56.15	5.62	2.81	1.87
150 µg	5 g	30.03	50.55	252.50	25.25	12.63	8.42
	10 g	16.13	25.28	126.40	12.64	6.32	4.21
	15 g	10	16.85	84.25	8.43	4.22	2.81
200 µg	5 g	40	67.40	337.00	33.70	16.85	11.23
	10 g	20	33.70	168.50	16.85	8.43	5.61
	15 g	13.33	22.47	112.35	11.24	5.62	3.75
250 µg	5 g	50	84.25	421.25	42.13	21.07	14.04
	10 g	25	42.13	210.65	21.07	10.54	7.02
	15 g	16.67	28.08	140.40	14.04	7.02	4.68
300 µg	5 g	60.24	101.10	505.50	50.55	25.28	16.85
	10 g	30.03	50.55	252.75	25.28	12.64	8.43
	15 g	20	33.70	168.50	16.85	8.43	5.62
400 µg	5 g	80	134.80	674.00	67.40	33.70	22.46
	10 g	40	67.40	337.00	33.70	16.85	11.23
	15 g	26.67	44.93	224.65	22.47	11.24	7.49

<sup>a</sup> 1.685 mg of KIO<sub>3</sub> contain 1 mg of iodine.



Fig. 3. Drip-feed equipment in Indonesia, using one feed bottle



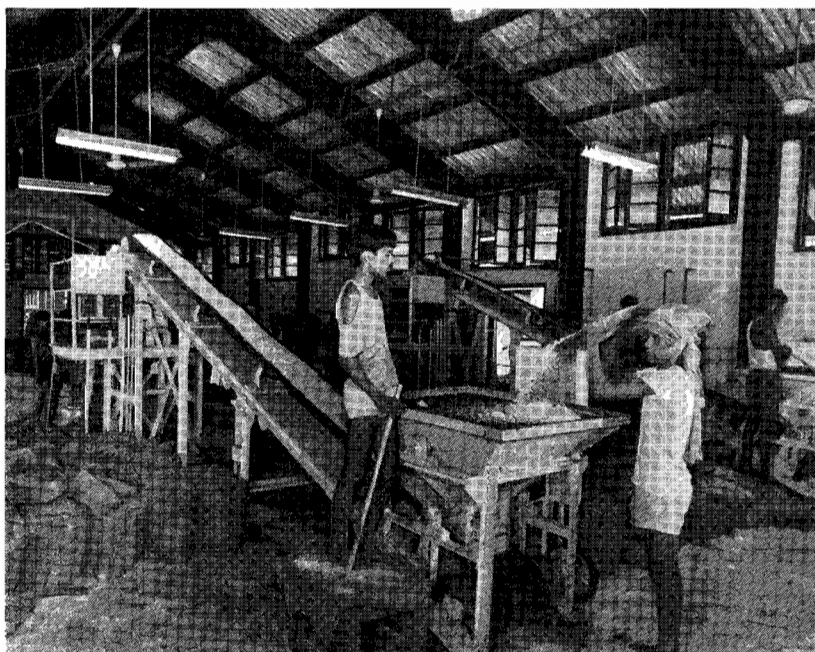
## Spray mixing system

A spray mixing plant with a capacity of 5000 kg/h is illustrated in Fig. 4 and 5. This capacity is considered adequate for efficient operation.<sup>1</sup> The salt is transported to the spraying chamber on an inclined conveyor-belt similar to that used in the drip-feed system.

The feed hopper for the spray system could be similar to that for the drip-feed system if the salt crystals are of a uniform size. Additional features are necessary to handle large lumps of salt effectively. A wire mesh screen or grating should be fitted on top of the feed hopper to prevent large lumps of salt from falling into it.

A rotating shaft provided with arms is fitted at the centre of the hopper to agitate the salt and prevent it from clumping. A second shaft with four plates is fitted in the outlet of the hopper and acts as a rotary valve, providing a continuous feed to the conveyor-belt.

Fig. 4. Spray mixing equipment, India, showing hopper and conveyor-belt



<sup>1</sup> A detailed construction drawing and equipment specification may be obtained from UNICEF, 11 Jor Bagh, New Delhi 110003, India.

Fig. 5. Elevation and plan of a spray mixing plant

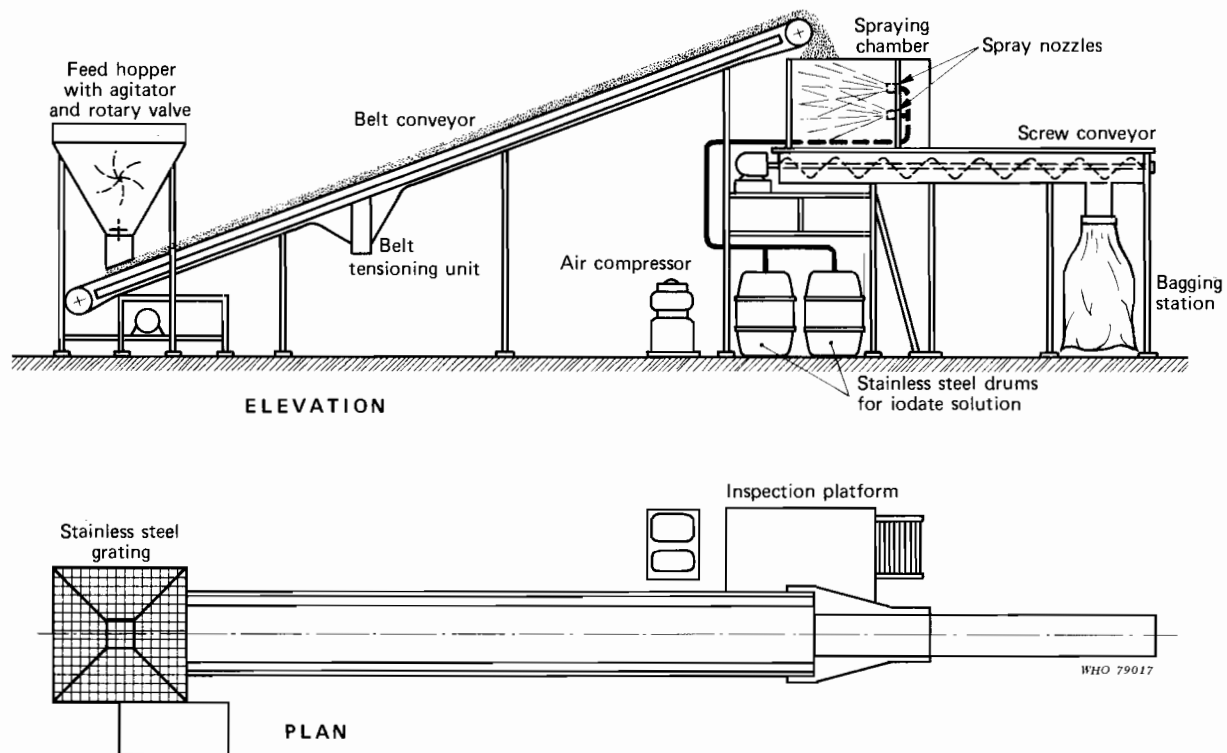
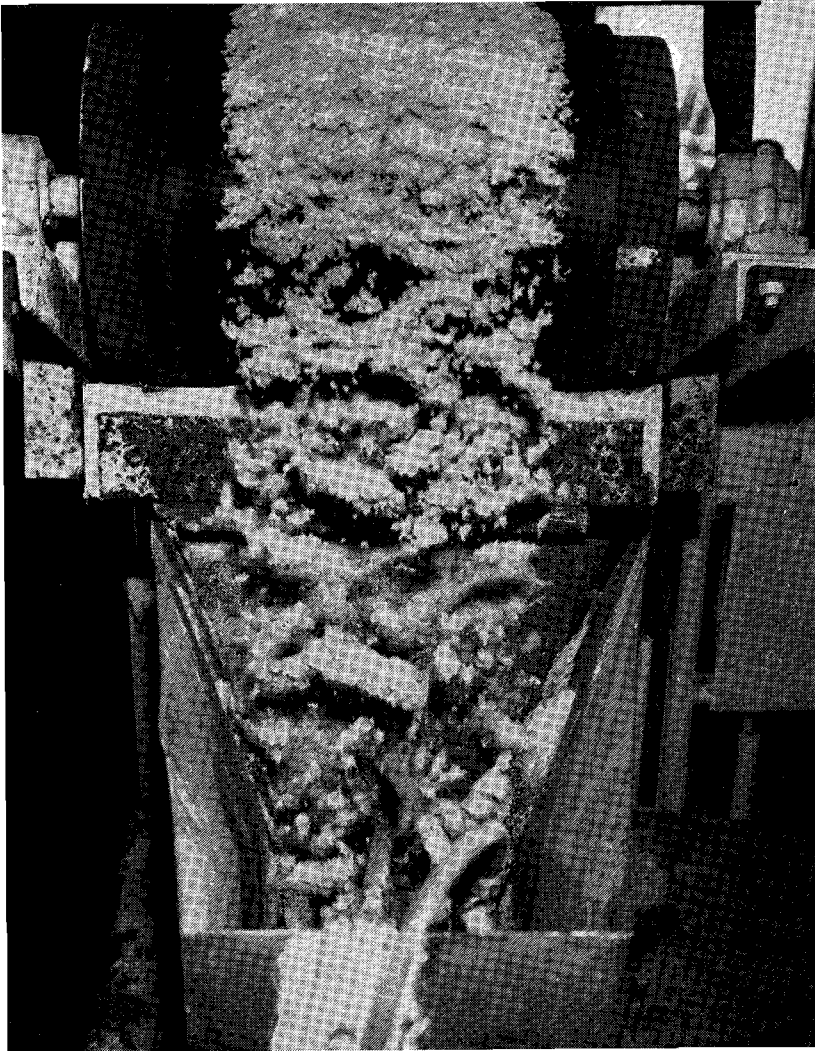


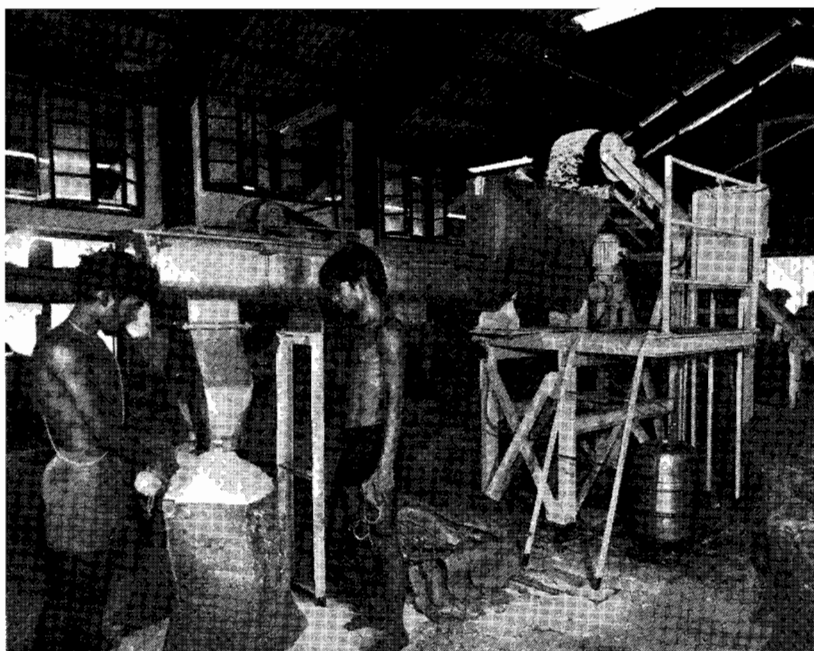
Fig. 6. Spray chamber



Both these shafts are driven by a variable-speed drive system and the rate of rotation is adjusted to give the required throughput.

The salt is carried up from the hopper on the conveyor-belt and falls into the spraying chamber (Fig. 6), where it passes through a fine spray of potassium iodate solution. The solution is sprayed at a pressure of 140 kPa (1.4 kgf/cm<sup>2</sup>) through stainless steel nozzles.

Fig. 7. Iodinated salt being discharged into bags from the screw conveyor



The tumbling of the crystals permits effective exposure of the salt to the atomized spray. The spray nozzles are designed to deliver a flattened spray that spreads over the entire width of the salt stream. The spraying chamber is provided with a viewing window.

The iodate solution is kept under pressure in two stainless steel drums each of about 80 litres capacity. The pressure in the drums is maintained constant by an air compressor equipped with a regulator.

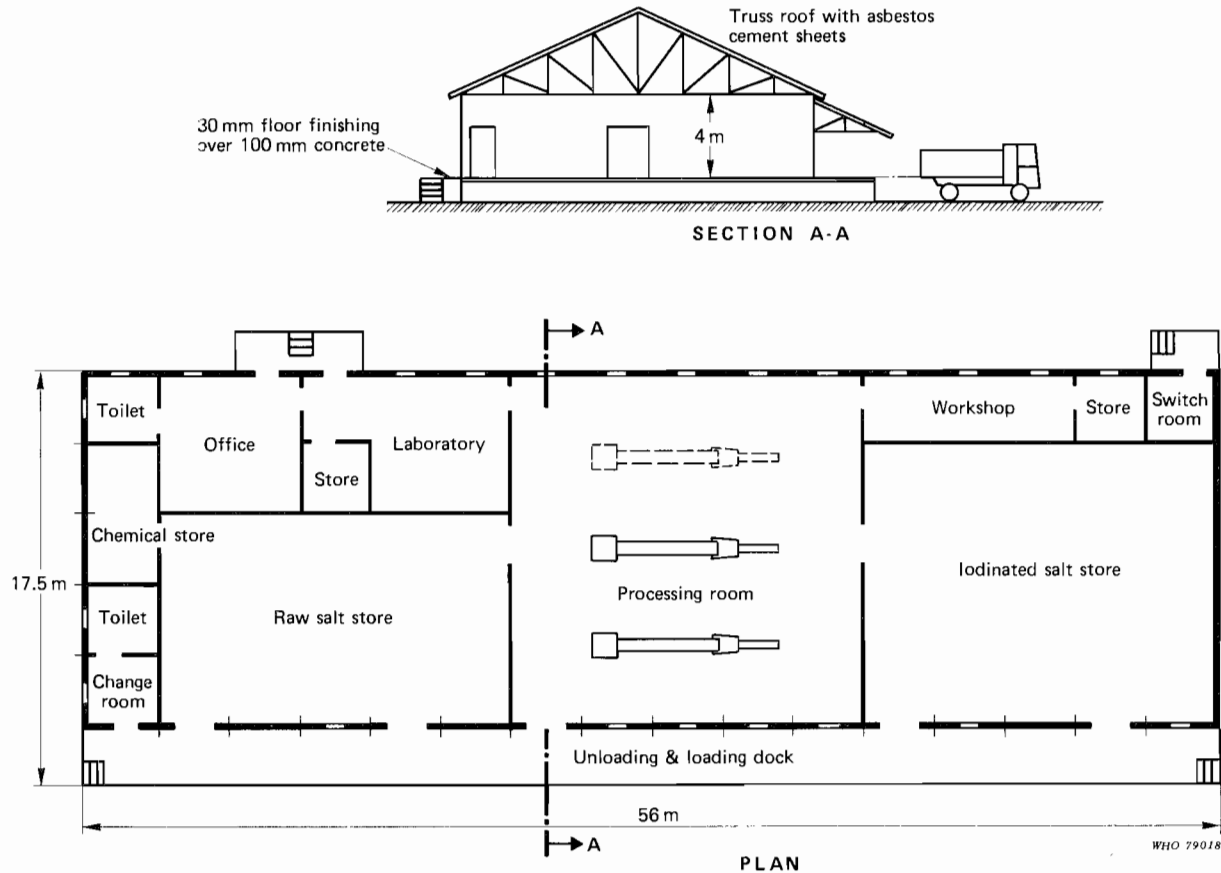
The salt crystals, wetted unevenly with  $\text{KIO}_3$  solution, fall into a screw conveyor about 20–25 cm wide and 2.5–3.0 m long, which mixes the salt and solution more thoroughly. The properly mixed and iodinated salt is discharged at the end of the screw conveyor through a twin outlet into bags (Fig. 7).

As with the drip-feed system, consideration should be given to the use of corrosion-resistant materials such as stainless steel, food-grade poly(vinyl chloride), or hardwood.

### Dry blending

Iodination may be carried out with the iodate in the form of dry crystals rather than in solution. In this case, owing to the small quantity

Fig. 8. Layout of a salt iodination plant



of  $\text{KIO}_3$ , the mixing should be done in two steps to obtain consistent blending and to reduce mixing time.

The main item of equipment for a batch process is a horizontal blender with an internal spiral or ribbon-type agitator. Sensitive weighing equipment should be provided for measuring out a pre-determined quantity of  $\text{KIO}_3$ .

### **Maintenance of equipment**

The orifices of the drip-feed system and nozzles of the spray system should be inspected daily to keep them clear of obstructions. The belt tension should be checked to ensure that the throughput rate does not fluctuate owing to belt slippage. All electrical connexions and control points should be periodically checked to prevent short-circuiting due to corrosion. All painted surfaces should be maintained with rust-resistant paints. A lubrication schedule should be followed to prevent excessive wear of equipment.

### **Building requirements**

New buildings are seldom required. The simple modification of an existing salt store is usually sufficient to house the iodination equipment. This can be done by reallocating the space available or by adding a separate room.

If, however, a new building is necessary it should be a very simple one to minimize cost (Fig. 8). The current building costs in India are US \$38/m<sup>2</sup> for a shed with asbestos cement sheet roofing.

A floor area of about 1000 m<sup>2</sup> would be adequate to accommodate a 2 weeks' supply of raw and iodinated salt, working space for two or three iodinating units, laboratory, office, workshop, loading platform, and other miscellaneous facilities. It is assumed that a warehouse for the seasonal supply of salt is available nearby. The building can be constructed from the most economical local material available. The headroom should be at least 4 metres. The roof should have adequate overhang over the vehicle access area to protect the salt from rain during loading and unloading operations. The floors should be of concrete and properly sloped, with trench drains at the sides. All electrical wiring, switches, plug points, connections, motor starters, etc., should be protected from corrosion. This is extremely important since corrosion can cause short-circuit hazards. It is recommended that the electrical wiring of the building be installed well above head level, with connections led down to the points where power and lighting are required.

## Quality control

A quality control system is essential. It ensures that the level of iodine in the salt is kept within the limits decided in accordance with anticipated iodine compound losses and the goitre control programme requirements. It also permits the immediate detection of excessive quantities of iodine, which may be harmful.

It is customary to take salt samples for iodine determination tests from each iodination line every one or two hours. The equipment, chemical supplies and staff requirements to operate a quality control system are quite modest. There are several ways of carrying out iodine determination tests. The content of iodine in salt iodinated with potassium iodide may be determined as follows (1).

Dissolve 50 g of salt sample in water, make up to 250 ml in a volumetric flask, and neutralize with 1 mol/l sulfuric acid using methyl orange as an indicator. Add bromine water dropwise using a burette until the quantity is equivalent to 20 mg of bromine and allow it to stand for a few minutes. Add dropwise, while mixing, 10 g/l sodium sulfite to destroy most of the free bromine in the solution. Wash down the neck and sides of the flask with water and complete the destruction of the remaining free bromine by adding 1 or 2 drops of 50 g/l phenol solution.

Now add to the solution 1 ml of 1 mol/l sulfuric acid and 5 ml of 100 g/l potassium iodide solution. Titrate the liberated iodine with 0.0025 mol/l sodium thiosulfate solution using starch as external indicator near the end of the titration (1 ml of 0.0025 mol/l sodium thiosulfate  $\equiv$  0.1058 mg of iodine  $\equiv$  0.1388 mg of potassium iodide).

For determining the iodine content of a salt iodinated with potassium iodate the following method may be used.

Dissolve 50 g of salt sample in water and make up to 250 ml in a volumetric flask. Add 1 ml of 1 mol/l sulfuric acid and 5 ml of 100 g/l potassium iodide and titrate the liberated iodine with 0.0025 mol/l sodium thiosulfate, using starch as external indicator near the end of the titration.

These methods can be used for analysing samples taken from points of consumption.

Dustin & Ecoffey (2) have developed a field test for the detection of iodine in salt, which is carried out as follows.

(1) *Test for iodide*. The test will detect the presence of iodide over the range of recommended levels of iodination (5–100 mg of potassium iodide per kg of salt). If a chemical balance is not available, weighings may be done on a good letter balance. The “drops” referred to are those delivered by a medicine dropper, i.e., about 0.05 ml each.

Prepare the following three solutions:

- A. Starch solution, 5 g/l, made by boiling 50 ml of water with 0.25 g of rice starch for 1 min. The resulting liquid is whitish rather than clear, but this does not



affect the test. Alternatively, 10 g of wheat starch may be mixed with 15 g of water and 90 g of glycerol and warmed to 90° C in a water-bath until the mixture becomes uniformly translucent. A preservative may be added. About 2 ml of this preparation dissolved in 45 ml water yields a homogeneous whitish solution that can be used instead of the 5 g/l starch solution.

- B. Sodium nitrite solution, 10 g/l, made by dissolving 0.25 g of sodium nitrite in distilled water and making up to 25 ml.
- C. Sulfuric acid, 352 g/l, made by adding 5 ml concentrated sulfuric acid (relative density 1.84) slowly and carefully to 20 ml water.

All three solutions should be stored in glass-stoppered dropper bottles. To obtain the iodide reagent, mix 50 ml of solution A, 10 drops (0.5 ml) of solution B, and 10 drops (0.5 ml) of solution C. The reagent is stable for 2–3 days in a temperate climate. In tropical conditions the least stable component is solution A, which should be prepared afresh if the test fails. Solution B is the next to be suspected, but solution C is safe to use as long as it remains colourless.

Place separately on a saucer a small amount of the salt to be tested and a similar amount of locally available iodinated salt. Moisten both portions of salt with two drops of the reagent. The iodinated salt will immediately turn blue and stay that colour for several minutes before turning grey and then white. If the salt being tested turns the same blue, it is properly iodinated.

The test cannot be used to measure the relative degree of iodination in different samples because it produces a uniformly deep blue over much of the range of recommended concentrations. It also cannot be used to detect the iodate ion because the reagent does not react visibly with iodates.

(2) *Test for iodate.* The test will detect the presence of iodate over the range of recommended levels of iodination (6–130 mg of potassium iodate per kg of salt).

Prepare the following three solutions:

- A. Starch solution, 5 g/l, made by boiling 50 ml of water with 0.25 g of rice starch for 1 min.
- B. Potassium iodide solution, 120 g/l, made by dissolving 6 g of KI in distilled water and making up to 50 ml.
- C. Hydrochloric acid, 100 g/l, made by adding 10 ml of 250 g/l HCl (relative density 1.12) to 15 ml of distilled water.

All three solutions should be stored in glass-stoppered dropper bottles. To obtain the iodate reagent add 12 drops of solution C to 25 ml of solution B and mix with 25 ml of solution A. The reagent is stable for 2–3 days in a temperate climate. In tropical conditions the least stable component is solution A, which must be prepared afresh if the positive test fails. Solutions B and C are usable as long as they remain colourless.

Place separately on a saucer a small amount of the salt to be tested and a similar amount of a locally available iodinated salt. Moisten both portions of salt with two drops of the iodate reagent. The iodinated salt will immediately turn greyish-

blue and stay that colour for several minutes before turning brown. If the salt being tested turns the same greyish-blue, it is properly iodinated.

The test can be used to estimate roughly the relative degree of iodination in different samples because it produces a range of greyish-blue colours over much of the range of recommended concentrations.

### **Salt packaging and iodine retention**

Iodinated salt can be packed in a number of ways depending on the requirements of the salt traders and the goitre control programme.

It is essential that the amount of iodine in the salt at the time of consumption be in accordance with the amount recommended. The retention rate of iodine in salt depends on the iodine compound used, the type of packaging, the exposure of the package to the prevailing climatic conditions, and the period of time between iodination and consumption. Moisture conditions surrounding the salt also have an effect on iodine loss. The critical relative humidity for salt is 76%. When the humidity is higher than this, moisture will be absorbed by the salt and the potassium iodate may migrate to the bottom of the sack. When the humidity is lower than 76% the salt will release surface moisture, which may also result in some loss of iodine. Losses could be minimized by packing the salt in airtight containers, but if this is not possible efforts should be made to improve the distribution network so as to reduce the time interval between the treatment of salt and its consumption.

It has been reported from a tropical country that iodinated salt stored in stitched plastic bags at room temperature for three months retained up to 75% of its iodine. After nine months' storage, the iodine dropped to 50%. Experience with salt packed in stitched jute bags has been less satisfactory. In extremely adverse conditions of packaging, storage, and handling, the amount of iodine remaining after 9 months may be as little as 10%.

A common practice is for the commercial salt producers to deliver the salt to a public iodination plant, where it is processed and poured into bags belonging to the traders, who retail it in the usual manner. This practice is followed to avoid additional packaging expenses. However, where ordinary jute bags are used this practice may not be satisfactory owing to loss of iodine. The problem will have to be studied at the local level and the chances are that the addition of extra iodate to compensate for the loss of iodine will be a cheaper solution than changing over to expensive plastic-lined bags or other kind of container impervious to moisture. The final decision therefore depends on the local cost of packaging materials.

Although the distribution of iodinated salt will have to comply with business procedures, efforts should be made to ensure that the salt is consumed within three months of iodination, in order to minimize iodine losses.

### **Staff requirements**

A superintendent or manager must be in overall charge of the day-to-day operations of the plant, with the responsibility of coordinating the reception, processing, and distribution of the salt. The superintendent should be assisted by a laboratory technician, a shift supervisor, and a maintenance officer. The supporting staff would be a laboratory assistant, a plant operator, and a labour force of 12 persons per shift. These are the minimum requirements for a plant with a capacity of 5000 kg/h.

Additional help in the plant and laboratory will be required for larger plants and for those operating on a two-shift basis.

### **Cost of iodination**

The cost of iodinating salt depends on several factors, including:

- (1) the rental or mortgage charges for the building;
- (2) the location of the building relative to the salt arrival and dispatch points;
- (3) the type and condition of the salt to be iodinated;
- (4) the *per capita* quantity of salt used for domestic consumption;
- (5) the quantity of iodine required for supplementation, which depends on the recommended iodine intake and *per capita* salt consumption;
- (6) the iodination process selected and the availability and cost of equipment;
- (7) the cost of installation, operation, and maintenance of the equipment;
- (8) the cost of the iodine compound;
- (9) the cost of services—e.g., water, electricity and sewage disposal;
- (10) the cost of staff;
- (11) prevailing borrowing rates;
- (12) the rate of depreciation of buildings and equipment.

Table 4  
Per capita cost of salt iodination, 1976-77

Country	Cost of salt, US \$/kg	Annual cost of iodination, US \$/person
Burma	0.10	0.0052
India	0.046	0.0035
Indonesia	0.06	0.0029
Thailand	0.022	0.0035

The annual consumption of salt may range from 2 to 5 kg per person. Cost of iodination is based on minimum iodine supplementation of 150 µg/day.

Actual iodination costs, taken from projects in Burma, India, Indonesia, and Thailand, are shown in Table 4. The figures clearly indicate the very small additional investment needed to avoid the risk of goitre.

In the countries listed in Table 4 the cost of iodination is borne by the government, so that the price paid by the consumer for iodinated salt is the same as that for non-iodinated salt. This was thought to be advisable since any price increase for iodinated salt would discourage the public from buying it. Alternatively the government might declare the sale of non-iodinated salt illegal within the area of the supplemen-

Table 5  
Equipment costs of 5000-8000 kg/h iodination system

	US \$
<b>1. Drip-feed system</b>	
Conveyor-belt, feed hopper, discharge hopper, jar platform and supporting structure	4 000
Drip-feed unit, controls, nozzles, and solution-mixing tank	450
Weighing machine (0-200 kg), two trolleys, and laboratory equipment	2 800
Installation	900
	<u>8 150</u>
<b>2. Spray mixing system</b>	
Conveyor-belt, feed hopper, and platform	8 000
3 stainless steel 80-litre drums	360
Spraying unit, nozzles, pipework, air compressor and solution-mixing tank	1 040
Spraying chamber and screw conveyor	4 000
Weighing machine (0-200 kg), two trolleys, and laboratory equipment	2 800
Installation	1 400
	<u>17 600</u>

tation programme. The cost of iodination is 6–9% of the cost of salt production, which, in India, is about US \$10–15/tonne. Distribution costs, however, bring the wholesale price to about \$50/tonne, and in relation to this figure the cost of iodination is only about 2%.

Table 5 gives the capital costs of an iodination plant of 5000–8000 kg/h capacity using either a drip-feed or a spray mixing system. While the figures are based on actual plants they constitute only a general guide. They cover only basic equipment for a single line and not buildings or special equipment such as transformers and diesel generating sets, which are required if there is no electricity supply.

The annual operating costs for a 16 000 kg/h salt-iodination operation in Thailand, comprising two drip-feed lines, are shown in Table 6. The operating costs for two spray mixing lines would be similar.

**Table 6**  
**Annual operating costs of a 16 000 kg/h drip-feed plant**

	US \$/annum
Labour (supervisors, quality control staff and unskilled workers)	11 450
Rent and insurance	900
Services (electricity and water)	400
Raw materials (KIO <sub>3</sub> , lubricants, and chemicals)	8 300
Maintenance and depreciation	1 150
	<u>22 200</u>

The costs shown in Tables 4, 5, and 6 do not include costs of salt preparation prior to iodination, e.g., washing, crushing, and milling. Usually salt washing is not required. If rock-salt arrives at the iodinating facility in large hard blocks it will have to be broken into small pieces with a jaw crusher, and, if a fine salt is required, the pieces must be ground in a mill. Costs for such items of equipment in India in 1977 were:

22-kW jaw crusher (capacity 8–10 tonnes/h)	US \$6600;
7.5-kW roller crusher (capacity 3 tonnes/h)	US \$1500;
19-kW mill (capacity 3 tonnes/h)	US \$1400.

To these prices would have to be added the cost of accommodating and installing the machines, and allowance should be made for the increased running costs involved in their operation and maintenance. Similar considerations apply to any mechanical handling equipment that may be required.

## **Project development**

The following important factors should be taken into consideration when developing a salt iodination programme.

### *Management*

The operation of the programme will depend on the nature of the salt industry, which might be a government monopoly or a business venture in the hands of a number of commercial producers. In most cases the iodination plant will be operated by a government department, but it is possible that a well organized commercial salt producer or distributor could be given the responsibility of operating the plant. In all cases it is recommended that a government department be made responsible for ensuring that the quantity of iodine supplementation conforms to the minimum and maximum limits set by the medical authorities.

### *Quantity of iodine intake*

In endemic goitre areas each person should receive a minimum daily dietary supplement of about 150  $\mu\text{g}$  of iodine. In areas of high endemicity, it may be necessary to increase the supplement to 300–400  $\mu\text{g}$ . The total number of people involved and the classification of goitre severity should be ascertained by conducting proper surveys involving medical personnel (see Annex). The results would indicate the degree of endemicity, the extent to which the diet is deficient in iodine, the level or levels of intake required, and the target group.

### *Levels of iodination of salt*

Having determined the target group and the quantity of the daily iodine supplement, the organizers of the project must calculate the level of iodination of the salt, which requires a knowledge of the estimated daily intake of salt (normal range 5–15 g per person) and the percentage of iodine lost from the time of iodination to the time of consumption (see page 33). The loss of iodine becomes noticeable about one month after the treatment of the salt.

It is recommended that tests be conducted with iodinated salt to determine the percentage of iodine loss that can occur. Such tests should be carried out in field conditions. The type of salt and packaging, relative humidity, time lapse between iodination and consumption, and storage conditions should be reproduced when determining the losses. The time lapse between iodination and consumption should be deter-

mined by surveying the existing salt distribution system in the area. Ways of improving distribution might be suggested at this stage.

#### *Choice of iodination process and equipment and packaging*

The choice of process and equipment should take account of the following factors.

(1) The quantity and type of salt available in the area and the traditional habits of salt consumption.

(2) The physical and chemical condition of the salt used in the area.

(3) The quantity of salt required per day (the actual consumption figure plus various processing and handling losses).

(4) The possible need for additional salt handling equipment such as a crusher to reduce the size of the salt crystals to the extent required for efficient iodination.

(5) The strength of the iodate solution and the quantity of solution that might be dispersed.

(6) The advantages and costs of using stainless steel for parts coming in contact with salt. Stainless steel costs 50% more than mild steel but increases the life of the equipment by 50%, so that annual depreciation is about the same.

(7) The packaging materials and containers available in the country (see page 33).

#### *Location of iodination plant*

It is advantageous to locate the plant where the salt is produced, so minimizing the handling costs. This is possible if the salt originates from a single public or private producer but not if it is supplied by a number of small producers, in which case it is better to locate the plant at the centre of the distribution network. Water, electricity, and a sewerage system should be available on the site. Since the operation is labour intensive, the plant should be in a place where there is no labour shortage.

#### *Staff requirements*

The process of staff selection should start during the planning stage of the project, although it will not be necessary to recruit all the staff before the plant is ready for production. The superintendent, who will have the overall day-to-day operational responsibility, should be involved in the planning of the project and if possible sent to a nearby salt iodination plant for training. The person responsible for the maintenance of the plant should be recruited in time to participate in

its installation because this experience will be valuable to him in his regular maintenance work. The rest of the staff and labour force will be required only when the plant is ready for test runs.

### *Budgeting*

The budget of the project should be based on the factors listed on page 34 and on the data collected during the preparation period. In essence, the cost of iodination depends on the following capital and operating expenditures, assuming the worst case in which a new building has to be constructed.

(1) Land development, including boundary walls or fencing and internal and approach roads. It is assumed that freehold land would be made available.

(2) Construction of building (see page 30 for requirements).

(3) Purchase of iodination equipment, ancillary equipment, and spare parts; installation of equipment; freight, insurance, and clearance charges; and other miscellaneous expenses for office furniture. Ancillary equipment consists of items required for water supply, electrical power system, workshop, waste disposal, and laboratory.

(4) Supply of potassium iodate. If this chemical is not available locally the purchase of a year's supply in bulk should be considered.

(5) Cost of electrical power, water, laboratory chemicals, workshop supplies, cleaning materials, packaging material, rent, taxes, and maintenance. The bags or containers used in the existing salt industry may well be suitable for iodinated salt; the choice will depend largely on local conditions (see page 33).

(6) Wages of permanent and temporary staff.

(7) Depreciation of building and equipment. The life expectancy of buildings is assumed to be 50 years, of salt handling equipment 7 years, and of other equipment 10 years. If stainless steel is used for parts coming into contact with the salt, the salt handling equipment should last about 10–11 years.

(8) Interest on borrowed capital.

The cost of iodination is the cost of the raw material, the cost of other necessary supplies and services, the cost of manpower, the cost of depreciation, and the interest on borrowed capital. It is assumed that no distribution costs are involved since the already existing distribution system could be used for iodinated salt. Certain improvements in the distribution system might be required to reduce the time between iodination and consumption, and any additional expenses incurred in making these improvements should be included in the iodination costs.



The costs given in Tables 4-6 are based on existing iodination projects and can be used as a guide for estimating the budget requirements of new projects.

A policy decision will have to be taken regarding the funding of the project, i.e., whether the cost will be borne by the government or the consumer.

## REFERENCES

1. HOLMAN, J. C. M. & MCCARTNEY, W. Iodized salt. In: *Endemic goitre*. Geneva, World Health Organization, 1960 (Monograph Series, No. 44), p. 438.
2. DUSTIN, J. P. & ECOFFEY, J. P. *Bulletin of the World Health Organization*, **56**: 657 (1978).

### 3. Prevention of severe endemic goitre with iodinated oil

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**I**ODINATED oil is an organic compound consisting of iodized ethyl esters of the fatty acids of poppy-seed oil. Current supplies of iodinated oil contain 475 mg iodine per ml (37% iodine by weight). It is manufactured by the André Guerbert Laboratories in Paris (16-24 rue Jean-Chaptal, 93609 Aulnay-sous-Bois, Cedex) under the trade name Lipiodol Ultrafluide. This product is also sold under licence in the USA under the name Ethiodol (Savage Laboratories, 1000 Main Street, Missouri City, TX 77459, USA) and in the United Kingdom under the name Lipiodol Ultra-fluid (May and Baker, Dagenham, London RM10 7XS).

One millilitre of iodinated oil contains roughly 30 times the quantity of iodine stored in the body (mostly in the thyroid gland). Doses ranging from 0.2 ml to 5 ml have been used in various studies and goitre prevention programmes.

Recent observations on the effects of iodinated oil show that a single injection given to every individual in a population group affected by endemic goitre reduces the prevalence of the disease, corrects the iodine deficiency, and restores normal thyroid function. The preventive effect that an iodinated oil control programme can have on the number of new cases of cretinism has been shown in a few studies (1-3). The results also suggest the possibility of an improvement in psychomotor development of children living in an endemic goitre area.

After injection, a portion of the oil is stored locally in the muscle and surrounding tissues (4). Another portion is metabolically deiodinated and the iodine used to restore the depleted iodine of the thyroid gland. However, by far the largest proportion of the injected iodine is excreted in the urine during the first few months after the injection. Various studies in highly endemic areas show that in the first few months after the injection of 2 ml of iodinated oil the urinary excretion of iodine is very high (i.e., 1-5 mg/day, or as much as 50 times higher than before the injection). The urinary excretion of iodine decreases gradually during the following months and years. Pretell et al. (5)

estimated that it took 27 months for the urinary excretion to fall to 50  $\mu\text{g/day}$  in adults, but later studies (4, 6) have shown that this level is reached only after 3½–5 years.

The administration of iodinated oil to all people in an area of endemic goitre dramatically reduces the prevalence of the disease in the following months. This reduction can be observed for goitres of all grades. Thereafter, there is a gradual increase in the number of cases. The reappearance is faster in children, in women of childbearing age, and in people who had small goitres. It is slower and less significant in individuals over 45 years of age, in men, and in people who had visible goitres, grades 2 and 3.

Studies have been carried out in Ecuador (1), Papua New Guinea (7, 8), Peru (4, 5), and Zaire (6, 9) on the various characteristics of thyroid function immediately before the injection of iodinated oil and at different intervals afterwards. A low level of thyroid hormone, a high level of thyrotropin, and a low iodine content of the thyroid gland are found before the injection, but the values become normal in the months following the injection. Thereafter a very slow but progressive change in thyroid function can be observed. In Zaire, 5 years after the injection, signs of iodine deficiency were seen in some individuals although the level of thyroid hormone remained normal. This fact must be emphasized, because thyroid hormone level is the best indicator of thyroid function. It thus appears that five years after the treatment, subjects are still functionally euthyroid.

### **The long-term effects of iodinated oil**

The optimum interval between successive administrations of iodinated oil to a population has not yet been precisely determined. Indeed, it depends both on the epidemiological or medical goals to be attained and on existing local conditions. There is a need for a cost analysis and a study of the organizational problems involved in giving booster shots.

The epidemiological and medical goals can be expressed in a variety of ways, each calling for a somewhat different programme. Examples of objectives are the maintenance of the goitre prevalence below a given percentage, the maintenance of the urinary iodine excretion above a certain level, the maintenance of the thyroid hormone level within certain limits, and the prevention of the occurrence of new cases of cretinism in the population. It is not known for what length of time a single injection into the mother will prevent cretinism in the offspring, but there is no doubt that the risk of cretinism in the child is related to the thyroid hormone level of the mother (2, 3). However incomplete the present data may be, one can nevertheless conclude that with one

injection of 1–2 ml of iodinated oil every 3–5 years it is possible to keep the goitre prevalence in an endemic region below 20% and urinary iodine excretion above 50  $\mu\text{g/day}$ . If the aim is simply to maintain normal thyroid hormone levels and to prevent cretinism, the interval between injections could be even longer.

In planning a preventive programme it is necessary to take account of the size and structure of the existing health services in the region or country where the programme is to be organized (8, 9). The administration of a dose of iodinated oil every 3–5 years to the inhabitants of an endemic goitre region is a relatively simple and inexpensive procedure and an acceptable alternative where salt iodination is not feasible.

### **Dosage and injection technique**

Iodinated oil was first used in medicine as a contrast medium for X-ray diagnosis, in doses of up to 5 ml. In 1963 McCullagh (10) injected 5 ml of iodinated oil in a single dose in order to obtain long-term effects in a preliminary control programme of endemic goitre and cretinism in Papua New Guinea. Thereafter, smaller doses, closer to physiological needs and ranging from 5 ml to as low as 0.2 ml, were used in various studies and control programmes. The dose must be large enough to restore the intrathyroid iodine to an adequate level and to ensure a long-term effect. Not enough information is available at present to allow a precise comparison of the effects and duration of various dosages, but it appears that doses of 1–2 ml of iodinated oil have been successful in controlling endemic goitre. This dosage seems sufficient both to replenish the body's iodine store and to provide a supply of iodine sufficient for 3–5 years. Similar effects can be obtained with a dose of only 0.2 ml, but the effect lasts only 15 months (4). In order to minimize the risk of hyperthyroidism smaller doses have been used in the past 10 years. In 1968 it was suggested (11) that the doses should vary with age, ranging from 0.2 ml for infants of up to 6 months of age to 1.0 ml for everyone above 6 years of age. In 1974, however, it was found on the basis of epidemiological studies (4, 6) that the requirements of children were relatively higher. Hence, a standard dose of 1 ml has been suggested for the entire population, with the exception of infants less than 12 months old, who should receive 0.5 ml. The administration of iodinated oil to people over 45 years of age is of little use because of the spontaneous remission of goitre after this age and the increased risk of hyperthyroidism.

Iodinated oil is administered by intramuscular injection into the gluteal region (buttocks) in small children or in the deltoid muscle (shoulder) or gluteal region in adults. Relatively large needles are used, and care must be taken that the oil is not injected intravenously.

The skin at the injection site should be cleaned carefully in order to prevent abscess formation. A different needle must be used for each individual. Syringes and needles should be carefully sterilized. In the field a portable cooking stove (e.g., a Primus) can be used to heat a steam autoclave or a hot-air sterilizing box.

### **Prevention programme using iodinated oil**

In the attack phase the aim is to administer iodinated oil to the entire population of the affected region—to all individuals, whether goitrous or not. The injection of iodinated oil is simple and quick. It is carried out by mobile teams of medical workers who have undergone a special one-month training. A team of 4–5 auxiliary personnel can treat about 500–1000 people per day. At the rate of 500 injections a day, one team can treat 100 000 people a year (200 working days) or 500 000 people in 5 years. Thus, on the basis of a 5-year interval between injections, three auxiliary teams could protect as many as 1.5 million people.

The collection of statistical data is an important part of the attack phase. The data should include the number of villages covered, the number of people treated, and the estimated prevalence of goitre and cretinism. Precoded data sheets can be used for this purpose.

Efforts should be made to obtain a good coverage of villages and communities. A participation rate of the order of 80% of the target population should be the minimum objective.

After the first injection, protection could be maintained either by further administrations of iodinated oil or by the iodination of salt. The decision must be based on a feasibility study and a cost-benefit analysis.

### **Organization of a prevention programme**

The prevention programme using iodinated oil is composed of (1) a central planning and coordinating unit and (2) a number of peripheral units to administer the iodinated oil.

#### *Central planning and coordinating unit*

This technical unit is responsible for planning the programme, training personnel, coordinating the field operations, and evaluating the results. It is sometimes located in the capital of the country but more often in a town in the endemic region. Its principal tasks are the collection of demographic and prevalence data, field reconnaissance,

the distribution of work between various peripheral teams, and the evaluation of the results from an epidemiological and operational point of view. A section within the unit will be specially concerned with laboratory work, particularly the determination of iodine in urine.

### *Peripheral units*

Peripheral units of two types can be created:

- mobile teams working directly under the central unit and essentially concerned with goitre prevention, and
- polyvalent units, either mobile or stationary, concerned more widely with the prevention of endemic diseases occurring in rural areas.

The latter units are administered by the peripheral health services but must be supervised by the central unit. Their programme includes the control of several endemic diseases, and their pace of work is therefore slower than that of the specialized units. The statistical data collected by the peripheral units are referred to the central unit for analysis.

### **Personnel, supplies and facilities**

The central planning and coordinating unit consists of an epidemiologist, a chemist-technician, and a number of auxiliary personnel. A vehicle is needed for field reconnaissance and evaluation.

A peripheral unit consists of four or five auxiliary personnel including a team leader, who is responsible for the local work schedule, the supply of iodinated oil, and the vehicle. One of the auxiliaries is a statistical clerk, responsible for the record keeping. Two or three auxiliary nurses are responsible for the injection programme and the sterilization of needles and syringes.

The iodinated oil can be obtained directly from the producer in France or from an affiliate in the United Kingdom or the USA. The oil, which is in 5-ml vials, sufficient for five injections, is stable with regard to changes in temperature and can therefore be easily transported. A large supply of needles and syringes will be required. Needles should be of large calibre owing to the high viscosity of the oil. Various types of sterilizing equipment are available.

The facilities required by the central unit are a few rooms and a small laboratory. The rooms will include the doctor's office and epidemiological section and an office for the analysis and storage of statistical records. The laboratory will be needed for measuring the iodine content of urine samples. An outside laboratory could be

**Table 7**  
**Estimated cost of a prophylactic iodinated oil programme**  
**for 1 500 000 people in central Africa (five-year basis, 1975-1980)**

	US \$	US \$
<i>Iodinated oil</i>		
1 500 000 doses (1 ml) × US \$0.20	300 000	
Medical equipment, syringes, registration forms	60 000	360 000
<i>One coordinating and evaluating team working 6 months every year</i>		
1 epidemiologist × 5 years	40 000	
1 chemistry technician × 5 years	20 000	
1 driver, 1 statistical clerk, 1 nurse, 1 chemistry technician (4 persons × 5 years)	15 000	
2 vehicles, fuel, and maintenance for 5 years	20 000	
Laboratory materials, chemical analyses	20 000	
Operating costs including accommodation	10 000	125 000
<i>One mobile team for mass treatment</i>		
5 full-time staff (1 driver, 1 statistical clerk, 3 nurses) US \$1500 × 5 persons × 5 years	37 500	
2 vehicles, fuel, and maintenance for 5 years	20 000	
	57 500	
<i>Three mobile teams</i>		172 500
<b>Total</b>		<b>657 500</b>
Per person treated	44 cents	
Per person-year of protection	9 cents	

employed, if necessary, for the determination of thyroid hormone and urinary iodine. Lodgings will be needed for the staff of the peripheral units; these can be provided through local and temporary arrangements.

### Costs

The costs involved in an iodinated oil programme can be subdivided under three main headings.

(1) The central planning unit. This expense is unavoidable but can sometimes be shared with programmes for the control of other endemic diseases.

(2) The supply of iodinated oil, syringes, needles, and sterilizing equipment.

(3) Personnel and vehicles for the peripheral units. The number of personnel involved will depend on whether the programme is carried out by special local units or by local health personnel.

Table 7 shows the cost estimates of an iodinated oil prophylaxis programme now in progress for 1.5 million inhabitants of Ubangi in

north-west Zaire. The estimated cost of protecting one person for one year is about 9 US cents. The programme is being carried out in a region where no local health service is available and where the only facilities provided are a few rooms for the central unit. In areas where control programmes for other diseases already exist, the cost could be reduced significantly by the sharing of expenses. An independent assessment made in Peru in an entirely different setting arrives at a similar estimate (12). The cost of such a programme appears to be compatible with the public health budget of many developing countries.

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## 4. Administrative and legal aspects of goitre control

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A NUMBER of scientists and politicians have for many years considered that the formulation of nutrition policies by governments is highly desirable. Despite special efforts to promote such policies the response of governments has been disappointing except under the stimulus of war. Recently there has been an increasing interest in a number of countries in regard to nutrition policies and planning. As yet there is no consensus on the best approaches that might be adopted by countries in various stages of development, but some of the main considerations have been discussed by the Joint FAO/WHO Expert Committee on Nutrition (*1*). There is, however, widespread agreement that there should be no delay in undertaking practical projects that seem to be reasonable and feasible while a nutrition policy is being developed. A goitre control programme is a classic example of such a project. Although the cooperation of various ministries is needed (e.g., health, planning, finance, and education) it has been demonstrated in many countries that a project of this type can proceed successfully without necessarily being part of a comprehensive nutrition policy. This is so because the projects undertaken, such as fortification of salt or some other vehicle, the injection of oil in selected target groups, or the distribution of supplements, are clear and specific and are much less complicated than projects calling for changes in food production and distribution. In addition, both the costs and the benefits of a goitre control programme are comparatively easy to determine.

### **Legislation**

Where salt production and distribution are under government control, legislation governing iodination may not be necessary; otherwise it is an essential step. Experience has shown that in order to ensure action provision should be made for the setting of standards governing the type and quantity of iodine compound added, the control of labelling and advertising, quality control, monitoring, and enforcement (*2*).

In 1964-65, one of the writers sent questionnaires to the governments of countries known to have an endemic goitre problem and known to have started a control programme, usually with iodinated salt. The results of this survey, which covered 28 countries, showed the legislation existing in these countries in 1967 (3). Eleven years later, in 1976, WHO sent a further questionnaire through its regional offices to Member countries. The results of this global survey are presented below and in Table 8.

In 1967, out of 28 countries covered by the survey, 23 had legislation regarding the use of iodinated salt. In 11 countries the legislation covered the entire country, and in the other 12 it covered only a limited area. In New Zealand, in the absence of legislation, a successful salt iodination programme was carried out on a voluntary basis. In the USA, salt fortification has also been voluntary (4).

In 1976, iodinated salt was being used in 43 countries and was available on a voluntary basis in nine others. Legislation governing its use had been enacted in 35 countries.

The Ministry of Health is usually given the responsibility for establishing laboratory facilities and other infrastructures needed for monitoring the iodination programme. It is similarly responsible for training personnel and for collecting, analysing, and distributing information about the programme. A commission should be formed to plan the programme, while implementation might be made the responsibility of the ministry in charge of promoting and supervising industrial and commercial operations. Provision of technical advice and other support may be necessary, especially to the small salt producers, and in this respect international assistance might be sought from WHO and UNICEF.

When the problem of goitre extends across national borders, and when salt supplies move across those borders, cooperation is called for between the countries concerned. Where countries are organized regionally with respect to food processing and distribution, regional programmes should be considered rather than national ones.

## **Regulations**

Regulation of the level of iodine in salt or other vehicles is necessary both to ensure the regular addition of a minimum amount and its stability during distribution and to ensure that excessive amounts of iodine are not added. The latter is unlikely, but there was recently some concern in the USA that large doses of iodine from sources such as iodinated water, therapeutic or diagnostic drugs, industrial chemicals, bread conditioners, and disinfectants used in the dairy and food industries had reached some groups and individuals. A report prepared for

Table 8  
Salt iodination programmes

Country	Year of legislation	Year of implementation	Coverage		Iodine compound and dosage
			Whole country	Limited	
North America					
Canada	1949	1949	×		KI, 100 mg/kg
Mexico	1942, 1962–74			×	KI, 20 mg/kg
USA		1920	voluntary		KI, 100 mg/kg
Central America and Caribbean islands					
Costa Rica	1941	1972	×		KIO <sub>3</sub> , 33–67 mg/kg
Dominican Republic			×		
El Salvador	1961	1972	×		KI and KIO <sub>3</sub> , 67 mg/kg
Guatemala	1954–55	1955	×		KIO <sub>3</sub> , 67 mg/kg
Honduras		1971	×		KIO <sub>3</sub> , 67 mg/kg
Jamaica			×		KI, 80 mg/kg
Nicaragua	1977	1977	×		KIO <sub>3</sub> , 67 mg/kg
South America					
Argentina	1953	1966		×	KI, 33 mg/kg
	1967		×		KIO <sub>3</sub> , 33 mg/kg
Bolivia	1969	1977		×	KIO <sub>3</sub> , 50 mg/kg
Brazil	1953	1957		×	KIO <sub>3</sub> , 10 mg/kg
Chile	1959	under study			KIO <sub>3</sub> , 100 mg/kg
Colombia	1955	1963	×		KI, 50 mg/kg
Ecuador	1968	1973	×		KI, 67 mg/kg
Panama	1955	1970	×		KIO <sub>3</sub> , 67 mg/kg
Paraguay	1954		×		KIO <sub>3</sub> , 50–100 mg/kg
Peru	1940			×	
	1969		×		KIO <sub>3</sub> , 50 mg/kg
Uruguay	1963	1964–72	×		KIO <sub>3</sub> , 30 mg/kg
Venezuela	1966	1974	×		KIO <sub>3</sub> , 20 mg/kg
Europe					
Austria	1963	1963	×		KI, 10 mg/kg
Belgium			voluntary		Iodinated salt available
Bulgaria	1956–58	1958		×	KI, 20 mg/kg

Czechoslovakia	1946	1947			KI, 25 mg/kg
Finland		1957	×		KI, 25 mg/kg
France		1952		voluntary	KI, 12.5 mg/kg
Germany, Federal Republic of				voluntary	KI, 4 mg/kg
Greece	1973-76				KI, 10 mg/kg
Hungary	1948			×	KI, 10 mg/kg
Italy	1972	1976		×	KI, 20 mg/kg
Netherlands	1942-68	1968		×	Iodination of salt for bread-making
Norway		1965		voluntary	KI, 40 mg/kg
Poland	1949	1952			KI, 12 mg/kg
Portugal	1963	1971	×		KI, 20 mg/kg
Romania		1954		×	KIO <sub>3</sub> , 20 mg/kg
Sweden		1936		voluntary	KI or NaI, 50 mg/kg
Switzerland	1924	1930s		voluntary	KI, 7 mg/kg
Turkey	1968		×		KI, 50-67 mg/kg
United Kingdom				voluntary	KI, 16-26 mg/kg
USSR	1950-55				
Yugoslavia	1953	1956	×		KI, 10 mg/kg
<b>Africa</b>					
Algeria	1967	1969		×	KIO <sub>3</sub>
Kenya		1970	×		KI, 20 mg/kg
Libyan Arab Jamahiriya				×	Iodinated salt imported
Nigeria				×	KI, 20 mg/kg
South Africa	1954				Iodinated salt available
<b>Asia</b>					
Burma		1970		×	KIO <sub>3</sub> , 60-80 mg/kg
China		1958		×	KIO <sub>3</sub> , 30 mg/kg
India	1955	1956		×	KI, 10-20 mg/kg
Indonesia	1975	1977		×	KI, 25 mg/kg
Iraq		1977			KIO <sub>3</sub> , 40 mg/kg
Nepal		1973		×	KIO <sub>3</sub> , 40 mg/kg
Philippines		1977		×	Pilot-scale project
Thailand		1962		×	KIO <sub>3</sub> , 50 mg/kg
<b>Oceania</b>					
Australia		1966			KIO <sub>3</sub> , 20 mg/kg in salt for bread-making
Papua New Guinea		1978			Iodinated salt imported

the US Food and Drug Administration, while calling for further studies, concluded that there was no evidence that dietary iodine intakes in the USA in recent years had led to any untoward effects.

Regulations on labelling and advertising should allow promotional claims consistent with the overall nutrition and health programme.

Apart from the regulations specifically directed at iodination, other regulations may affect iodine intake. For example, new regulations reducing salt in commercial infant foods will affect iodine intake if the manufacturers have been using iodinated salt.

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## 5. Prevalence of endemic goitre and present measures of control

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IN 1960 WHO published a monograph on endemic goitre (*1*), which reviewed in great detail the information then available concerning the geographical distribution and prevalence of the disease. The aim of the present chapter is to update that publication with new data that have become available since 1960; it should therefore be considered as an addendum to the monograph. Unless otherwise indicated, the information reported was provided by governments in response to a questionnaire sent to them in 1976-77. Only those countries for which new information has become available have been listed.

The information may not always be representative of the situation in a particular country because of poor sampling techniques and the limited number of observations, but it is believed that in sum the data collected do give an idea of the size of the problem on a world scale and will motivate governments to undertake a serious assessment of the situation and establish an adequate control programme. It is hoped that in this way the present information will rapidly become obsolete. Unfortunately, past experience shows that the situation regarding endemic goitre changes very slowly, and it is likely that much of the information will still be valid in 10 years' time. It will at least serve to establish a baseline that will be useful in the assessment of progress made towards the control of endemic goitre.

Goitre, as this survey shows, exists almost everywhere. Very few countries are completely free of it, and some areas of the world, such as the Andes or the Himalayas, have a notoriously high endemicity.

In 1960 there were about 200 million people in the world suffering from goitre (*1*). Since then a number of countries, particularly in Central and South America, have introduced control measures and reduced the prevalence of the disease. These measures have narrowed the geographical distribution of the disease but have probably not affected the total number of goitrous people because of the increase in world population.

## North America

### *Canada*

A nationwide survey conducted in 1970–72 on a random sample covering all ages showed a prevalence of goitre ranging from 0 to 2.4%. Women generally showed a higher prevalence than men (2). Goitre has long been endemic in the Great Lakes region (Ontario) and was assumed to be due to primary iodine deficiency. It has apparently responded favourably to the salt iodination programme.

Canada adopted legislation in 1949 making compulsory the iodination of all table salt. Potassium iodide is used for this purpose at a dosage of 100 mg/kg.

### *Mexico*

During the 1950s Stacpoole (3) carried out surveys in eight central states of the country in which one million people of all ages were examined. The overall prevalence of goitre was 20% (range 5–46%). In some communities up to 90% of the people were found to be goitrous, and many of them had grade 2 and 3 goitres. Cretinism and deaf-mutism were also present. A law had been passed in 1942 obliging all municipalities with prevalence rates of more than 20% to use iodinated salt exclusively, but the law was apparently not implemented. In 1962 and 1963, new legislation was adopted requiring all salt for human consumption to be iodinated at 20 mg/kg with potassium iodide.

Recent epidemiological studies (1970–72) report a goitre prevalence of 8% at the national level. Currently there are only four or five areas where endemic goitre exists, and these are generally areas in which community development programmes are not well established.

### *United States of America*

A nationwide survey conducted between 1971 and 1974 (4) on 20 174 people aged from 1 to 75 years showed an overall prevalence of goitre ranging from 0 to 7.3% (average 5%). The sample represented 75% of a national probability sample of 28 000. Prevalence was always greater in females, after the age of 6 years. There were marked regional differences: prevalence was significantly greater in the north-east and middle-west than in the south and west. The middle-west was always an archetypal endemic goitre area. It included states located on the southern shores of the Great Lakes, where the prevalence of endemic goitre ranged from 26% to 100% (5).

Iodination of salt has never been the subject of legislation in the USA; it has always been voluntary. Potassium iodide is used, at a dosage of 100 mg/kg.

## Central America and the Caribbean

A high prevalence of endemic goitre, sometimes associated with cretinism and deaf-mutism, existed in all the Central American countries. The problem is being brought progressively under control. In every country legislation has been passed and a programme of salt iodination is being implemented. The first programme was started in Guatemala in 1955.

### *Costa Rica*

A survey carried out in 1965 showed an overall goitre prevalence of 18% (range 13–24%) among 3735 people of all ages (6). Legislation on salt iodination was passed as long ago as 1941 but was implemented only in 1972. Potassium iodate is used, at a dosage of 33–66 mg/kg. A follow-up survey is in progress, the early results of which already show the effectiveness of the programme.

### *Cuba*

Two surveys were conducted by the Ministry of Health between 1967 and 1973 on 5208 schoolchildren and adolescents aged 6–20 years, drawn from two mountainous regions in the north-east of the country and from the city of Havana. In nine locations in the mountains, the prevalence of goitre reached 58.3%; in Havana, the prevalence was only 3%. No salt iodination programme is planned at present.

### *Dominican Republic*

A 1969 survey of a random sample of 2469 people over 13 years of age revealed a range of 0–25% of goitre of all sizes (7). An older report (8) refers to the frequency of goitre, with associated cretinism, among country people in the mountains of Jarabacoa. No legislation for salt iodination exists, but there are eight plants for iodinating salt from the national salt mines.

### *El Salvador*

A 1967 survey (6) of 3009 persons of all ages demonstrated an overall goitre prevalence of 48% (range 26–70%). Goitres of all sizes were observed but no deaf-mutism or cretinism.

Legislation on salt iodination was adopted in 1961 but not implemented until 1972. Both potassium iodide and potassium iodate are being used, at a level of 67 mg/kg. A study in 1973 showed a decrease in the prevalence of goitre of about 50%. In view of this, the level of iodine in the salt has been lowered to 30–50 mg/kg.



### *Guatemala*

Legislation on salt iodination was adopted in 1954 and implemented in 1955. Potassium iodate is used at a dosage of 67 mg/kg. This compound was found to be more stable under the warm and humid climatic conditions prevailing in Guatemala. Of the salt produced in the country 80–95% is believed to be iodinated, although recent spot checks have revealed an increase in non-iodinated salt reaching the markets. A survey in 1965 showed an overall prevalence of 5% (range 0–14%) among 3866 people examined (6). It would thus appear that Guatemala was the first country in Central America to tackle its serious goitre problem successfully.

### *Haiti*

The examination of a random sample of 3113 people in 1959 showed an overall goitre prevalence ranging from 18% to 39% in females and from 1% to 16% in males (9). No salt iodination programme is planned.

### *Honduras*

A 1966 survey showed that, of 3059 people of all ages examined, 17% (range 3–35%) had goitre (6). Legislation on salt iodination was adopted in 1961 and implemented in 1971. Potassium iodate is used at 67 mg/kg, and recent information indicates that this programme is a successful one.

### *Jamaica*

In the numerous nutrition surveys conducted in Jamaica over the past 25 years no endemic goitre has been found. While there is no legislation to the effect, all salt is iodinated with potassium iodide at a concentration of 80 mg/kg.

### *Nicaragua*

In a survey conducted in 1966, 3302 persons of all ages were examined (6) and the overall goitre prevalence was found to be 32% with a range of 13–48%. Legislation on salt iodination was adopted in 1977.

### *Trinidad and Tobago*

A survey of 4119 people carried out in 1961 showed an overall goitre prevalence of 8%, with a range of 3–20% (10).

## South America

Endemic goitre has traditionally been highly endemic in the Andes and is usually associated with cretinism and deaf-mutism. In the mountainous region of Ecuador, for instance, the prevalence of cretinism ranges from 0.4% to 8.2%. Goitre is also present in areas not geographically related to the Andes, such as the Amazon basin. Most countries on this subcontinent have taken control measures, usually the iodination of salt and sometimes the administration of iodinated oil (Ecuador, Argentina). These measures have proved very effective in some countries but less so in others, possibly because the level of iodination is too low.

### *Argentina*

In 1968 a survey of schoolchildren aged 6–16 years and of army recruits aged 18–20 years, conducted in 16 provinces, showed a goitre prevalence in the range of 12–50%.

Legislation for salt iodination was adopted in 1953 for Mendoza and in 1967 for the whole country. Implementation started in Mendoza in 1966. Both potassium iodide and potassium iodate are being used, at a level of 33 mg/kg. Iodinated oil is also being used in selected groups.

Detailed information concerning endemic goitre and its evolution is available for the province of Mendoza. The first survey in 1940 showed a prevalence in the range 24–46% in schoolchildren and 12–18% in army recruits. In 1968, after 13 years of salt iodination, the overall goitre prevalence was 3.2%. The salt iodination programme thus appears to have had a significant effect on the disease. There has, however, been an increase in the prevalence of thyroid cancer and of Hashimoto's thyroiditis since iodination began.

### *Bolivia*

The goitre prevalence in schoolchildren appears to be about 70–80%, and the overall prevalence in the population of four states in Bolivia is about 20%, with a range of 15–60%.

Legislation on salt iodination was adopted in 1969 and is now being partially implemented. Potassium iodate is used at a level of 50 mg/kg. Iodinated oil is being used in a pilot project in one area, and after one year reductions in goitre prevalence have been observed.

### *Brazil*

A nationwide goitre survey conducted in 1965–66 on 102 000 persons showed an overall prevalence of 11–59%. The examination in 1974–76

of 421 756 schoolchildren aged 6–14 years, representative of the whole country, showed an overall goitre prevalence of 14.1%. Few grade 2 and no grade 3 goitres were observed. In comparison with data collected 20 years earlier, this figure represented a 20% decrease. The lowest prevalence was found in the state of Paraíba (1.0%) and the highest in Bahia (33.3%). The states of Minas Gerais and Mato Grosso also had high prevalences.

Legislation on iodination was adopted in 1953 for areas in which goitre prevalence was more than 15% in males and 25% in females. The legislation was implemented in 1957 in the north-east and in 1967 in other areas, potassium iodate being used at a level of 10 mg/kg. According to recent information the programme has now been discontinued, but if progress is to be continued in the control of goitre it would appear to be necessary to reinstitute it, perhaps with an increase in iodate level to 20 mg/kg.

### *Chile*

In 1960, an examination of 5370 people of all ages demonstrated an overall goitre prevalence of 1.3% (11). In 1972, an examination of 8407 persons in three communities near Santiago showed an overall prevalence of 24.8%. Legislation on salt iodination was adopted in 1959 but has not apparently yet been implemented.

### *Colombia*

Legislation on salt iodination was adopted in 1955 and implemented in 1963. Potassium iodide is used at a level of 50 mg/kg. In 1965, the overall goitre prevalence was found to be less than 2%, in striking contrast with the figure of 53% reported in 1945. It would thus appear that within two years of the institution of an iodination programme there was a considerable drop in the prevalence of goitre. If that is correct, the salt iodination programme must be considered highly successful, making Colombia the first country in South America to succeed in solving its goitre problem. However, more recent data from the highly endemic areas would be useful to ensure that the success has been sustained.

### *Ecuador*

A national survey in 1970, in which 46 570 people were examined, showed an overall goitre prevalence of 28% in the mountains and 12% on the coast. The prevalence of cretinism in the mountainous areas was 0.4–8.2%.

Legislation on salt iodination was adopted in 1968 and implemented in 1973, with the use of potassium iodide at a level of 67 mg/kg. Iodi-

nated oil is also used in selected areas. A follow-up survey in five provinces in 1976 showed a marked reduction in prevalence.

### *Panama*

An overall goitre prevalence rate of 17% (range 1–37%) was found in a national survey of 2724 people of all ages carried out in 1967 (6). A further survey in 1975, in which 4084 people of all ages were studied, showed that the overall prevalence had decreased to 6%. This result may be attributed to the salt iodination programme initiated in 1970 using potassium iodate at a level of 67 mg/kg.

### *Paraguay*

The overall goitre prevalence in 1965 was 18%, according to a survey in which 8500 people were examined (12). A national nutrition survey carried out in 1976, in which 4078 people were examined, yielded the following prevalences of the three grades of goitre: grade 1, 15.2%; grade 2, 2.7%; grade 3, 0.2%. Thus there appears to have been little change in the situation between 1965 and 1976, in spite of the adoption of legislation in 1954 and the iodination of salt with potassium iodate at a level of 50–100 mg/kg. The effectiveness of the programme must therefore be questioned.

### *Peru*

A survey of 181 000 people of all ages showed an overall goitre prevalence in 1967 of 22%. Legislation on salt iodination was adopted as long ago as 1940 for goitrous areas only and was extended in 1969 to cover the entire country, but it is only recently that the law has been effectively implemented. All salt for human and animal consumption must now be iodinated, using potassium iodate at a rate of 50 mg/kg.

### *Uruguay*

A nutrition survey carried out in 1962 on a sample of 5377 people of all ages revealed an overall goitre prevalence of 8% in males and 24% in females (13). A further survey in 1969 covering 25% of school-children aged 7–20 years showed an overall goitre prevalence of 23%.

Legislation on salt iodination was adopted in 1963 and was progressively implemented between 1964 and 1972, using potassium iodate at a level of 30 mg/kg.

### *Venezuela*

A nationwide survey of 470 000 schoolchildren aged 5–14 years, carried out in 1966, showed an overall goitre prevalence of 13%, with

a range of 4–31%. The great majority were grade 1 goitres. In the Andean region, the prevalence was 32.6%.

In the same year legislation on salt iodination was adopted but was implemented only in 1974, using potassium iodate at a level of 20 mg/kg.

## **Europe**

In most of the countries in Europe goitre has either never been a problem or it has been reduced to an insignificant level by control measures. However, there are still a few areas where the problem persists.

### *Austria*

Goitre associated with cretinism and mental retardation has been known for centuries to be highly endemic in the Alpine valleys of Tyrol and Styria. Although goitre prevalence has decreased following the introduction of iodinated salt, the problem is not yet under complete control.

### *Czechoslovakia*

Legislation on salt iodination was adopted in 1946 and implemented the following year, using potassium iodide at a rate of 25 mg/kg. The effect of this programme can be seen in Table 9, which summarizes the results of national surveys conducted between 1947 and 1975. The programme is apparently most successful in children, less so in young adults, and least successful in older adults, particularly in Slovakia.

### *Federal Republic of Germany*

Marked regional differences exist, the lowest prevalence being in the north (4%) and the highest in the south (32%). This is corroborated by the urinary excretions of iodine which decrease from north to south. Iodinated salt is available in special diet stores, but it is not subject to legislation.

### *Greece*

Goitre is endemic in the mountainous areas of Pindos-Thessaly, in the plain, and on some islands such as Crete (14). Legislation has been adopted but only partially implemented.

Table 9  
Prevalence of goitre in Czechoslovakia, 1947-75

Year of survey	Number of people examined	Prevalence rate (%) in following age-groups:			
		6 - 10	11 - 20	21 - 50	51 - 65
<i>Czech Socialist Republic</i>					
	<i>Male</i>				
1947-48	85 460	44.8	60.7	70.0	41.2
1955-57	31 422	33.2	42.1	45.5	40.1
1973-75	33 196	7.4	11.0	12.6	16.8
	<i>Female</i>				
1947-48	112 635	45.4	70.4	84.2	66.6
1955-57	39 380	46.5	64.1	75.2	67.3
1973-75	39 346	11.9	34.5	54.6	49.8
<i>Slovak Socialist Republic</i>					
	<i>Male</i>				
1949-53	61 823	33.5	39.3	34.3	21.8
1957	14 139	20.3	31.8	—	—
1969-71	24 487	10.1	16.2	21.3	19.6
	<i>Female</i>				
1949-53	96 042	41.3	52.2	56.2	45.4
1957	4 635	23.4	44.9	—	—
1969-71	30 092	15.1	33.3	55.70	48.9

### *Italy*

Endemic goitre exists in the Aosta valley, Piedmont, and Alto Adige, and localized foci are found in Sardinia, the Apennines, and Calabria. Legislation on salt iodination was adopted in 1972, and implementation began in 1976, using potassium iodide at a rate of 20 mg/kg.

The significantly lower prevalence figures in the Aosta valley and Piedmont (11%) as compared with Alto Adige (48%) can be explained by the partial salt iodination programme that has existed in the Aosta valley for the past 15 years (30-40% of the kitchen salt has been enriched).

### *Poland*

Goitre is still endemic in the Carpathian and the Sudety mountains in spite of a salt iodination programme. This may be due to too low a level of iodination (12 mg/kg).

### *Spain*

There is moderate to severe goitre endemicity in Spain, especially in some interior areas. A nationwide survey in 1968-69, in which

226 915 people were examined, revealed a total goitre prevalence in males of 6.6% and in females of 18.7% (15). The prevalence in males ranged from 2.3% to 14.6% and in females from 9.3% to 29.5%.

A survey of 8475 schoolchildren aged 5–15 years in Cadiz province showed prevalence ranges of 8.8–24.0% in the coastal area and 19.7–89.2% in the interior region (16). There is no salt iodination programme at present.

### *Turkey*

There are three major endemic areas. A survey conducted in the north-east of the country in 1970–74 indicated prevalence rates of 23–47% in the coastal region and 28–70% in the interior. Legislation was adopted in 1978 but has not yet been implemented.

### **Africa**

In some areas endemic goitre and cretinism constitute major public health problems. Except in a few countries where control programmes have been initiated, the situation has scarcely changed over the past 20 years.

### *Algeria*

A goitre control programme was initiated in 1969 but there is no information on its effectiveness. The iodinated salt appears to reach only a small percentage of the population.

### *Central African Empire*

A countrywide survey in 1971 found generally a very low goitre prevalence (below 1%). However, in the Nola region, prevalences of up to 25% have been reported in some groups.

### *Ethiopia*

It is estimated that one million people in Ethiopia (5% of the population) suffer from endemic goitre. In 1965 a study of 1115 children aged 1–12 years showed a total goitre prevalence of 8.5% in Addis Ababa, 26.9% in Ijaji, and 53.1% in Batko (18). The prevalence increased markedly with age. A supplementary feeding programme with Faffa (based on a local cereal called *teff*) was instituted whereby each child received 100 g of Faffa daily containing 2.3 mg iodine and 14 g protein. Within two years, the overall goitre prevalence in Ijaji had declined to 4.4% and in Batko to 12%. Grade 2 goitre completely

disappeared. This is a good example of goitre control with an iodine fortified food.

### *Ghana*

A nutrition survey in 1961–62 in the Upper Region showed overall goitre prevalences of 3% in men and 24% in women, among the 826 adults examined. The prevalence of grade 2 and grade 3 goitre was 9% in women, though negligible in men.

### *Ivory Coast*

The major endemic areas are located in the north and west of the country. Between 1966 and 1969 a total of 14 798 people of all ages in 31 villages in 6 provinces were examined. The overall goitre prevalence was 18.5% (range 4.2–68.0%). Most of the goitres were grades 1 and 2, and cretinism and deaf-mutism were rare.

### *Kenya*

A 1962–64 survey covering 28 250 schoolchildren showed an overall prevalence of 30.2% (grade 1, 21.9%; grade 2, 7.13%; grade 3, 1.14%). Prevalences were higher in the highlands of the Central, Nyanza, Western, and Rift Valley Provinces and lower in the Eastern and Coast Provinces.

A salt iodination programme began in 1970 using potassium iodide at 20 mg/kg. A follow-up survey in 1972 showed a decrease in prevalence of grade 2 and grade 3 goitres in schoolchildren.

### *Libyan Arab Jamahiriya*

In 1974, a survey of 741 schoolchildren aged 11–20 in Fezzan showed an overall prevalence of grade 1 and grade 2 goitre of 46% (42% in boys and 51% in girls). The government recently imported iodinated salt for distribution in this area.

### *Mali*

In 1968 a goitre survey showed overall prevalences in children of 32.7% (grade 1), 8.8% (grade 2), and 7.0% (grade 3) and in adults of 19.0% (grade 1), 14.4% (grade 2), and 4.6% (grade 3).

### *Niger*

A goitre survey was carried out in 1968 on a sample of 3746 people of all ages, of whom 1300 were schoolchildren. The prevalences by age and sex were as follows:



<i>Age (years)</i>	<i>Grade 1</i>		<i>Grade 2</i>		<i>Grade 3</i>	
	Male	Female	Male	Female	Male	Female
0- 5	15.4	15.9	5.5	5.3	0.6	0.3
6-12	32.4	39.2	5.6	7.6	0	0
13-18	32.9	36.9	5.3	20.0	0.2	0.5
19	15.4	30.2	4.1	23.0	0.3	4.5

There is thus a moderate goitre endemicity, somewhat similar to the one existing in Ivory Coast.

### *Nigeria*

A number of surveys were carried out in various parts of the country between 1954 and 1974, and goitre was shown to be endemic in many areas. An inverse correlation was found between goitre prevalence and the iodine content of water supplies. Iodinated salt is being used in affected localities.

### *Senegal*

Goitre surveys were carried out in 1970 in two areas—Casamance and East Senegal—using a total sample of 12 000 people. The overall prevalence was 33% in males and 46% in females, over 90% of cases being grade 1. Another survey in 1976, using a sample of 2424 people, showed similar prevalences.

### *South Africa*

According to recent information there is no endemic goitre in the country. No control programme exists but iodinated salt is available. In some areas, thyroid enlargement of unknown etiology has been observed.

### *Southern Rhodesia*

In 1968, a goitre survey was carried out on tribal trust lands in the Kariba district, 550 men, women, and children being examined. The overall prevalence was 45% (6.6% grade 2 and 2% grade 3).

### *Sudan*

A 1975 survey in Dar Fur Province showed an overall goitre prevalence of 57.5%, comprising 39% grade 1 goitre, 14.4% grade 2, and 4.1% grade 3. In the Khartoum area the overall prevalence was only 6.3% and the goitre mostly grade 1. There was, however, considerable variation with age. Among 2919 people under 20 years of age the prevalence was 9.4%, while among 2000 people over 20 years of age it was only

1.7%. A prophylactic programme has been started in Dar Fur Province using potassium iodide tablets.

### *Tunisia*

A nationwide nutrition survey took place in 1973–75 in which 10 789 people, representing 81% of the total random sample drawn, were examined. Overall goitre prevalence was low, being 2.13% for grade 1 and 0.48% for grade 2, but in two areas in the north-west of the country the prevalence was much higher. Among women of child-bearing age 12.8–17.4% had grade 1 goitre and 5.4–10.8% had grade 2 goitre. Prevalences were significantly lower in men.

### *United Republic of Cameroon*

In 1968, a survey of more than 4000 schoolchildren aged 6–16 years was carried out in two mountainous areas (17). Total goitre prevalence in the eastern area was 75.2% with associated cretinism, while in the western area the prevalence range was 49–95%. A more detailed population survey carried out in the eastern part of the country in 1969, in which a random sample of 39 980 people was examined, showed a total prevalence for men of 48.4% and for women of 67.6%. A third endemic goitre area exists in the north of the country, but no prevalence data are available. Endemic goitre is clearly a public health problem of some importance in Cameroon. An iodination programme is still in the planning stage.

### *United Republic of Tanzania*

Several surveys conducted between 1953 and 1970 have shown goitre to be highly endemic in various mountainous regions of the country. Prevalences were as high as 76% in the Njombe area in the south-west. In Mwezi the overall prevalence was 70% among schoolchildren aged 5–17 years.

### *Zaire*

Two highly endemic goitre areas have been the subject of special study during recent years. In the Uele area in the north the prevalence of goitre among schoolchildren is 80–90%, and on Idjwi Island prevalences of 55–70% have been observed. The prevalence of cretinism in these two areas ranges from 0.7% to 7.6%. In 6910 people from randomly chosen villages in the Uele area, the overall prevalence ranged from 26.5% to 60% in males and from 47.5% to 77.6% in females. The prevalence of grade 2 and grade 3 goitre was 12.3% in males and 28.6% in females. Among 9000 people of all ages in Idjwi Island the

overall prevalence was 55.4%. At the age of 14 years, 92% of girls have goitre as against 77% of boys (19). A large-scale iodinated-oil programme is being carried out in both areas (20).

### *Zambia*

In 1971, 54 830 persons of all ages from 37 locations were examined. The overall goitre prevalence was 50.5%, and grades 2 and 3 represented 13.13%. The highest prevalence was found in North-Western Province (76.2%) and the lowest in Copperbelt and Central Provinces.

### **Asia**

In view of the widespread distribution of endemic goitre in this region and of its extreme severity in some areas, a number of countries have initiated control programmes during the past 20 years. Although these programmes are proceeding well, there is still a need to develop them further and to increase their effectiveness.

### *Afghanistan*

A survey conducted in 1967 on a population sample of 9170 people of all ages showed an overall goitre prevalence ranging from 10% to 60%. The prevalence of goitre in women was 5 times greater than that in men.

### *Bangladesh*

Detailed results of a 1976 nationwide survey have not yet become available but preliminary findings from four villages, in which over 1000 people were examined, indicate a prevalence ranging from 4.3% to 40.3%. Endemic goitre therefore appears to be prevalent in some areas.

### *Burma*

A goitre survey, limited to the mountainous areas, was carried out in 1968 on a sample of 2239 people aged 6–14 years. The overall goitre prevalence was 62.8% in males and 74.6% in females, and the great majority were grade 1.

An iodinated-salt programme limited to the highly endemic areas in the Chin Hills started in 1970, using potassium iodate at 60–80 mg/kg. A follow-up survey in 1972 showed a reduction in goitre prevalence from 90.3% to 19.4% in males and from 97% to 19.3% in females. It is planned to extend the programme to other areas.

## *China*

Since 1958, campaigns of iodine supplementation have been initiated in several regions. In Taiwan, a salt iodination programme was begun in 1967, using potassium iodate at 30 mg/kg; follow-up surveys among 77 605 schoolchildren have shown a 90% reduction in prevalence of grade 2 goitre and a 75% reduction in grade 1 goitre.

## *India*

The endemic goitre belt in the Indian subcontinent is known to stretch across the Himalayas from Jammu and Kashmir in the west to Arunachal Pradesh in the east. Since 1960 surveys have been carried out every 5 years on population samples of 8000–10 000 people of all ages living in villages in the goitre belt. The samples include 5% of the schoolchildren, 1% of the rural population, and all ethnic groups (both tribal and non-tribal) and they are drawn mainly from the lower economic groups. Prevalence rates (%) by age and sex according to the 1975 survey were:

<i>Age (years)</i>	<i>Males</i>	<i>Females</i>
0– 4	8.85	10.00
5– 9	34.31	38.57
10–14	46.31	33.19
15–19	41.88	54.44
20 and over	14.14	26.92

Prevalence rates were equally high in rural and urban areas.

Salt iodination was adopted as a control measure in 1955 and implemented at different times in different states, beginning in the Kangra valley, Himachal Pradesh.

Results over a 12-year period for the percentage prevalence in schoolchildren in three different areas (21) are given below:

		<i>1956</i>	<i>1962</i>	<i>1968</i>
KI 20 mg/kg from 1956	Male	34.1	19.3	7.5
	Female	51.4	18.4	10.4
KIO <sub>3</sub> 25 mg/kg from 1963	Male	34.2	39.8	17.2
	Female	51.7	41.5	17.0
KIO <sub>3</sub> 25 mg/kg from 1956	Male	36.0	14.5	8.4
	Female	47.4	14.9	10.6

## *Indonesia*

During 1971 and 1972 all the schoolchildren were examined in 39 villages of high endemicity in North Sumatra, West Sumatra, East Java, and Bali. The overall prevalences were 62% in North Sumatra, 89% in West Sumatra, 83% in East Java, and 21% in Bali.

In 1974–75, 92 000 people (women up to 45 years old and men up to 20 years old) in areas of high prevalence were injected with iodinated oil. It was decided in 1975 to phase out the iodinated oil programme in 1978 and replace it with one based on iodinated salt using potassium iodate at 40 mg/kg. To this end 10 iodination plants in Madura, Surabaya, and Central and West Java were commissioned in 1977.

### *Iran*

Between 1962 and 1967 goitre prevalences ranging from 1.7% to 32% were recorded in six provinces (22). A goitre survey in 1968 covering 40% of the population in 45 villages south of Teheran (13 567 persons of all ages) showed prevalences of 24.5% in males and 39.4% in females.

### *Iraq*

A number of goitre surveys between 1965 and 1971 showed high prevalences in certain areas. A salt iodination plant has been in operation since the beginning of 1977.

### *Israel*

In 1961 an examination of 2189 children and adolescents aged 8–18 years in Kiriath Shmona showed a prevalence of 6% in males and 12% in females. In seven Arab villages in the north (total population of 20 000), 4675 schoolchildren and 825 adults were examined in 1963 (23), showing overall prevalences of goitre of 23% in males and 41.5% in females. Among 690 Jews in the same area, of whom 250 were schoolchildren, overall goitre prevalence was 16.5% in males and 47% in females. Of 1250 people in Jewish settlements in the Jordan valley, 1100 were examined, of whom 450 were schoolchildren, revealing overall goitre prevalences of 11% in males and 35% in females. Urinary iodine excretion values and the iodine content of the water in the area indicate a dietary deficiency of iodine.

### *Japan*

There is no endemic goitre in Japan, owing, probably, to the high consumption of sea-fish and of algae rich in iodine. In fact, the goitre reported from one coastal area in 1965 was found to be due to an excess intake of iodine from seaweed, and after a reduction in the consumption of seaweed the goitre disappeared. This is the only recorded instance of goitre caused by excess of iodine.

### *Jordan*

In 1962 a nutrition survey was conducted on 9500 people of all ages in 87 localities (24). Overall goitre prevalences were 6.8% in children and 15.7% in adults. Females over 15 years of age had six times the rate of males of the same age.

### *Lao People's Democratic Republic*

In 1968–69, 200 persons randomly selected at 15 sampling sites in populated areas were examined and the overall prevalences of goitre in various groups were found to be: tribal groups, 18% in males and 41% in females; rural population, 12% in males and 29% in females; urban population, 5% in males and 12% in females.

### *Malaysia*

In 1970 a goitre survey was carried out on 6784 women more than 10 years old. Overall prevalences in peninsular Malaysia were 36.7–58.3% for Malay women, 27.4% for Chinese women, 54.1% for Indian women, and 66.6% for Orang Asli women (aborigines). In Sarawak overall prevalences were 28.7% for Malay women and 34.5% for Chinese women.

### *Nepal*

A survey was carried out in 1965–66 in 19 villages covering 7466 people, 6056 of whom were over 13 years old. About 80% of the population in each village were examined. Overall prevalences were 6–89% in males and 10–94% in females. In one community 11.5% of the population showed mental or physical abnormalities associated with severe iodine deficiency. The severest problem exists in the high mountain valleys. A control programme has been in operation in these valleys since 1973, using iodinated salt imported from India. The compound used in fortification is potassium iodate at 40 mg/kg, though the actual level may vary considerably. Six iodination plants have recently been installed.

### *Pakistan*

Goitre is endemic in the north according to several surveys between 1968 and 1972. In the Gilgit Agency, a survey of 589 persons of all ages showed an overall prevalence of 74%. In Chitral District in a highly endemic area another survey revealed prevalences of 72% in males and 88% in females. Cretinism was 3.8% and deaf-mutism 4.4%.

### *Philippines*

A number of surveys covering more than 20 000 schoolchildren aged 9–14 in virtually every region of the country have shown that 60% of the children have goitre; most have grade 1 and some grade 2, but none have grade 3.

A survey conducted in 1970 in highly endemic mountainous areas on a sample of 1557 schoolgirls aged 12–20 years in 16 locations in four provinces showed an overall prevalence of 68.6% (range 59.0–94.4%). A high percentage had grade 2 and grade 3 goitres. Cretinism and deaf-mutism were also present. An iodination plant has been constructed.

### *Republic of Korea*

Repeated surveys of random population samples between 1969 and 1973 in rural and urban areas across the country showed a very low prevalence of goitre—in most cases below 1% for both men and women.

### *Thailand*

Surveys in the seven northern provinces between 1960 and 1968 showed 44.7–62.9% of goitre in children aged 7–14 years.

An iodination programme started in 1962 in one province and had expanded to the northern provinces by 1969. One plant capable of iodinating 14 000 tons of salt a year serves the needs of the 4 million people in the region. The compound used is potassium iodate at 50 mg/kg.

Follow-up surveys between 1969 and 1972 have shown a significant reduction in goitre prevalence. The programme is being expanded to provide 100% of the population in these provinces with iodinated salt.

## **Oceania**

### *Australia*

The data available refer to the island of Tasmania, where goitre has been endemic. A control programme was instituted in 1966 using potassium iodate (20 mg/kg) in the salt intended for breadmaking. Periodic surveys of schoolchildren aged 5–17 years have been carried out since 1965. Total random samples were 24 457 in 1965, 8132 in 1969, and 9165 in 1976. In the three successive surveys the percentages of grade 1 goitre were 16.5%, 13.8%, and 3.7% and the percentages of grade 2 goitre were 5.8%, 2.6%, and 0.5%.

Other sources of iodine have become available within the past 10 years—e.g., from the use of iodophors for disinfecting equipment in the dairy industry. It is thought that these iodophors are partly responsible for the near disappearance of endemic goitre in both Australia and New Zealand.

### *Fiji*

Surveys in endemic areas have yielded prevalences of 51.9% in males and 76.7% in females.

### *Papua New Guinea*

The highlands in Papua New Guinea are known to be a highly endemic goitre area. In 1966, grade 2 goitre prevalence rates in adults were generally 5–20% and in some areas reached 80%. Cretinism was common.

An iodinated oil programme has been in operation since 1965. Iodinated oil is administered every 4 years to all women of child-bearing age in high-prevalence areas. Up to January 1972, 150 000 people had received it. Iodinated salt has been imported since 1978.

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## Annex

# Technique of endemic goitre surveys\*

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This annex is intended for the guidance of health personnel in carrying out surveys to determine the prevalence of endemic goitre in a population. The procedures outlined will result in data that can be used with confidence in planning public health programmes.

In a survey various types of goitre may be encountered. Goitres are classified according to both physiological and morphological characteristics. Their division into "toxic" and "non-toxic" is entirely functional. "Toxic goitres" are characterized by an increased output of thyroid hormones into the bloodstream; they are important because of their dramatic manifestations and the effects they may have on the life of the patient. In field surveys "toxic goitres" are hardly ever seen, though some signs such as exophthalmos and fine tremor may lead to the discovery of an occasional case.

The "non-toxic" or endemic goitres usually present no dramatic symptoms and are frequently ignored by the goitrous person unless they are disfiguring or produce mechanical interference with respiration. These non-toxic or endemic goitres may appear at different ages according to the severity of the deficiency. A mild degree of deficiency may not become evident until there is an increase in the physiological requirement for iodine. During adolescence, particularly in girls, a significant increase in the number of hyperplastic glands becomes apparent. This so-called "adolescent" goitre is not a normal physiological phenomenon but a reflection of an iodine deficiency that has become manifest owing to an increased demand of the body for iodine. Goitres frequently appear during pregnancy and lactation for the same reason.

When the lack of iodine is more severe, endemic goitre may appear very early in life. The pathology of goitres in infants and young children does not differ from that in older children and adults.

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\* This is a revised version of the paper by C. Pérez, N. S. Scrimshaw, and J. A. Muñoz that was published in: *Endemic goitre*, Geneva, World Health Organization, 1960 (Monograph Series, No. 44).

In areas where iodine deficiency has long been present, goitres with adenomatous nodules of various sizes may appear. This type of goitre is called "adenomatous" or "nodular" goitre. Functionally, such goitres usually remain non-toxic. When no nodules are present, the term "simple" or "diffuse" is used.

The prevalence of endemic goitre in a population gives a good indication of the severity of iodine deficiency without the need to consider the functional status of the thyroid. The goal of an endemic goitre survey sponsored by a public health authority is to determine the existence and degree of goitre in the population.

### **Methods employed in goitre surveys**

It is recommended that a thyroid gland be classified as positive for goitre only when it is 4–5 times larger than the normal size. Adenomatous nodules in the parenchyma should be noted regardless of the size of the thyroid. When the neck is short or the muscles are well developed, inspection alone may fail to reveal a gland that is already 4–5 times enlarged. This may occur also when there is a thick layer of adipose tissue or when the goitre is retrosternal.

On the other hand, in persons with very thin necks the lobes of the gland can be readily seen and may give the impression of a visible goitre, even though the thyroid is actually not more than 4–5 times its normal size. A similar false impression may sometimes be given by the configuration of the larynx and trachea in a person with a thin neck. Furthermore, nodular glands that would be unnoticed on visual examination of the neck are frequently discovered by palpation.

The diagnosis of goitre depends not simply on the visibility of the thyroid gland but on the degree of enlargement of the gland or on the presence of nodules in the gland. The use of the palpation method, therefore, is recommended as the most accurate and reliable way of diagnosing endemic goitre and estimating its severity. Fortunately, palpation does not add appreciably to the time required for examination and frequently permits the prompt resolution of doubt about the size of the thyroid.

### **Significance of non-visible goitre**

In many countries in the world there are areas commonly recognized as goitrous owing to the high prevalence of visible goitre—too large to escape the notice even of the lay visitor. In such cases it is frequently assumed that the rest of the country is relatively free from endemic goitre. However, careful surveys using palpation often reveal a high goitre rate in many areas where the disease was unsuspected.

From a public health point of view, the prevalence of goitre that is readily palpable but not readily visible with the head in normal position may be of great importance. The following reasons reinforce the recommendation that both palpation and visual inspection should be used in carrying out goitre surveys.

(1) It is most convenient to carry out mass surveys in schoolchildren. However, large visible goitres are usually much less prevalent in children than in the adult population, although the total prevalence of enlarged thyroid is more clearly comparable. Palpation must therefore be used to obtain an accurate indication of the prevalence of goitre in the whole population.

(2) If an attempt is made to measure the effectiveness of iodination programmes by the change in size and frequency of visible goitres, two problems are encountered. Many of the goitres are fibrotic and change very little in size even under optimum treatment, and it is almost impossible to evaluate by inspection alone the change in size of a relatively large thyroid. If, on the contrary, the criterion for evaluating the response to iodine administration is the disappearance of the goitre, the task becomes feasible. Most of the diffuse goitres in children, which are palpable but not visible with the head in normal position, will disappear after relatively limited periods of adequate iodine administration.

(3) In a population in which goitre is moderately prevalent but in which most of the glands are not particularly large, failure to include palpation could lead to the false conclusion that the goitre is not sufficiently prevalent to be of public health consequence. While this is particularly true of cross-sectional samples with large numbers of children, it may also apply to adult populations.

(4) Adenomatous goitres in children are usually detectable only by palpation.

### **Assessment of size of gland**

The normal size of the thyroid varies with the age and build of the individual. In the adult, the lobes are about the size of a lima bean with the isthmus appearing as a thin connecting strand. The gland has a rather firm consistency, is slightly compressible, and presents a smooth surface. On palpation the lateral lobes can be felt beneath the muscles on both sides of the trachea. The isthmus is either not palpable or just barely palpable.

As stated previously, it has been found practicable for survey purposes to list as positive for endemic goitre a gland estimated to be more

than 4-5 times the normal volume. To avoid exaggerating the prevalence recorded, doubtful cases of enlarged glands should be classified as normal. These procedures will give a very conservative estimate of the prevalence of endemic goitre, but one in which very few normal people will be erroneously recorded.

It should be noted that, in any field examination, no matter what criteria are adopted, a certain percentage of the people examined will be borderline from the point of view of goitre diagnosis. It has been found in practice that two different observers, even if similar in experience and training, will make different decisions on the classification of many of the borderline cases and yet arrive at about the same average goitre rate. In other words, the variations in assigning borderline cases to either the normal or the positive category tend to be random for most observers.

Any attempt to define the normal thyroid gland in terms of an arbitrary standard tends to break down in actual practice. However, persons carrying out field surveys soon become familiar with the size of the thyroid in normal individuals of various ages and sizes through the examination of populations with little or no goitre. For adults, the size of the thumbnail of the person being examined can be used as an approximate reference, the thumbnail being visualized as outlining a kidney-shaped bean. Usually a thyroid gland whose lateral lobes have a volume greater than the terminal phalanx of the thumb of the person being examined will be considered goitrous.

### **Technique of examination**

Children and adults are examined while standing with the head and neck first in a vertical position and then in an extended position, the examiner sitting or standing directly in front of them according to the height of the subject. The examiner inspects the thyroid area and without delay uses both thumbs to palpate very gently the full extent of the lobes and the isthmus. It is advisable to ask the patient to relax the neck muscles by throwing the head slightly downwards, and it may be helpful to get him to swallow several times.

For the most accurate and reliable clinical appraisal of patients, most physicians advise examination from behind, using the forefingers for the palpation of the thyroid gland, but for general survey work it is more convenient to adopt a position in which visual inspection and palpation can be carried out almost simultaneously without requiring the patient to turn round. Such a procedure is much better adapted to the rapid examination of lines of people. The examination from behind, using the forefingers, can still be resorted to in those relatively few cases in which extra sensitivity is required.

When an infant is examined, the child should be lying on its back with the examiner's left hand under its shoulder-blades, lifting it slightly so that its head remains in touch with the surface of the table on which it is lying. The child can be held securely if the examiner places his left thumb in its right armpit. The region of the thyroid is then palpated with the right forefinger. The gland should not be palpable at all, and the isthmus should be palpable only as a thin strand no more than 1–2 mm thick.

### Classification of goitre

Many different criteria have been employed for the classification of the various degrees and kinds of goitre. The need for standardizing the criteria used in endemic goitre surveys is evident, especially when several surveys made at different times by different examiners may be used to draw conclusions about the effectiveness of prophylactic measures. Most classifications distinguish between visible and palpable goitres and record the presence or absence of nodules. Visible goitres, as a general rule, indicate a moderate to severe deficiency of iodine of relatively long duration and thus tend to be common among older people. Their presence in children suggests a particularly severe deficiency of iodine. Similarly, nodules are likely to be present to a significant degree only in areas where there has been a marked deficiency of iodine for a very long time.

The following classification represents a synthesis of the various suggestions made by a number of authorities. Every effort has been made to present a classification in terms as universally acceptable as possible. Its practicability has been proved in extensive field studies in a number of countries.

Grade <sup>a</sup>	Description
0	Thyroid not palpable or, if palpable, not larger than normal.
1a	Thyroid distinctly palpable and definitely larger than normal but usually not visible with the head in a normal or extended position.
1b	Thyroid easily palpable and visible with the head in an extended position. The presence of a discrete nodule also qualifies a patient for inclusion in this grade.
2	Thyroid easily visible with the head in a normal position.
3	Goitre visible at a distance.
4	Monstrous goitres.

<sup>a</sup> It is recommended that nodules and adenomas should also be noted.

## Organization of survey

Surveys for endemic goitre can be carried out most rapidly if forms are available for recording the necessary data on each individual examined. An example of such a form is given in Appendix 1. Name, age, sex, locality, and years of residence in that locality are generally included, with a space for indicating a previous place of residence when applicable. The date should always be indicated, and there should be a space for the examiner's initials—an important consideration when several people are engaged on the survey.

It is essential to record such information as the size and type of locality, its altitude, and its type of water supply. When a school is examined, it should be noted whether it is public or private, urban or rural. In localities containing distinct racial groups, it may be of interest to tabulate any racial variations in prevalence, which may be due to differences in response to environmental influences. In this case, an indication of race must be recorded on each form.

The numbers 0, 1a, 1b, 2, 3 and 4 should appear, widely spaced, together with the letter "A". The number corresponding to the size of the thyroid gland encountered can then be conveniently circled. The "A" can also be circled whenever nodules or adenomas are encountered. These forms need not be large and may be mimeographed on cheap paper.

When examinations are being carried out in schools it is convenient to leave sufficient forms with the teachers to be filled in before the examination. Usually a few words of instruction to the teachers will be sufficient. At the time of the examination the children should be lined up by grades in front of the examiner with the data forms in their hands. In the absence of another assistant, a teacher should be asked to act as recorder. As each child steps forward, he should hand his paper to the recorder. The examiner has only to call out the number indicating the size of the gland and indicate those cases in which the "A" is also to be circled. In this manner an experienced person can easily examine 150–200 children per hour. This technique can be adapted to other institutions, such as orphanages, factories, nurseries, large farms, and refugee camps. In general, the preparation will require as much time as the actual examinations.

In many situations, especially when there is no expectation of returning to examine the same persons, the recording of names takes unnecessary additional time. In general, when the form has to be filled in at the time of examination, the data recorded can be limited to age, sex, and locality. Previous residence need be recorded only when many people are known to have recently come into the area where the examination is being carried out.

It has sometimes been found convenient to have the necessary data for many people listed in tabular form in advance on a single sheet and have them called for examination in the order in which their names appear.

It is important to bear in mind that the sample studied should be statistically adequate and representative of the population as a whole.

### **Selection of sample**

The sample to be examined in endemic goitre surveys should represent, as far as possible, the different population groups and geographical localities of the country. For practical purposes, it is not necessary to attempt to determine the prevalence of goitre with a high degree of accuracy. Ordinarily, if the figures presented to the health officials are not in error by more than 25%, they can serve as an adequate basis for action.

In planning the survey one of the major requirements is to ensure that the areas to be studied constitute a random sample of similar localities within a geographical area. Geographical characteristics, agricultural patterns, water supplies, racial distribution, economic status, and even dietary practices, when known, should all be taken into consideration in selecting localities.

Care must be taken to treat urban areas and larger towns and cities as different groups, even though they are within the same region, because it may sometimes happen that the capital of a department or province has very little goitre while the prevalence in surrounding small towns is quite high. Within urban areas the higher economic groups, with their more varied food habits, are likely to have a relatively low prevalence compared with the inhabitants of poorer districts in the same town.

The number of persons to be included in the survey in a particular region varies with the homogeneity of the area and the apparent severity of the problem. It has been suggested that about 1% of the population of a country or of a large geographical area within a country should be examined, but in densely populated areas this may result in the examination of far more people than is necessary for practical purposes while in thinly populated districts such a sample may be entirely inadequate as a basis for recommendations to health authorities—especially if the prevalence is low.

The degree of accuracy obtained from the sample from any relatively homogeneous area or group depends on the number of goitre cases encountered as well as on the number of persons examined. This is shown in the table, from which it can be seen that, when the goitre rate is 40%, only 96 people need be examined to give a value accurate to within 25%, while 256 people will have to be examined to achieve the



same accuracy when the goitre rate is only 20%. When the rate is only 5% it will be necessary to examine 1216 people. The table can clearly be used both to help determine the size of sample required and to estimate the degree of accuracy achieved for each area when the survey is completed. It should be noted, however, that the figures in this table apply only to data derived from a relatively homogeneous group or area.

Relationship between prevalence of goitre,  
number of persons to be examined, and relative error of the findings  
(based on a 95% confidence interval)

Prevalence of goitre (%)	Number of persons to be examined to achieve following relative errors:				
	10%	20%	25%	30%	40%
5	7 600	1 900	1 216	855	485
10	3 600	900	576	405	225
20	1 600	400	256	180	100
30	932	233	150	105	58
40	600	150	96	68	38
50	400	100	64	45	25

Example. When the goitre prevalence is 30%, only 150 people need be examined to obtain a 95% confidence interval covering a range given by 30% plus or minus 25% of this value, i.e.,  $(30 \times 0.75)\%$  to  $(30 \times 1.25)\% = 22.5\%$  to 37.5%.

In practice it will generally be convenient in surveys of school-children to examine all the children in attendance at each school visited. A properly planned survey will usually result automatically in the examination of sufficient people for the error involved in the estimate of prevalence to be relatively small. Occasionally, however, the number of people available for examination in a particular situation may be so small as to raise doubts about the validity of the conclusions. In such cases, reference to the above table will be helpful.

The foregoing discussion emphasizes the fact that taking a simple percentage of the total population or of the school population will not prove to be the most efficient way of selecting a sample. In densely populated and homogeneous areas, such as a capital city, a fraction of 1% may suffice, whereas in other circumstances 2% or 3% of the group should be examined. The sample should include all numerically important segments of the population in the age groups studied—important, that is, from both the geographical and occupational points of view—but need include no more of each relatively homogeneous population unit than is required to reach a reasonably reliable conclusion.

If the survey is conducted to determine the need for a national iodination programme, it should be unnecessary to spend time and money examining sparsely populated and relatively inaccessible areas, the inclusion of which would not significantly alter the final goitre rate encountered or the need for prophylactic measures. For most purposes an accuracy to within 25% will suffice, but the numbers that must be examined to achieve true random sampling together with the tendency to examine all subjects who have been conveniently assembled at a given time and place will usually result in a much higher degree of accuracy.

### **Tabulation and presentation of survey data**

The tabulation of the data obtained in endemic goitre surveys must proceed in several stages. It is usually convenient to start by tabulating the type and severity of goitre in each age and sex group for the different localities or populations studied. A typical summary sheet for this purpose is shown in Appendix 2. The ages have been selected to provide an approximate separation of pre-school children, primary-school children, adolescents, and adults. While in theory these ages might vary with the age of puberty and with educational practices in a country, the intervals of 0–5, 6–12, 13–18 years, and 19 years and over are recommended for the sake of uniformity.

This summary sheet can also be used to group data pertaining to political units such as cities, counties, provinces, and departments. Although males and females are usually tabulated separately, this is not a matter of practical importance in children 12 years of age and under. The summary sheet should not be used to total the number of persons with different kinds of goitre unless the age groups are proportionally represented. Usually it is sufficient to estimate the severity of goitre in a population from inspection of the data alone, without making a quantitative summation. When the prevalence of group 2 and 3 goitres is so high that it is desirable to present figures showing this, the goitres should be tabulated separately for each age group.

The form in Appendix 3 has been designed primarily to combine data by age group for the various political divisions of a country. Since many surveys will collect data only from children, the use of the form for the 6–12-year age group is illustrated. It should be remembered that the survey will obtain values for different areas that cannot be averaged because they represent varying percentages of the total population. However, when the population of an area is known (column 2), the percentage it represents of the total population in the country can be calculated (column 3). Each figure for the prevalence of goitre in an area (column 4) can then be multiplied by this percentage to determine

the amount (column 5) that it should contribute to the total percentage. When these figures are added, the estimated goitre rate in the age group tabulated is obtained, as shown in the lower right-hand corner. When sufficient data are available for age groups other than schoolchildren, they can be tabulated in the same way. Each goitre rate for an area should be based on the examination of a sufficient number of subjects to have an accuracy of at least 25%.

Where family surveys have been carried out or where adequate information has been obtained for all age groups, it will be possible to obtain an overall figure for the prevalence of endemic goitre in a large area or a country by means of the tabulation shown in Appendix 4. Just as weighted percentages were obtained in Appendix 3, the overall figure for an age group can be adjusted according to the percentage of the total population that it represents. The sum of the weighted percentages will then give the rate for the total population of the country. However, this is not as useful as it might appear because iodination programmes should be based on the current need for iodine, which is best indicated by the prevalence of goitre in children.

### **Observations to supplement endemic goitre surveys**

Cretinism, deaf-mutism, and mental deficiency are epidemiologically associated with severe endemic goitre. An effort should be made to learn of the existence of such cases in endemic areas and, if possible, verify the diagnosis by actual examination of each case reported. If it is possible to determine the frequency of these conditions in severely goitrous areas by house-to-house visiting or from information furnished by school authorities, valuable evidence might be obtained by comparing the findings with those of similar studies in areas relatively free from goitre.

It is also important to note information that may help to explain differences in prevalence between nearby communities. This will include water supply, altitude, prevailing agricultural or industrial activities, economic level, proximity to the sea, and prevailing dietary habits. Dietary information suggesting a high consumption of foods known to be goitrogenic will be pertinent, as will information indicating a high consumption of seafood, which tends to reduce the frequency of goitre.

Appendix 1

SAMPLE INDIVIDUAL FORM FOR ENDEMIC GOITRE SURVEY

Department .... *Coclé* ....

Date ..... *April 1962* .....

Locality ... *Santa Ana* ...

Type of place *Primary school*

Years in locality .... *12* ....

Former residence .....

Name .... *Juan Pérez* ....

Sex *M* Age *12* Race *W*

Thyroid

0

1 a

1 b

2

3

4

A

Other observations .....

Examiner *RGB*

Appendix 2

SAMPLE TABULATION OF DATA FROM A LOCALITY

Place: *Chepo*

Political unit (Department, State,

Date: *April 1962*

Type of population: *Primary school*

County or Province): *Cartago*

Classification: *Urban*

Sex	Age group (years)	0	1 a	1 b	2	3	4	A1 b	A2	A3	A4	Total examined	Total positive	% positive
Male	0-5	—	—	—	—	—	—	—	—	—	—	—	—	—
"	6-12	77	55	10	2	15	1	0	0	0	0	160	83	52
"	13-18	2	2	3	0	1	0	0	0	0	0	8	6	*
"	19 and over	3	2	1	0	0	0	0	0	0	0	6	3	*
Female	0-5	—	—	—	—	—	—	—	—	—	—	—	—	—
"	6-12	65	69	2	0	3	1	0	0	0	0	140	75	54
"	13-18	2	4	1	0	0	0	0	0	0	0	7	5	*
"	19 and over	1	3	0	0	1	0	0	0	0	0	5	4	*

\* Percentage not given owing to the small number of people examined

Appendix 3

**SAMPLE TABULATION OF DATA FROM ONE AGE GROUP  
IN SEVERAL LOCALITIES**

Department or Province	Population 6-12 years	Percentage of total population 6-12 years	Percentage with goitre	Weighted percentage *
<i>Progreso</i>	1 400 000	40	20	8.0
<i>Union</i>	175 000	5	28	1.4
<i>Yoro</i>	770 000	22	18	4.0
<i>Granada</i>	525 000	15	35	5.2
<i>Cartago</i>	630 000	18	30	5.4
Overall total	3 500 000	100		24.0 (total goitre rate)

\* Obtained by multiplying the figures in columns 3 and 4 and dividing by 100.

*Appendix 4*

**SAMPLE TABULATION OF DATA FROM ALL AGE GROUPS  
IN AN AREA OR COUNTRY**

Age group (years)	Total population in age group	Percentage of total population	Percentage with goitre	Weighted percentage *
0- 5	200 000	10	5	0.5
6-12	200 000	10	28	2.8
13-18	300 000	15	30	4.5
19 and over	1 300 000	65	25	16.2
Overall total	2 000 000	100		24.0 (total goitre rate)

\* Obtained by multiplying the figures in columns 3 and 4 and dividing by 100.

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